Land Market Integration, Structural Change, and Smallholder Farming in Zambia

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Ad Marjorem Dei Gloriam.

Andrew M. Larson
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To Ingrid

Abstract

As developing economies grow, structural transformation affects not only sector shares of labor, value added, and consumption, but also intrasector marketing channels. One of the most dramatic examples of this transformation is in the evolution of food marketing channels in countries such as Zambia. Reardon's supermarket revolution research shows how supermarkets enter and transform food marketing channels in historically short periods of time compared to the earlier experience of developed nations. This study employs a dynamic general equilibrium model to examine the effect of this structural transformation story on smallholder farmers in Zambia. Two policy experiments are carried out against the baseline case.

In the first experiment, the bifurcation of Zambia's agricultural land markets prevents smallholder farmers from participating in modern food marketing channels. High transaction costs in terms of time and financial resources make conversion of customary land into commercial land title prohibitively expensive for smallholder farmers. The simulated conversion of land title, without changing ownership, instigates a reallocation of capital and labor resources in the modeled economy that benefits smallholders in their roles as producers and household owners of factors of production. With the increase in commercial land area, labor becomes scarce and farm production becomes more capital intensive, thus increasing labor productivity and smallholder household income. This analysis highlights the importance of integrating land markets and giving smallholders an effective increase in the range of their resource allocation decisions.

In the second experiment, constraints to smallholder participation in modern food marketing channels are relaxed in order to understand the effects on not only smallholder farmers, but also on Zambia's factor and output markets. Participation in modern marketing channels allows smallholders to supply not only greater downstream value-added processors, but also the world wholesale market. The results show that policies to open modern channels to smallholders benefit smallholders as households and producers.

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1 Introduction

The world has recently witnessed the beginnings of a remarkable transition in emerging economies from traditional food marketing channels to commercial channels employing the technology common to advanced countries. Modern, commercial food marketing channels have been growing rapidly compared to traditional food marketing channels in economies across Latin and South America, south east Asia, and parts of Africa (Weatherspoon and Reardon 2003). Traditional food marketing channels consist of small stands and hawkers selling in the informal, open air market or on the streets (Kaynat and Cavusgil 1982). Modern marketing channels, on the other hand, are relatively more capital intensive from the farm-gate to the processor, and finally to the retailer (Reardon et al. 2003). This study examines, from the point of view of structural adjustment, the effect of this transition story on smallholder farmers, who participate in traditional food channels.

In the course of economic development, farms and food marketing firms introduce more capital intensive methods of production along with new technologies. As a result, labor productivity rises in the modern relatively capital intensive sectors, with the tendency to pull labor from the traditional sector. Thus, the evolution of the modern food marketing channel instigates changes in the allocation of capital and other resources. However, many of these economies feature missing markets that, in the process of transition growth, can adversely affect the traditional farm sector due to high transaction costs and transaction risks (Emongor 2008, Dorward, Kydd, Morrsion, and Urey 2004). Primary food products (as opposed export crops such as coffee, almonds, and cocao) produced by the traditional farm sector tend not to be exported, so that the farm gate price faced by traditional farmers tends to be uncorrelated with world prices. For example, Weatherspoon and Reardon (2003) show with FAO statistics that in Africa very little fresh fruit and vegetable production is imported or exported. Whereas, commercial farmers and primary commodity wholesalers, like their counterparts in advanced countries, tend to have access to foreign markets, making their products a traded good. Thus, price transmission from food retail to the farm gate affects traditional farm prices differently than prices received by commercial farmers. Moreover, many traditional farms in dry-land areas are of relatively small acreage, and located on marginal, less fertile land areas that are economically distant from markets (World Development Report 2009).

For this, and perhaps other reasons (such as the lack of well-defined and enforceable property rights and problems with contract enforcement), land in traditional farms tends not to be rented out to the owners of commercial farms. Consequently, the transition to more modern marketing channels servicing modern supermarkets can be particularly worrisome to owners of land in traditional farms. This effect is possibly made more onerous when, as numerous studies suggest (Stokke 2009, Weatherspoon and Reardon 2003), the rate of transition from modern to traditional channels appears to be occurring at a pace that exceeds the historical pace experienced in today's advanced economies (Reardon et al. 2003).

Transitions in food marketing channels also create structural adjustment difficulties as relative factor prices change in response to new patterns of sectoral supply and demand. Differences in capital intensity across sectors affect factor incomes and profits. Labor and capital flow to the expanding, more profitable sectors, which bid up factor prices, while other sectors experience higher factor costs and lower profits. If a factor market is not integrated, such as agricultural land in Zambia, additional difficulties arise since the allocation of resources is not able to adjust to price signals.

1.1 Contribution

Economists (Neven and Reardon 2004, Reardon and Berdegue 2002, Reardon et al. 2003, Swinnen 2009) have conducted observational studies in recent years to understand the rise of modern food marketing channels. Emongor (2008) conducted case studies of three Southern Africa countries, incorporating a partial analysis of sectors. These studies, however, lacked a dynamic perspective, which would allow one to model general equilibrium effects on resources, factors, profits, and relative prices over a number of years. Roe and Diao (2004) emphasize differences in the relative capital intensity of modern channels compared to traditional channels to explain some of the transition. The process of capital deepening hastens the movement of labor from traditional agriculture to the urban economy. Stokke (2009) examines the effect of supermarket chains on local agriculture through changes to local constraints related to production capacity and market access. The model represents these constraints through the mix of skilled and unskilled labor in modern and traditional food marketing channels. The constraints (such as human capital, infrastructure, and access to credit) change the mix of skilled labor which in turn affects the productivity of labor and thus sends signals to supermarkets regarding the choice of suppliers. If domestic farm labor productivity is low, supermarkets may decide to import food products meeting their quality standards. These papers, however, do not address the rapid rate of recent transitions, nor do they explain the role of intermediate factor inputs in the marketing process. By explaining only some partial direct causes of the transition, they neglect to capture the dynamic general equilibrium effects across other sectors of the economy.

To address the issues posed in the introduction, the dynamic growth perspective of this study allows us to understand the forces affecting the modern and traditional food channels, and also the broader economy. This growth model also provides a systematic structure useful for studying other emerging economies facing similar transitions in food marketing channels. In order to attain this goal, we aim to achieve the following objectives. First, estimate the structural changes in output, productivity, factor prices, intermediate goods prices, retail prices, and sector profits over the course of the baseline model projection. Second, estimate and compare with the baseline model the effects of a partial integration of agricultural land markets. Third, estimate and compare with the baseline model the effects of an increased rate of participtation of smallholder farmers in the modern marketing channel. With this goal and the related objectives, we aim to further our understanding of the economic dynamics governing transitions in food marketing channels and to recommend policies designed to help smallholder farmers adjust during the transition.

1.2 Procedure

We intend to achieve these objectives by constructing a unified theoretical framework consisting of a dynamic-endogenous savings general equilibrium (DGE) model of the Zambian economy, which solves the steady state level values for prices, growth rates, and production shares. This DGE growth model consists of six sectors–smallholder agriculture, commercial agriculture, modern food marketing, traditional food marketing, industry, and services,. The two food marketing sectors are characterized by their degree of capital intensity, product characteristics, economies of scale, and geographic dispersion. These sectors employ intermediate inputs from other sectors of the economy. This model will be calibrated to data and solved backward and forward in time, dating from 1994, the eve of the implementation of Zambian economic reforms.

Once the model is fit to data, and a validation exercise conducted to assess the degree to which the model can replicate at least major economic aggregates (such as sector GDP, fixed capital formation) the results are used to address the questions posed above, that is, to provide an explanation of the various factors influencing the economy's transition growth over a historical period, say 1994 to 2010. We also estimate a baseline scenario of the modeled economy into the future that shows growth paths for factors, prices, output, and profits. Starting from this baseline, we propose to conduct two counter-factual experiments to understand the effects of changes in factor prices and shares on output and income, whether the mentioned missing markets affect transition growth and cause immiserization to farmers in the traditional sector. In order to model production stages further downstream in the two channels, we introduce intermediate inputs from the other sectors. This step will help us to identify relationships across sectors and more specifically in the processing stage of production.

Data for calibration comes from World Bank Development Indicators (WDI) and Zambian sources. The Zambian sources provide more specific data on the nature of Zambian food market channels, ranging from farm-level production through processing to retail. In summary, this model gives a dynamic perspective on the transition of food marketing channels, an area which has recently been the focus of static modeling.

1.3 Food Marketing Channels

1.3.1 Background

This section provides a background to and broader perspective of agricultural production marketing chains. Many dimensions and features of these chains are beyond the modeling scope of this study. Nevertheless, to assess whether the level of abstraction and stylization required of a dynamic general equilibrium model is best suited to study the key issues mentioned, it is useful to discuss this broader perspective.

Food marketing channels are rapidly evolving in the developing world as countries open up to foreign direct investment and adopt cutting edge technologies. For these economies, the accompanying economic growth presents opportunities and challenges that are occurring at a rate not previously experienced in developed countries. These adjustments feature a relatively rapid reallocation of factors of production and associated development of supply chains in the agricultural sector (Reardon at al. 2003).

It is well known that economic growth is linked to many factors, including institutions, endowments, technological change, and capital formation. The structure of institutions contributes to economic growth through the mechanism of the distribution of political power in societies (Acemoglu et al., 2005) Such institutional arrangements efficiently organize information by creating uniform, informal or formal, codes of conduct in society and in economic relations (Schuh 1983).

At the sector level, agriculture can serve as a springboard to higher growth for the industrial sector. Tiffen and Irz (2006) find that for developing countries, agricultural value added per worker causes per capita GDP to increase. In their study of agricultural growth and poverty reduction, de Janvry and Sadoulet (2010) explore direct and indirect growth linkages between agriculture and the aggregate economy. Increased labor productivity reduces the demand for agricultural labor to the benefit of other economic sectors, supplies food at declining prices for non-internationally traded commodities, and increases a country's capacity to import traded goods. Associated savings supply investors with capital to invest in the expansion of the industrial sector which in turn supplies agriculture with material and capital inputs.

Along the path to increased productivity and growth, Kislev and Peterson (1982) observe significant changes in the structure of the agricultural marketing chain. They document the influence of input prices, nonfarm income, and technology on the size of family farms in the U.S. As an economy grows, the share of workers in the agricultural sector tends to decline as urban populations grow, along with improved in urban sanitation, electrification and lower cost transportation that serves to lower costs of market access. As education becomes available to larger segments of the population and gender equity becomes more commonplace in labor markets, the opportunity cost of time to adult household members rises. Household preferences and shopping patterns change. Preferences for foods of more uniform quality, variety, and time-saving features in both preparation and searching rise.

From the demand and supply sides, we see forces pushing and pulling the agricultural marketing channel into more complex configurations, but not necessarily in a sector-wide fashion. In villages and in the poorer areas of cities, traditional food retailers encounter new, low cost competition from modern national-scale retailers such as Shoprite (Weatherspoon and Reardon 2003). Consequently, what arises is the emergence of two marketing channels–the older channel is small scale and employs traditional inputs such as hand tools and animal traction. The newly emergent channel shows a faster rate of growth, more modern factor inputs, and complex combinations of capital all of which are required to meet the quality, variety, dependability, and time-saving features of modern super markets. Additionally, because it has the ability to meet enhanced standards of quality and packaging, the commercial channel has access to export markets.

These bifurcated marketing channels illustrate Adam Smith's observation that the division of labor is limited by the size of the market (Stigler 1951). It appears profitable for the growing commercial channel to divide the production process into more specialized intermediate steps. Traditional farmers and firms do not have the volume, uniformity in quality and variety to garner higher returns from the addition of more intermediate steps. Even though the traditional market may be large in aggregate, it remains geographically dispersed and limited in scope because higher transaction costs make it unprofitable to support additional intermediate steps of specialization.

Marketing channels are conduits not only for physical delivery of goods, but also for communication of information about product attributes, contractual terms, credit, and payments. A product may be further differentiated by the characteristics of time, place, and form (Lanchaster 1966). The attribute of time refers to temporal availability–when the consumer has access to it. Place refers to geographic availability of the product–where the consumer can acquire the product. Form refers to the quality and variety of the product, and in the terms of food, these attributes affect the household's time required for meal preparation. In food marketing channels, goods often begin their journey as raw commodities. With the allocation of additional resources and technologies, they acquire time, place, and form attributes in the supply chain on the way to retail markets. The retail outlet can be viewed as performing an agglomeration function, where the attributes of time-space-form are assembled over the entire basket of food goods.

Traditional and modern marketing channels, easily defined in terms of these attributes, reveal striking economic differences. In terms of time, since traditional marketing channels have little capacity to store fresh produce for future delivery, they must deliver supplies to the market when they become available. Traditional channels typically lack forward contracting arrangements and refrigerated storage capacity to smooth the demand and supply of goods and reduce price risk. In contrast, modern marketing channels have better storage and transportation technology that facilitates more timely deliveries.

In contrast to modern channels, traditional channels lack efficient means of shipping, warehousing, and dispersing bundles of goods to locations convenient to consumers. Consequently, demand for bundles of traditional food is spatially limited. With modern channels, however, farmers can expand the spatial boundaries of their markets through mechanized transportation and access to intermediaries who can provide needed collection, assorting and delivery services to retail markets.

Technology also improves the form attributes of goods, to the benefit of the modern channel. Traditional channels are unable to produce consistent product and packaging because of the absence of processing equipment and the lack of consistency in primary supply. According to Stokke (2009), they may remain stuck in a low productivity poverty trap related to production capacity and market access constraints.

The common feature found in these three attributes is the function of technology. The modern sector employs technology that provides a relatively more desirable bundle of attributes that urban, higher income consumers are willing to purchase, albeit at higher prices than the same product (but with different attributes) might obtain in the traditional market. Products possessing more desirable time, place and form attributes receive a premium price because higher income consumers are willing to purchase them in exchange for reduced search costs, and enhanced and dependable quality and availability.

The technology and specific human capital required by the modern channel was first developed for food marketing chains in advanced economies. Efficient consumer response (ECR), for example, is an inventory management practice that uses computer systems and internet-based communication of data to reduce inventories and related costs (Reardon et al. 2004). Related to ECR is closer real time coordination of intermediate inventories with suppliers. Food processing has also benefited from innovations in food packaging, storage, and pasteurization technologies. The diffusion of these technologies is benefiting food marketing chains in developing countries, where commercial firms implement them at relatively low cost since the technological problems have already been solved.

From another point of view, the nature of a marketing channel determines the size of the marketing markup from the farm-gate price to the retail price. In a competitive economy, this wedge is the unit cost of producing the bundle of time-space and form attributes discussed above. Marketing channels encompass not just the movement of goods, but several processes and relationships in a more or less harmonious system of coordination (Stern and El-Ansary 1988). Raw, intermediate, and final goods move down the marketing channel through deliveries. In addition, payments move up the marketing chain while, in the case of traditional channels, technical assistance moves down the chain. As a marketing channel increases in the number of suppliers and functions performed, the number of relationships needing coordination increases along with its cost (in the absence of scale economies), and consequently the marketing margin grows as well. In channels with abundant unskilled labor and numerous small supliers, marketing services are provided through less costly labor intensive means (Pingali 2007). Therefore, in traditional channels, human or animal traction, instead of mechanization, provides transport services to the nearest village market.

Fragmented value chains can also play a factor if intermediate food products are exported to another country for further processing. In a fragmented value chain, the production process is split into different intermediate steps which may be implemented in different locations, including different countries (Jones and Kierzkowski 1990). Not only is the production process fragmented, but the value-added benefits of each stage of production are fragmented across economies as well. For instance, in the case of Southern Africa agriculture, new fragmented value chains have appeared which require capital-intensive methods of transport across South Africa and between South Africa and Zambia (Weatherspoon and Reardon 2003). Modern channels add value for retail markets with fragmented value chains. However, traditional channels are not long enough, limiting small holders to accept the lower value-added, commodity-oriented segments of production.

Longer global value chains provide the benefit of contractual relationships with buyers of agricultural goods in which extension services or factor inputs are offered to farmers in exchange for a commitment to sell output to the buyer. Swinnen (2009) illustrates several examples of these mutually beneficial relationships. With the buyer serving as the intermediary, the global nature of these marketing chains facilitates the movement of capital and extension services to farmers. The benefit for both buyers and farmers is that they contract to an agreed upon delivery price and quantity, although farmers may be tempted to conduct side sales to third parties at higher prices. This framework allows farmers begin to participate in the commercial sector by supplying product with enhanced attributes at prices intermediate buyers and consumers are willing to pay.

Marketing channels, the networks through which trade occurs, are complex, dynamic structures that convey goods, credit, payments, and a variety of other market-related information between numerous economic agents along the path to the consumption of final goods (Stern and El-Ansary 1988). Institutions respond to change when a sufficient number of agents, especially holders of power, embrace change according to Parente and Prescott (2002) in their book, Barriers to Riches. Because ideas, technology, and methods are easily adaptable, the rate of modernization of marketing channels in recently emerging economies is much faster than the rate of institutional strengthening, which requires the consent of agents holding market and political power.

When institutional reform lags behind the modernization of marketing channels, it impedes complementary adjustments in traditional markets, especially the labor markets. Weak institutions prevent agricultural labor from reallocating to more productive occupations and, consequently, traditional farmers are more likely to remain in the less productive traditional sector. Thus, their comparative advantage weakens while their ability to reallocate resources, due to weak land markets, is reduced (Nurmagambetov and Roe 2001). Modernization creates demand for more labor while marketing channels adjust by adapting new technologies, but traditional channels cannot provide a strong complementary response.

Food marketing is susceptible to market failures due to several factors related to technology, human capital, infrastructure, and societal customs. Smallholder farmers have difficulty participating in the modern food retail channel because their products fall short of quality and food safety standards modern grocers demand. They also have difficulty in joining modern export channels not only because of the inability to meet product specifications, but also because of capacity and organizational constraints. Land markets also contain market failures since the supply of land is not integrated between freehold and customary land tenure. For a number of reasons, transfer of title is expensive and cumbersome.

The process of growth from an agricultural economy to an industrial and service sector-based economy has historically taken a considerable amount of time, as discussed by Parente and Prescott (2002). The speed of transition depends upon the state of technology and the supply of capital. Hanson and Prescott (2002) propose that countries cross a threshold in TFP that triggers a switch from a traditional, classical production function to a modern, neoclassical production function. The determinant factor in this transition is the degree of economic efficiency, as relating to a country's policies and institutions. The pioneering economies in the transition, such as the United Kingdom and the U.S., transformed over decades as they implemented new technologies in a step-wise fashion. Economies entering transition in more recent years have the advantage of employing the latest technology, thus jumping over the incremental technological advances pioneered by the early economies.

1.3.2 Transition Experience of the United States

The transition experience of the U.S. economy serves as a template for economies entering transition in more recent years. Although the context, of course, is different, patterns in markets, production, and resource utilization bear a similar although slower pattern over time. For instance, in the U.S. experience, the number of farms declined from 3,962,000 in 1960 to 2,099,000 in 2005 while the average farm size increased from 297 to 445 acres (NASS USDA). The capital stock of U.S. farms increased in nominal terms from $19 billion to $113 billion (ERS) while workers exited farming as rural labor was pulled into higher paying non-farm employment In 1960, about 7 million people worked on farms compared to only about 3 million in 2005 (NASS USDA). Purchased inputs contributed to the increase in agricultural productivity too. In terms of thousands of nutrient tons, the application of nitrogen, phosphate, and potash increased almost three-fold from 7,464 to 22,146 thousand nutrient tons (NASS USDA).

This story of increased productivity is evident in the USDA's indexes of production. The output index (where 1996=100) increased from 0.55 in 1960 to 1.11 in 2005. The index of inputs, however, fell slightly from 1.01 to 0.97. These indexes agree with the increase in total factor productivity (TFP), which increased from 0.54 to 1.14 (ERS). These figures reveal a productivity story involving a changing allocation of resources. Over this period, American farmers increased agricultural production by increasing capital intensity, allowing factor shares of land and labor in production to fall.

Marketing margins in U.S. agriculture contribute to the enhanced productivity story by reflecting the increase in value added downstream in the supply chain. Analysis of marketing margins reveals that commodity producers receive a smaller percentage of the retail price as intermediate steps in production add value along the way to the final retail market. In commercial supply chains, intermediate processors enhance the value of the primary commodity with modern packaging, faster transport, the addition of other ingredients such as vitamins, and higher, more consistent quality standards. In the case of U.S. agriculture, the farmers share of consumers food expenditures fell from 33% in 1960 to 19% in 2005 (ERS). This change in marketing margins shows that while other factors such as concentration and market power may have a role, the agricultural marketing chain becomes longer and more complex as it modernizes. In contrast, traditional marketing chains remain relatively simple and more direct because less value is added in fewer intermediate stages.

In the commercial food channel, the processing stage assumes more importance as products accumulate added-value during this stage. From 1958 to 1997, annual capital expenditures per processing establishment grew by a remarkable 7.1% in constant 2005 dollars. Shipments per establishment and value added per establishment grew at annual rates of 3.3% and 5.8%, respectively. Of note is that the value-added output per establishment grew faster than shipments. This difference suggests that processors added new value to their output in terms of time, place, and form, and simultaneously benefited from lower input prices, especially in terms of agricultural commodity inputs. During this time, the number of establishments decreased by 0.8% per year. As is evident, the food processing sector consolidated while it experienced capital deepening and increased value-added output. This story also illustrates correlation between capital deepening and consolidation, but not necessarily causation. Smaller processors may tend to be less capital intensive, and through this period, advances in food processing technology were adapted. Even net of depreciation, the faster growth of capital expenditures helped to stimulate production.

Moving down the marketing channel, we observe increased productivity in the U.S. food wholesale sector. Data from the Census of American Business and the Economic Census show that sales per employee (in constant 2005 USD) increased about 1.9% per year between 1958 and 1997. Sales per establishment increased over the same period by 4.7% per year. Employees per establishment increase by only 1.6% per year, however. During this time, sales increased faster than the growth of either the number of establishments or the number of employees. This data suggests that the U.S. wholesale food sector became more productive over the last forty years. Higher levels of sales, in constant dollars, were obtained with smaller proportions of establishments and labor. The throughput of sales per establishment increased, possibly due to the introduction of information technology, physical expansion of establishments, and consolidation in the wholesale market. The relatively slower growth of sales per employee also suggests the increase in capital intensity of the sector.

At the end of the marketing channel, the retail food (grocery) sector exhibits signs of consolidation, following demographic trends in the U.S. While the number of establishments fell by 1.7% per year, sales increased by 1.7% per year in constant 2005 dollars. During the same 39 year period, the number of employees fell by just 0.3% per year. These figures reveal an interesting storywhile sales per establishment increased greatly by 10.1% per year, sales per employee grew at just 2.3% per year. This difference in growth rates points again to productivity gains due to consolidation of the retail sector. To a lesser extent, the smaller growth rate of sales per employee reflects capital deepening and the trend towards self-service shopping. Finally, sales per establishment grew at an annual rate of 4.1%, reflecting not only consolidation but also greater average store sizes.

The U.S. economy, with its agricultural sector, has already experienced this transition process over the course of several decades. In contrast, emerging economies are proceeding through the same transition at a much higher speed because, unlike the U.S., these economies can adopt and benefit from the latest publicly available proven technologies. The study of the experience of the U.S., which is a rich source of reliable data, provides a framework for understaning the transition of Zambia's food marketing channels.

2 Zambia in Transition

In this study, we select the economy of Zambia because it is in the early stages of the transition process from traditional food channels to modern, commercial channels. Zambia represents a modern copper and other base metal mining and refining industry set in the environment of a traditional agrarian economy. The capital intensive mining industry, which earns most of Zambia's foreign exchange, also generates some intermediate processing and fabrication of the metals. Although the mining industry is dominant, it employs relatively few workers compared to the agricultural sector.

Figure 2.1: Map of Zambia

Zambia falls in the low income group of nations with a GNI of US$12.5 billion and total population of 12.9 million in 2009. Life expectancy at birth was 45 years compared to the low income group average of 57. GNI per capita was US$960 versus US$1,126 for sub-Saharan Africa and US$512 for low income nations.

As a percentage of GDP, the structure of the Zambian economy consists of services–44.3%, industry–34.1% of which manufacturing is 9.6%, and agriculture–21.6%. The primary industries are base metal mining and metal refining. The leading exports are copper, cobalt, electricity, tobacco, flowers, cotton, copper cables, maize and sugar. Leading imports include machinery, transportation equipment, petroleum products, fertilizer, food stuffs, and clothing. While Zambia is highly urbanized, especially in Copperbelt province, agriculture represents about 85% of employment.

Zambia is endowed with land, rainfall, and sun for agricultural production. Agriculture in Zambia employs about 85% of the workforce, mostly in smallholder farming. Only about 17% of the arable land is under cultivation, partly due to slight underpopulation in the countryside. Zambia's largest crop and staple is maize. Depending on the success of the harvest, Zambia may be a net exporter or importer. Since the 1960's, irrigation schemes have helped to increase agricultural output.

In colonial times, white settlers farmed large estates found along the line of rail. On the other hand, the average smallholder farm is just a few hectares. This legacy is part of the story of the bifurcation of Zambian food channels. Smallholder farmers, because of their small scale, low levels of education, and geographic dispersion from the benefits of infrastructure and larger markets, face higher transaction costs that inhibit competition (Ortmann and King, 2010).

Zambia's food retail sector is divided into two branches–the informal which includes stands, kantembas, and hawkers, and the formal market which includes supermarkets and other large formats. The growth of the modern channel is relatively new with Shoprite entering the market in 1995 with the purchase of state-run stores in major cities as a part of the economic reforms. The international grocer, Spar, also operates 7 stores in Zambia with plans to open 30 more by 2015.

On the wholesale level, the modern firms began to centralize procurement with the establishment of regional distribution centers which supplied local supermarkets. Local stores no longer were responsible for their own sourcing of product. The consolidating pattern of food marketing channels follows historical precedent going back to the Middle Ages. Braudel (1979) reports that as towns and cities arose, fragmented local markets gave way to more specialized, central markets with wholesaling functions. The transition occurred first in dry goods and later in fresh produce through the 19th century with further specialization in fresh produce into the 20th century with advances in technology (Codron and Lauret 1993). Earlier waves of the food retailing revolution followed the same general path affecting wholesale and retail markets that we observe in earlier times and, just beginning, in Zambia.

Competition in food retail generally begins in high margin, high income markets, and then spreads to other local markets as margins deteriorate. Zambia is experiencing the early stages of this growth, as illustrated by the experience of earlier wave countries such as Costa Rica and Argentina.

3 Overview of the Zambian Economy

3.1 General Features

Zambia, a landlocked country in southern Africa with a population of 12.9 million (2009), is known for its natural attractions such as Victoria Falls and wild game parks. With an area slightly larger than the state of Texas, Zambia is endowed with arable land and significant mineral resources. In Zambia, 68% of the population is below the national poverty line and 36% of the population is urban compared with 37% for sub-Saharan Africa. Population density is highest in the Copperbelt and central provinces. As of 2009, life expectancy at birth is 45, down in recent years due to HIV/AIDS.

Zambia enjoys a favorable combination of a tropical climate and an elevated plateau, with local variations in topography, which are conducive to growing a variety of arable crops. Different amounts of rainfall and variations in geography create three general growing zones (Saasa et al. 1999). Zone I, located along the western two-thirds of the southern border, is characterized by low rainfall, variable terrain, a short and hot growing season, and the high risk of drought. Zone III, making up roughly the northern half of the country, has ample rainfall, cooler temperatures, acidic soils due to leaching, and a longer growing season. Between Zones I and III is Zone II, which is characterized by moderate climatic features, periodic drought, and nutrient deficient soils. Across the country and within zones, Zambia has a sufficient degree of variation in soil types, topography, and rainfall to host a large variety of crops.

The ecological diversity of the country allows for a variety of agricultural activities. Maize is grown generally in the south-eastern half of the country. Traditional smallholder farmers produce a number of subsistence crops, especially white maize. Casava and millet are widely grown in Northwestern and Western provinces as well as in Northern province. Sorghum, rice, and wheat are also cultivated in parts of the country.

Zambian agriculture grows a number of cash crops with the aid of technology, mechanization, and hired labor. The commercial farming sector, mainly along the line of rail, grows most of the non-traditional export crops which include maize, wheat, Virginia tobacco, soybeans, sugarcane, seed maize, coffee, and horticultural crops such as cut flowers.

Zambian farmers use a variety of inputs, depending on their resources including the size of land holdings, labor availability, access to credit, and technical knowledge. Smallholders farming less than 2 hectares generally use handheld implements, which is indicative of high labor intensity. They may use hybrid seeds for maize and some commercial fertilizer. Emergent farmers working from 5 to 20 hectares of land employ animal traction and more animal manure than smallholders. Commercial farmers employ irrigation, commercial fertilizer, herbicides and pesticides, mechanization, and hired labor. As land under cultivation increases to about 5 hectares, yields fall; after that, yields increase with the land under cultivation. This U-shaped yield curve is the result of two opposing forces–labor intensity at first giving way to scale economies.

Smallholder farmers are dispersed across Zambia while commercial farmers are generally concentrated on better land situated along the line of rail from the Copperbelt through Luska to Livingstone, and in Eastern Province. There are about 800,000 smallholder farmers, of whom half are subsistence, farming on average 1.5 hectares. Emergent farmers, numbering around 50,000, cultivate with oxen as draught animals. The third group is that of about 1,000 commercial farmers engaged in the production of cash crops.

The total land area of Zambia is about 75.3 million hectares, of which 25.7 million hectares are dedicated to national parks, game management areas, or are bodies of water. Of the total area, 47% is potential arable land but only 15% of this is under cultivation, which represents about 7.0% of total area. Thus, Zambia is endowed with a large area of arable land which is not under cultivation. Stateland, defined as land with title deeds, represents only 3.7 million hectares, including urban areas and agricultural land along major highways. Traditional lands, defined as under the control of local chiefs, represent 47.9 million hectares. According to the Zambia Constitution, all land is held in trust for the nation by the president, and may be leased up to 99 years. Commercial farms can obtain title deeds for state land, however few smallholder farmers hold title deeds to traditional land. Instead, they access land through the customary land tenure system upon the approval of tribal chiefs. Accordingly, much traditional land remains occupied, but uncultivated.

Zambia gained independence from Great Britain in 1964 with Kenneth Kaunda as its first president. Kaunda converted Zambia into a one party state by the 1970's and instituted state ownership of mineral rights under the threat of expropriation. Policies favoring import substitution and infrastructure projects were an attempt to diversify away from copper mining and encouraged production for home consumption instead of for exports. The Zambian economy held up in the first ten years with favorable copper prices and the legacy stock of capital. Zambia then experienced two shocks to its economy–the sharp rise in oil prices in 1973/74 and 1979/80 and the fall in copper prices starting in 1975. Moreover, Zambia's lack of continuing investment in the mining industry and a greater overburden to ore ratio led to falling production levels for copper. These shocks, combined with an overvalued exchange rate, import tariffs, and subsidies made Zambia one of the most heavily indebted nations in the world by the 1980's. Zambia failed to respond to these developments and could no longer maintain its previous standard of living (Saasa 2003).

At that time the IMF insisted on a structural adjustment program (SAP) to help stabilize and restructure the economy in light of its heavy dependence on copper. The SAP included the following proposed measures: lifting of price controls, devaluation of the kwacha, reductions in government expenditures, cancelation of food and fertilizer subsidies, and increased prices for farm produce. The subsequent removal of food subsidies caused riots among the urban population, resulting in Kaunda's decision to ignore the IMF program in 1987. However, as economic imbalances persisted and socialist governments were beginning to collapse, the Zambian government renewed its cooperation with the IMF. In addition, Kaunda decided to step down and hold multi-party elections.

In November 1991, Frederick Chiluba was elected the second president of Zambia. Committed to a course of economic reforms, the Chiluba government privatized many state industries and lifted foreign exchange controls. During this period, in 1995, six state-owned food stores were privatized in a transaction with Shoprite Holdings. In 2000 the parastatal mining company was sold to private investors. The copper industry revived with the help of rebounding prices and new investment from China.

Infrastructure is critical to the Zambian economy, especially since it is a landlocked country. Zambia has two main railways. The oldest, Zambia Railway Systems, operates a network from the Democratic Republic of Congo border and the copperbelt through Lusaka and Livingstone, connecting to Durban and beyond. The Tazara Railway is Zambia's second system, running northeast from Lusaka to Dar es Salaam.

According to the National Road Fund Agency (NRFA), Zambia had one of the best highway networks in the 1970's, but neglect of maintenance led to deterioration of 80% of roads. Trunk highways generally run north to south, connecting the copperbelt to Lusaka; and east to west, passing through Lusaka.

Although Zambia is landlocked, the country has access to several trade corridors through adjacent countries. To the west, Namibia's Trans-Caprivi Highway connects Zambia to the port of Walvis Bay on the Atlantic Ocean, making up a section of the most-northernly paved highway connecting the Atlantic and Indian oceans, except for coastal highways along the Mediterranean Sea. Also to the west is the newly rebuilt Benguela Railway connecting the copper fields of Zambia and DR Congo to the Atlantic port of Lobito, Angola. To the east highways connect Zambia to the Indian Ocean port of Beira via Harare. Another eastern corridor runs by highway from Zambia to Lilongwe, Malawi and then by rail to the deep sea port of Nacala, Mozambique on the Indian Ocean. These transport corridors show that while Zambia is landlocked, it has several options for participating in international trade through existing corridors that have potential for improvement.

The recent economic history of Zambia provides the context for understanding the current state of food marketing channels and their respective agents–farmers, suppliers, wholesalers, and retailers. The Zambian economy is dualistic, composed of an enclave copper mining sector set within a nation-wide agrarian economy. Copper mining drives the modern Zambian economy. In terms of exports and foreign exchange earnings, mining is Zambia's dominant sector, even though the service sector, which includes government expenditures, holds a larger share of GDP. Associated with the mining sector are additional downstream metal and wire fabrication industries in Copperbelt Province. Altogether, Zambia's industrial sector is the source of demand for skilled, high income labor, which in turn has derived demand for modern food retail products in areas such as Copperbelt Province, Lusaka and Livingstone.

The mining and processing of copper was responsible for 34.1% of GDP in 2009. Due to years of managerial neglect and a lack of investment, copper output slowly dropped. After falling from 700,000 metric tons in 1973 to 226,000 tons in 2000, copper output turned up with the privatization of the mines. In 2010 copper production amounted to 720,000 metric tons. The Copperbelt continues to be the center of commerce and industry for Zambia with the revival of the mines.

The agricultural sector plays an important role in the Zambian economy, although its share of GDP is only about 21.5%, by employing 85% of the workforce. Maize is the main cash crop and also the primary staple for the country. Other crops include cassava, wheat, soybeans, sugar cane, millet, and other vegetables and fruits. The amount of rainfall determines the success of the maize crop and whether Zambia is an exporter or importer of maize. The food processing sector supplies meat and produce to modern retailers such as Shoprite.

The service sector has experienced rapid growth since the institution of economic reforms in the 1990's. A part of this growth was the entry of modern supermarkets such as Shoprite in 1995 as it purchased six state-owned grocery stores.

3.2 The Zambian Agricultural Land Market

3.2.1 Land Tenure

The Land (Conversions of Title) Act of 1975 had a far reaching impact on Zambia's land market. The Act had several provisions, among which are 1) all land in Zambia was vested in the President, 2) the conversion of freehold land to statutory land not exceeding terms of 100 years, 3) nationalization of vacant land and undeveloped lots. The Land Act ceased private ownership. Consequently, land had no saleable value nor was it useful as collateral.

The new market-oriented Chiluba government instituted land tenure reform with the passage of the Lands Act of 1995 which repealed the Land Act of 1975 and previous acts, and is now the basis for the current land tenure system (van Loenen 1999). The main new feature of the Lands Act was the establishment of a Lands Tribunal and a Land Fund. The Lands Tribunal, on the same level of authority as the High Court, hears all land conflict cases, including customary areas. The purpose of the Land Fund is to encourage land development through the provision of services in newly opened areas. Acting on behalf of the President, the Commissioner of Lands is delegated with authority to actually control land transactions. Thus, the Zambian land tenure system remains divided into two types: customary tenure rights derived from earlier Reserve and Trust land, designated for native Zambians from colonial times; and statutory tenure rights applying to State land which formerly was Crown land reserved for settlers.

Customary tenure covers 93% of Zambia's area and is characterized by the recognition of use and occupancy rights, but not ownership rights. Customary land is occupied by 73 tribes, headed by 240 chiefs, 8 senior chiefs, and 4 paramount chiefs (Mudenda 2006). Among these rights are individual ownership, concurrent interests, and communal interests. Individual ownership means that the occupant has more rights than anyone else. Concurrent interests means that other parties may enter the plot of land and use it for other purposes. The security of customary land tenure rights depends on the decision of the chief, and thus is subject to a change of mind or the installation of a new chief. The powers of the chief are limited by the consent of his people, and by overriding decisions of the President. Smallholders holding customary tenancy may sell their land to another member of the local village, but not to outsiders.

According to Mudenda (2006), conversion of customary tenure to leasehold tenure in not worth the cost in terms of money and time. The fee for a 14 year lease costs at least US$100 per lease and a few visits to one of the two Commissioner of lands offices in the country. The fee for a 99 year lease costs at least US$500 per lease for a more technologically advanced survey and several visits to district and commissioner of land offices. In addition, leaseholders are required to pay annual ground rents (land tax) of 20,000 kwacha (US$4.26) for the first hectare and 250 kwacha (US$0.53) per hectare up to 100 hectares as of 2004 (FIAS 2004, Global Financial Data).

In a sense, then, customary land tenure offers a degree of secure property rights which allows limited access to formal credit. Smallholders lack the incentive to convert customary land to state land given the monetary and time costs according to Mudenda, although ground rents are nominal. However, the strength of rights is not great enough to satisfy potential international investors in customary agricultural land (Adams 2003). One purpose of customary land was to serve as a security net for those villagers who migrated to the city and subsequently fell upon hard times (Adams 2003). In such cases, they could return to their village and exercise their right to avail.

State land tenure covers the remaining 7% of Zambia's land area and tends to include the best agricultural land and most accessible land in terms of transport, communications, and other infrastructure. Allocated to settlers in colonial times, State agricultural lands are cultivated mainly by commercial farmers, who prefer security of tenure by the registration of title documents (Amankwah and Mvunga, 2011). Compared to customary land, leaseholders of state land feel more secure because titles are defined by modern survey methods. Thus the registration of title to state land creates a barrier to the integration of state and customary tenure. Yet, according to Adams (2003) the process of selling land or obtaining title is not efficient; because of the lack of government funding, the Ministry of Lands is short of professional survey staff and processing can take years. This situation results in a diminished security of holdings of state land as well. Because of these administrative and financial barriers, the percentage of land transferred from Customary to State land is small.

Administrative and budgetary limitations in the Ministry of Land highlight the importance of prioritizing needs. Adams (2003) suggests that the Ministry of Land should focus its effort on commercial transactions involving state land and let traditional authorities and structures administer customary lands

Land tenure disputes have arisen among several parties such as smallholders, tribal chiefs, the government of Zambia, and investors due to the insecurity of customary rights and the lack of administrative resources to administer the law (Mudenda 2006). Since land is the basis of authority for tribal chiefs, they are reluctant to encourage the transfer of tenure to State land. According to Oxfam, investors have been able to obtain title to customary land for virtually no cost and then turn around and sell it to other investors. The Government of Zambia has recently initiated a policy to introduce large scale commercial farming on customary land in the form of outgrower schemes. However, the popular news media reports that smallholder farmers feel they are not treated fairly compared to their commercial counterparts. The newly elected Sata government has sided with the smallholders in these schemes. There appears, then, to be sufficient conflict among all these parties to preserve the customary land tenure into the long-run.

An incoherent land tenure system leads investors to focus their demand on state lands in intensive agricultural production, thus driving up the cost commercial agriculture. Customary lands, also, do not benefit from the resources that investors could otherwise bring to the smallholder sector, especially with insecure land tenure and likely suffer for a lack of capital investment.

In summary, dual land tenure in Zambia has created two land markets–state and customary. Following European settlers, commercial farmers farm the better quality state land while tribal authorities oversee the allocation of customary lands for smallholders. Although conversion of title from customary to State land is allowed by law, administrative and financial barriers, as well as smallholder and chiefs' understanding of regulations, limits conversions to a tiny fraction of land.

4 Food Marketing and Processing–from the farm-gate

Food marketing channels in Zambia reveal important characteristics about the stages of development of farmers, traders and processors, and consumers. Food marketing channels may be short and momentary for subsistence farmers or long and multi-staged for commercial processors and exporters. Thus, although this study divides the analysis into smallholder/traditional and commercial/modern stages, several types of channels operate along a continuum. In Zambia, food marketing channels may be readily specified by three general stages: production, marketing, and consumption. Additional stages in the marketing process such as cleaning, sorting, grading, aggregating, distributing, break-bulking, and arranging, provide greater insight into where value is added along the channel. The length, in terms of the number of stages, of a channel reveals how much intermediate input goes into the final product.

4.1 Traditional Food Channels

Traditional food channels are distribution chains linking smallholder family farms to local consumers in the context of long-established, traditional economies, which are characterized by low levels of capital, short structures of production, and subsistence levels of living. Subsistence farming is the shortest possible marketing channel. In this environment, labor productivity remains low, inhibiting the formation of capital. The structure of production is short and momentary, consisting of a few labor-intensive stages of production and distribution. Larger smallholder farming operations can afford to employ more implements, animal traction, and hired labor. They also purchase more inputs such as fertilizer. Smallholders store a portion of their harvest for home consumption through the next year and market the rest in a number of channels (Hantuba 2003). The most direct marketing channel is farm-gate markets where farmers sell their produce to others such as neighbors, workers with non-farm incomes, and fellow farmers, in the vicinity of their farm. In areas with heavier traffic, farmers might sell at roadside stands for cash, barter, or credit.

Because of limited resources, smallholders often cooperate to bring produce to local markets, taking advantage of economies of scale. For instance, Bauer (1954) describes how local farmers aggregate their production and choose one of their own to bring their produce to the market on the market day. Another technique in food distribution is to transport sacks of grain, for example, to the nearest terminus of truck accessible roads, thus dividing transport costs between farmers and merchants.

Zambian farmers have used a variety of marketing channels for their produce. Most accessible to smallholders are farm-gate markets through which produce is sold to neighbors and the surrounding village populations. Consisting of cash, barter, and some credit transactions, farm-gate markets are limited and unpredictable, depending on traffic and on what has recently been harvested. About 20-50% of agricultural produce is estimated to be marketed in farm-gate markets.

A longer, frequently used channel is through a middleman, often a family relative or member of the village who purchases produce on cash or credit to resell in more distant markets. Serving as an extension to farmers, middlemen offer aggregation, bulking, and distribution services that would be prohibitively expensive for an individual farmer to take on. This arrangement benefits several smallholders at once by reducing per unit transaction costs related to transport and distribution. Policies that encourage the participation of middlemen increase demand for farm output, resulting in higher prices received by farmers. Since the period of market liberalization in the 1990's, middlemen have filled the gap left by parastatal agencies, often setting up along rural roadways outside major cities. This marketing channel terminates at an informal retail outlet such as an open air market or a roadside stand.

Moving further into urban areas are the informal channels of Ktembas (makeshift residential stalls) and street vending. These retailers are served by larger informal markets such as Soweto Market in Lusaka by breaking down bulk shipments from farmers and distributing smaller quantities. The large, open air markets such as Soweto serve as an important outlet for all kinds of farmers and middlemen around Lusaka. In addition, the market serves as a wholesale market supplying smaller urban food retailers. For modern retailers and their commercial suppliers, informal city markets are an outlet for surplus produce, absorbing excess supplies and satisfying demands for fresh produce. Large, open air city markets sell about 10-25% of produce supplied by smallholders and up to 75% of produce supplied by middlemen.

4.2 Modern Food Marketing Channels

Modern food marketing channels are longer and more complex, indicating greater capital intensity and more intermediate inputs, depending on the product. They are characterized by the greater use of technology, forward contracting, international sourcing, and urban retail markets. Modern food retail consumers, mostly urban, have higher incomes, preferring food with the attributes of higher and more consistent quality, and timeliness. There are three main types of modern food marketing channels in Zambia. First, wholesalers and retailers may import from foreign suppliers who can meet their quality standards. The second channel originates from Zambian commercial farmers who also have the capacity to meet standards. Third, the smallest channel originates with smallholders, who have difficulty meeting product standards for a number of reasons. The first two modern food channels can supply fresh produce with the attributes that modern retailers prefer. Better technology across the production process produces higher yielding and better quality produce. Capital equipment such as refrigerated trucks, warehouses, and packaging equipment enhance the marketing process. In order to ensure consistency of supply, they make contractual arrangements with farmers, most of whom are commercial farmers, domestic and foreign, and some smaller scale farmers. However, the smallholder remains decentralized, lacking much vertical organization.

The wholesale link in the modern food marketing chain is an important part of modern retail strategy. Distributers, such as Shoprite's Freshmark, perform the wholesaling function with point of sale inventory control systems, a requirement for modern grocers managing far-flung stores across southern Africa. The system of regional distribution centers can more effectively control for quality and also smooth out the timing of incoming and outgoing shipments to retail stores. Moreover, transaction costs are lower since the distribution centers deal with a limited number of qualified suppliers. Only commercial farms have the capacity to enter into forward contracts for the future delivery of produce.

At the retail level, supermarkets have operated in Zambia for several decades. As in other parts of Africa, Greeks, other foreigners, and some locals own and operate individual supermarkets such as Melissa Supermarket, Kabulanga Supermarket, and Konkola hypermarket for example. These stand-alone grocers provide a range of processed food and produce, but remain relatively small in market share.

In addition to local independent supermarkets, larger food retail chains such as Shoprite have entered Zambia. The marketing channel for these chains is more complex. Based in South Africa, Shoprite operates 19 stores supplied by two distribution centers in Lusaka and Kitwe, with South Africa supplying much of the processed food and non-food items. The level of complexity is much greater: several local and foreign firms supply the two distribution centers which supply the nineteen retail stores and other retail customers. It is evident that such a complex marketing channel requires the input of a variety of support services and equipment such as skilled labor, transport services, legal and accounting, information technology, logistics, various levels of management, marketing strategy design, etc.

Overlapping the traditional and modern food sectors is a small marketing channel connecting smallholders to modern food retailers. Hantuba (2003) estimates that this hybrid channel represents less than 5% of market share of locally produced foods. Unless smallholders can adapt good agricultural practices, their capacity to participate in modern channels will remain limited. The logistic challenges this channel presents are considerable. First, a retailer and one or more smallholders must negotiate a contractual arrangement, most likely verbal specifying quantities, delivery schedules, quality standards, packaging and payment. They also must share a coincidence of needs since districts of Zambia vary in their agro-ecological endowments. A particular store in Northern Province may have more than enough cassava, which grows well there. The ability of farmers to grow a crop does not guarantee that the local retailer will be able to absorb their supply. Instead, middlemen would need to purchase the produce and market it in another region.

As a solution to these problems, Shoprite's Freshmark serves as an intermediary between the smallholders and the local Shoprite supermarket. This arrangement allows the retail stores to focus on marketing and sales and Freshmark to handle quality control issues in a standardized fashion. This marketing channel includes the intermediary role quality control by Freshmark, but produce is shipped directly from the smallholders to the local Shoprite supermarket.

It is important to note that food marketing channels differ according to consumer tastes, the amount of processing, perishability, and agro-ecological conditions. Maize, the leading product of smallholder farms, is consumed as mealy meal, stock feed, and in brews. Millers and other intermediaries process the maize, and are primarily responsible for quality standards. Because of the processing stage, supermarkets find these products acceptable to stock. Thus, smallholders benefit indirectly from retail participation.

4.3 Contract Farming and Outgrower Schemes

In Zambia, modern wholesalers and retailers have used outgrower schemes to ensure timely supplies of produce exhibiting consistency in quality and quantity. In an outgrower scheme, a modern channel food retail contracts with a smallholder, a commercial farm, or a group of farmers, such as with a cooperative, for the delivery of agricultural produce meeting specified characteristics in exchange for monetary consideration and assistance given to the farmer. Given the high transport costs in Zambia, a food retailer would prefer to procure produce from local growers if possible. Because they are catering to mostly urban, higher income customers who demand quality and consistency, modern retailers have an incentive to source their produce at the least cost. The problem, however, is that although local smallholders grow various kinds of produce, they lack the technology, human capital and financial capital to grow sufficient quantities with the attributes that modern retailers demand.

Outgrower schemes are a means of overcoming the constraints that both farmers and retailers face. Smallholders find difficulty in accumulating capital in the forms of working capital and capital equipment such as oxen, plows, and irrigation equipment, to varying degrees, depending on how close they operate to subsistence. Therefore, the crops they raise do not possess the value-added attributes that modern food retailers desire; smallholders then must market their produce through traditional channels or consume them at home. Other supply channels have been available for Zambian smallholders for agricultural loans, seeds, fertilizer, and extension services. However, since the structural adjustment program reforms of the 1990's, budgets have fallen and subsidies have been removed.

Modern food retailers face a dilemma of high transport costs for produce imported from, say, South Africa and high transaction costs of local procurement from smallholders. In addition, at least with Shoprite Zambia, when the Government of Zambia sold off its six state-owned food stores in a 1995 privatization deal, Shoprite was required to open at least one store in each of Zambia's provinces. From the beginning then, Shoprite's expansion had a more rural and middle to lower income strategy. To serve the retail groceries, Shoprite's wholesale subsidiary, Freshmark, set up two distribution centers in Lusaka and Kitwe. For logistical reasons, Shoprite would prefer to distribute goods and produce through Freshmark. Individual store procurement of fresh produce at least would quickly complicate their distribution system. For instance, to streamline procurement, Shoprite has had some forward contracting arrangements with Zambeef for meat and poultry products. It is clear that procurement from numerous individual smallholders by individual stores would reduce operating efficiency for the whole enterprise.

In an effort to overcome these obstacles and secure local supplies of produce at favorable prices, Shoprite and other grocers enter into outgrower schemes with various levels of involvement. In some cases, the store provides the seedlings to the smallholders with the understanding that the harvest would be sold to Shoprite. In other cases follow-up extension services are provided.

There is no one size fits all retailer-smallholder outgrower scheme. The specific structure depends on the local situation. It is evident, however, that these schemes introduce the concepts of forward delivery planning and commitment to parties of the transaction. It is unacceptable to the retailer to take delivery of produce on a spot basis with no controls for quality and quantity. Modern retailers are not set up to receive deliveries in wheelbarrows, as is the case from time to time, at favorable prices for the smallholders. Nor can the smallholders rise to meet quality and food safety standards without outside investment and training.

Contract farming also exists between smallholders and commercial farming operations or agricultural processors (Mansur et al.2009). Under this structure, the commercial partner or sponsor may provide inputs, loans, marketing assistance, or extension services under a contract in exchange for the smallholder providing land, labor, and a commitment to sell the harvested produce at an agreed upon price. Different variations of outgrower schemes exist, depending mostly on the structure of the commercial partner. In the centralized model, also known as outgrower schemes in Africa, smallholder production quotas are distributed at the beginning of each season, and quality is tightly controlled. (Eaton and Shepherd, 2001). The commercial sponsor purchases the crop from smallholders, and then adds value through processing and marketing. Centralized schemes, common in Zambia, are found in the cotton, tobacco, sugar cane, bananas, and tree crops. Assistance to smallholders varies greatly, ranging from seeds to field preparation and harvesting services. An example of the centralized model is Lonrho Corporation growing cotton in Zambia with 15,000 smallholders supplying its ginnery.

The nucleus estate model is a variation of the centralized model in which the sponsor farms a parcel of land in a central location to serve as a demonstration farm and to provide a minimum level of throughput. Smallholders in the surrounding area are then introduced to the techniques and management style of the demonstration farm.

Under the multipartite model, governmental and private partners form a joint venture with separate members responsible for the various tasks and stages of production and marketing. Sponsors benefit by having to work with only one farmers' organization instead of numerous smallholders. While this arrangement reduces the risk of side-selling, it does not develop management skills for individual farmers.

Under the informal model, entrepreneurs or retailers may make simple, informal production contracts with smallholders on a seasonal basis, particularly for crops requiring minimal processing such as fresh vegetables and fruit. Minimal support is offered in terms of seeds, and grading and packaging for retail distribution. Sometimes an entrepreneurial promoter or developer will serve as the sponsor and provide a valuable service of consolidator and distributer for the downstream retailer. Long-term contracts do not exist and the smallholders and consolidators are exposed to the risk of default. This model appears most similar to the approach of Shoprite. There is no one best model of contract farming, nor must a particular approach remain static. Since local situations and markets vary geographically and over time, a good contract farming scheme will be flexible.

4.4 Marketing Boards

Agricultural marketing boards have existed in Zambia, as in many other former British colonies, since 1936 in one form or another, characterized with strong governmental control and price subsidization (Wichern et al., 1999). Up until 1992, the purpose of the marketing board was to provide cheap food to the urban markets while paying fixed prices to farmers for produce, especially maize. Farmers along the line of rail were assured of a market for their produce, but more remote farmers also received the same price, although their marketing margins were greater, resulting in lower net revenue. The board also provided subsidized inputs and financing under favorable terms. All farmers enjoyed price and procurement guarantees, with preference for maize production.

The policy of pan-territorial pricing and abundant, cheap staples for the urban populations suffered unsustainable financial losses. As a result, the Agricultural Marketing Act was passed, which partly liberalized the market and freed several producer prices, except for maize. After 1992, the new government aimed to decontrol prices and reduce subsidies to enhance the market's price signals. This step was part of a larger program of structural adjustment to put the country on a better footing. However, implementation over the 1990's was incomplete and at times ill-timed, resulting in unfavorable indirect effects among market participants, including traders. Throughout this period, market integration was hampered by infrastructure and institutional problems. Moreover, a hike in tariff rates in 1996 ran against the move toward liberalization.

During this time several policies suppressed private trader participation in the markets. Sometimes the government would fix producer prices, but not consumer prices. On another occasion, the government issued credit vouchers in lieu of cash for the purchase of maize. But the problem was that these notes did not mature for a year, locking up farmer and traders' working capital, and in addition lost value in the high inflation environment. Another type of interference from mandated consumer prices and increased supplies of food aid reduced the incentive of traders to be present in the market. Also, export restrictions up until 1996 in the form of unnecessarily long bureaucratic delays and even bans prohibited farmers and traders from receiving higher prices in neighboring countries such as Malawi and Zaire (Congo).

Thus, up to the 1990's, with the government's policy of intervention there was little uncertainty for market participants. This well-known structure disappeared as various parts of the liberalization policy were implemented and then rescinded. The production share of maize, which enjoyed preferential treatment in the 1970's and 1980's, began to fall, with cassava's share increasing. In addition, the production of maize in marginal regions such as Northern, Northwestern, Luapula, and Southern provinces fell significantly, especially in more remote districts.

It is interesting to note that smallholders profited from the policy environment of the 1970's and 1980's. Their marketed production share increased from 60% to more than 80%. Managerial capabilities mattered little since the input and output markets were backstopped by policy. In effect, smallholders were contract farmers for the national government, which provided them with seed, fertilizer inputs, extension services, guaranteed the procurement, marketing, storage, and financing of their production. In poor harvest years, the government allowed loans to be converted into grants, thus providing a kind of crop insurance. This situation raises the question of why the smallholders of the 1970's and 1980's were not able to increase productivity and incomes and graduate into the larger scale emergent class of farmers, as the smallholder policy development economists argue.

4.5 Foreign Trade Channels

Foreign trade represents a significant portion of Zambia's agricultural production and consumption. After liberalization, informal cross-border trade has been estimated to represent about 20% of all agricultural production, reflecting the fact that the formal sector may find trade among poorer and more remote districts unprofitable. Due to its central location and depending on regional production, Zambia's trade in maize flips from export to import from time to time. The COMESA free trade agreement has helped to facilitate trade in the region in recent years by streamlining the border-crossing process for traders. However, before the structural adjustment program of the 1980s, the agricultural sector suffered the effects of the overvalued Kwacha exchange rate. This policy suppressed agricultural exports by making them relatively more expensive and encouraged the import of agricultural goods, which put further pressure on domestic markets. The copper industry did not share this disadvantage since revenues and many expenses were in terms of dollars. To further diminish the competitive position of Zambian agriculture, significant amounts of food aid increased domestic supplies and reduced the prices received by farmers.

4.6 Marketing Channels of Zambia's Major Agricultural Products

Wheat products are widely consumed across the country as secondarily processed baked goods. Urban populations have stronger preferences for wheat products, as indicated by Shoprite's crowded bakery counters. The wheat marketing channel includes imports as well as local supplies grown on commercial, irrigated farms. With relatively higher quality standards and the required capital intensity, wheat production is not suited to smallholders.

As traditional staple foods, sorghum and millet are widely grown and consumed by rural populations. However, urban populations with more modern preferences view these as inferior and virtually unknown foods. Hence, supermarket demand is also weak. Yet the greatest source of demand is among brewers and stockfeed processors. In this case, the marketing channel remains rural-based and spills over into processing, with little opportunity for modern retail penetration.

Zambia's middle class consumes rice, both local and imported varieties, mostly from Thailand. These higher income consumers prefer imported varieties because of the perceived difference in quality. Local varieties have yet to reach acceptable standards, and thus supermarkets are reluctant to stock them. With added production and milling technologies, it would be possible for smallholders to participate in modern retail channels.

The commercial farm sector produces about 80% of Zambia's soybeans, which are mostly processed into oilseed products for human consumption and stockfeed. By adapting good agricultural practices, such as improved varieties, smallholders could increase their participation in the channel. Processing is a major step in the soybean channel.

In contrast to soybeans, smallholders produce 99% of Zambia's sunflowers. Having a higher oil content, sunflowers are mainly processed into oil and stockfeed, both of which are carried in supermarkets. The marketing channel for sunflower starts with smallholders and passes though the processing stage onto supermarkets. With strong indirect demand, smallholders could grow the channel with improved varieties.

Groundnuts are widely grown by smallholders and consumed in Zambia as raw and processed nuts, and as peanut oil. This channel is easily accessible and already supported by supermarkets. There is room for smallholders to expand this channel, especially if they could attract processors with good agricultural practices.

Dry beans, likewise, which are widely grown and consumed in raw and baked form in Zambia, have informal channels upon which to build. With improved varieties yielding desired attributes, dry beans would be worth stocking in supermarkets. The potential expansion of this channel rests on its present strong supply and demand across the country.

Some marketing channels have failed in Zambia, as is the case of coffee. Within the last 15 years, commercial scale irrigated coffee was introduced with the help of some development financing. However, the main commercial operation went bankrupt because, apparently, its costs were too high and it received below market-rate financing which made the project appear profitable.

A recent addition to Zambia's crops is the spice paprika. Production has grown rapidly among smallholders, accounting for 25% of production, and large scale farmers. Paprika is locally processed for its oil, which is used for its color. With strong domestic and world demand, paprika holds potential for profitable smallholder participation, as do other spices carried by supermarkets. This export oriented channel holds much promise for Zambian smallholders.

Another relatively new marketing channel has opened up for horticultural products such as roses and baby corn. These types of products require high managerial skills, but offer high returns. Numerous smallholders may not be able to attain the required standards. Domestic channels serving supermarkets already exist as well. Vegetables also have widespread demand and supply, but further growth in general is limited by insufficient cold storage facilities and institutional frameworks which make market functions such as price discovery more difficult.

Root crops such as cassava and sweet potatoes are widely consumed and carried in supermarkets. The processed form of cassava flour and its leaves are becoming more popular among urban populations. Cassava is an example of a marketing channel that is already established, starting among smallholders and reaching traditional and modern retail.

The above examples of major tradable agricultural marketing channels illustrate that no one best marketing channel exists. Marketing channels form for the purposes of transporting product, communicating information about consumer preferences and supplies, and transmitting payments. Thus, individual channels will vary according to the characteristics of supply, processing options, and sources of demand. Similarly, the growth of marketing channels into modern retail will display unique structures according to the commodity.

5 Literature Review

5.1 Growth Theory

The study of Zambia's food marketing channels and their impact on the structure of the economy is rooted in economic growth theory. The dynamics of Zambian food channels are located at the crossroads of economic sectors and factor markets. It is another case in the ongoing discussion of agriculture and structural transformation in developing countries. de Janvry (2010) summarizes the recent history of agriculture in development in three stages. First, in the 1960's, agriculture was viewed as an engine of development. Then, in the 1970's, industrialization and import substitution were emphasized at the expense of agriculture. Finally, in the 2000's, agriculture is seen once again as an engine, but for broadened goals of development.

Bruce Johnston (1970) discusses the early theories of development and the debate over the secular decline in agriculture. As production chains grew, some home activities were replaced by food processing. With manufacturing attracting more labor out of agriculture, Arthur Lewis postulated that the marginal productivity of farm labor was basically zero. Jorgenson considered how agricultural surpluses funded growth in non-agricultural sectors. Similarly, Ed Schuh highlighted how agriculture supported the development of trading centers such as Sao Paulo. Paul Bairoch raised interesting points on the role of technological diffusion in creating several related sectors. Rosenburg also discussed the importance of a local capital goods industry which is able to adapt and modify technology to local needs. Harry Johnson, similarly, raised the need for complementary levels of human and organizational capital to match the accumulation of physical capital. Peter Kilby states that entrepreneurs do respond to incentives. Johnston's survey of the literature points towards the important effect of capital accumulation with complementary growth in local adaptation. Human capital needs to grow in step with physical capital. The best kind of capital accumulation would appear to be in equipment that is easy to adopt, effective in raising labor productivity, easy to manufacture locally.

In support of Arthur Lewis, Roe (2001) presents a CGE model featuring two characteristics– Engel's Law and concentrated downstream processors in the food marketing and production channel. In order for the agricultural sector to accumulate capital, become more productive, and release labor, it must first realize income gains attributable to the productivity of its factors of production. Where agricultural producers are not organized to counter the market power of the downstream processors, they are not as able to realize income and accumulate capital. Thus, smallholders facing oligopsonistic buyers can experience lower rates of growth.

Gollin (2009) examines the theories of economic growth and poverty reduction in Africa. Lewis, Rosenstein-Roden, and Rostow see the job of development as growing the modern sectors and so employ the pool of labor represented by subsistence agriculture. In an alternative view, T.W. Schultz believed that poor nations face a food drain and must first increase agricultural productivity to feed the population, and then to release resources from the agricultural sector into other sectors. This theory may best apply for certain landlocked countries for whom imports are too expensive, such as Zambia. Gollin suggests three possible answers to the question of why agricultural incomes remain so low in sub-Saharan Africa (SSA), and why semi-subsistence economies remain the norm. The first possible reason is low agricultural productivity caused by several reasons such as the lack of research on Africa's staple foods. A second possible reason could be input price distortions caused by distribution costs to smallholders or a lack of subsidies. The final possible reason is poor market access due to poor transportation infrastructure as remoteness and isolation are signs of poverty.

Kislev and Peterson studied induced innovations and farm mechanization in the U.S. (1981). Using a Hicksian framework, they concluded that both agriculture and manufacturing provide and use factors from one another. Innovations in manufacturing induced change in agriculture. The question remains why it has taken so long for these innovations to affect countries like Zambia.

Sector growth is also affected by the extent of the market. In a famous article, Stigler (1951) explains the rationale for increased specialization (division of labor) as the market grows. Increased specialization in Zambian agriculture would allow for more productivity and capital deepening.

Yang and Zhu (2013) use a two sector growth model to investigate the relationship between the modernization of agriculture and long term growth. The growth model is compared with data from 1790-1909 England. Because of the fixed resource of land and population growth, traditional agriculture income and productivity remain stagnant. However, as the modern sector grows, prices of industrial goods (all kinds of modern agricultural inputs) fall to the point where they become affordable to traditional farmers. At this point, farmers begin to switch to modern methods of farming. Agricultural labor shares fall and incomes rise. The excess farm labor is free to move into the modern sector. In Zambia, this transition seems to happen only among the small emerging farmers, however.

Roe and Diao (2004) model the significance of capital accumulation for the retail food industry of Morocco with a Ramsey growth model. They found that differences in relative capital intensity explained, in part, the process of economic growth and capital deepening. Echevarria (1997) also shows how consumption goods are produced with various factor intensities, which affects sectoral composition and growth. Herrendorf et al (2013) also confirm patterns of structural transformation first identified by Kuznets. Using a variety of data series, they find unique patterns of employment shares, value added, and consumption expenditure as GDP per capita grows. Agriculture experiences diminishing GDP shares while services records growth. Manufacturing experiences a somewhat inverted U pattern of growth, peaking at the point of greatest growth of services. These results provide a general framework for understanding the process of structural transformation.

5.2 Theory, Functions, and Development of Marketing Channels

Marketing channels are the critical networks linking agriculture and consumers, but their structure varies depending on the nature of the market. Starting with the broad framework and ending with the specifics of Zambia's case, we survey the literature. Shenoy (2007) describes vertical division of labor, working capital, and the services of fixed capital necessary for the production process through time. Generally speaking, as investment chains lengthen, quantities, quality, and the variety of products improve. Because of their lack of capital, investment chains for smallholder farmers are necessarily short. Grubler (1990) explores the diffusion of technologies over the course of economic growth. First adapter economies tend to have longer diffusion times and higher saturation rates than subsequent followers. The followers catch up quickly in diffusion, but do not have as high rates of saturation. The first adapters have the time and resources to build their life around newly emerging technology, which the followers lack. Therefore, one should not expect the followers to replicate the pattern of technological diffusion of the early adapters. Levine (2012) models the fragility of production chains in a modern economy. As chains lengthen, they become more fragile, susceptible to shocks at any point and increasing in volatility. The OECD (2007) discusses how globalization has transformed value chains, an example of which is manifested in the development of the modern food sector in Zambia.

Marketing channels are multi-purpose pathways connecting producers with consumers, according to Stern (1988). Marketing channels convey goods, market information, and payments between numerous suppliers, consolidators, wholesalers, retailers, and consumers. From beginning to end, channels organize such functions as sorting, grading, bulking, shipping, warehousing, breakbulking, distribution, and packaging, for example. Bucklin (1970) adds that market channels serve an important coordination function among participants.

Focusing on agricultural markets, Swinnen (2007 and 2009) describes the importance of supplier contracting, quality standards, and extension services offered by buyers to secure dependable sources of produce. In Senegal, contracting schemes with medium sized processors shifted the labor market as more smallholder bean farmers decided to become laborers.

Roe (2004) used a structural model to compare traditional and modern channels in Morocco and discovered that relative capital intensity explained part of the evolution of growth. Smallholder farmers experienced both a push and pull from agriculture. In a related paper, Alvarez-Cuadrado and Poschke (2011) use relative prices of manufactured and agriculutural goods to determine, along a nation's structural transition, whether labor is pulled into the industrial sector or whether it is pushed out of the agricultural sector. Evidence shows that nations first experience increases in industrial productivity which pulls labor out of agriculture. Then after 1960, the agricultural sector experiences increased productivity, which in turn pushes out labor.

In his study on West African trade, Bauer (1954) describes the useful roles of marketing channel intermediaries such as middlemen, who provide services to farmers and buyers that would be too costly for anyone individually to provide. Bauer offers two policy prescriptions to assist farmers to receive higher prices: increase communications infrastructure, and reduce barriers to entry for traders and middlemen. Chauvin and Porto model the effects of changes in the structure of value chains on the prices paid to Zambian farmers. Commercialization increases the structure, resulting in higher demand for agricultural inputs because commercial crops show higher returns than home consumption crops.

The supermarket revolution (Reardon and Gulati, 2008) is a story of the global modernizing of food marketing channels. Reardon concludes that supermarkets are rapidly growing across the world as economies develop and incomes increase. Tshirley (2010), however, finds that supermarkets are not growing as rapidly in SSA (ex South Africa) because of several reasons such as traditions, weak infrastructure, urban growth, and lack of information transmission along channels, and lack of access to modern factor inputs. Montiero et al (2008) found that in Brazil, the growth of supermarkets did not slow down the growth of traditional food retailers because consumer demand was heterogeneous. Smaller retailers were able to differentiate themselves. In a related study, Stokke (2009) tries to reconcile evidence about causation regarding growth of supermarkets and growth in farm productivity in developing countries. The level of skilled labor in commercial farming is an indicator of how well they can meet the standards of supermarkets. If commercial farming grows fast enough, it can continue to absorb the unskilled labor that it attracts. Haggblade (2011) explores the link between growth in African agribusiness and Africa's general development. He expects agribusiness to grow tremendously as it benefits from new technology, specialization in marketing functions, economies of scale, and increased competition.

5.3 Empirical Studies of Agriculture and Food Marketing

Empirical studies of the agricultural sector and associated food marketing channels show that development economists have focused on the effectiveness of various policies designed to assist smallholders. They have also examined specific problems encountered along the marketing channels. Wiggens (2010) argues in favor of smallholder farming as a path out of poverty for SSA for several reasons. Smallholders easily provide the labor for low productivity farmwork. They also have more detailed information about their land, which is an advantage since agronomic conditions vary greatly. Growth among smallholders increased when regulations and subsidies were removed. Flexible and committed family structures were more conducive to their operation as ongoing concerns. Wiggins highlights the major conditions for smallholder development: 1) Favorable investment climate; 2) Investment in public goods that support agriculture–transport, electricity, research, extension; 3) Development of economic institutions to allocate and protect property rights, to facilitate trading, reduce risk and allow collective action; 4) Existence of demand that is felt at the farm-gate; 5) Conservation of land resources for sustainable farming.

Arguing that commercial agriculture is the only sufficient mode of development in Africa, Collier and Dercon (2010) identify characteristics necessary for the growth of African economies. The conventional smallholder model is flawed because of questions raised by three potential scale efficiencies–skills and technology, finance and access to capital, and the organization and logistics of trading, marketing, and storage. These scale economies are not intrinsic to the size of farms, but to the form of organization–informal to formal, personal to impersonal. Smallholder agriculture, however, is not equipped to generate higher growth rates. Commercial contact in its many forms is exactly what smallholders need. Smallholders can benefit from long-term contracts, knowledge transfer, vertical integration and coordination. Diao et al (2006) conclude from a multi-country study including Zambia, that agricultural growth is still important for the alleviation of poverty in SSA.

FDI in food manufacturing leads to a significant boost in TFP of domestic suppliers in Romania, according to Javorcik and Li (2013). A decomposition of this productivity gain suggests that about half comes from within firm improvements and the rest by between firm reallocations (changes in market shares). During the expansion of foreign retailers, aggregate weighted productivity in the supplying industries increased by 16.4% compared to 5.3% in other sectors. The results suggest that opening up to FDI stimulates productivity growth and improves allocation efficiency.

Jayne et al. (2010) provide a thorough list of major issues facing smallholder farmers in Eastern and Southern Africa with the goal of identifying strategies for developing markets and enhancing smallholder productivity growth. Rao et al. (2010) seek to identify the characteristics of farmers who participate in the modern supermarket channel by analyzing the results of a cross-sectional survey of vegetable farmers near Nairobi, Kenya. Participation of farmers in supermarket supply chains carries the challenges of food quality and safety standards. Traditional markets are cash spot, no contracts. They also serve an overflow function for the supermarket channel. In contrast, supermarket farmers may have contracts regarding price, quality, quantity, hygiene, consistency, and scheduling, and verbal contracts. Because of contractual commitments, supermarket farmers tend to specialize more than traditional farmers. They find that supermarket farmers exhibit a level of productivity 18 points higher than traditional farmers. Propensity score matching shows that age, education, and use of advanced irrigation positively determine participation in supermarket channels. Landes et al. (2011) survey the expansion of modern food retail and trade in 103 developing countries. They find that demand growth leads to the entry of modern retailers. The data suggest that expansion is related to growth in demand for non-price characteristics of food products. Louw et al. (2009) examine the effects of restructuring of the fresh produce food markets on smallholder farmers and retailers. The growth of modern channels creates adjustment problems for smallholders as they face time, consistency, and spatial constraints to supply. Traditional agents continue to prefer informal markets because barriers are lower and doing business is easier.

Dorosh et al. (2012) study the relationship between transport infrastructure, population location, and agricultural production in SSA. The spatial relationship shows that as travel time increases, agricultural production falls. Road improvements could improve agricultural production, but the benefit may not exceed the cost. Weatherspoon and Ross (2008) find that lively informal market activity in Zambia indicates, counter-intuitively, that consumers are willing to purchase from a formal store a better product at the same price. Diao et al. (2008) use a CGE model and a disaggregated SAM to measure the effect of increased cereal and oil seed prices on smallholder farmers and the urban poor in Morocco. They show that increased prices benefit small farmers, who are more likely to grow cereals, more than they hurt poor consumers.

Regarding the southern Africa maize market, Myers and Jayne (2012) consider spatial price transmission effects under government of Zambia (GoZ) and private importing regimes. They find that when the GoZ imports maize, it reduces the price transmission effect from the landed imported price from RSA to the domestic Zambian price. This happens because the maize is sold at subsidized prices, thus dampening any transmission effects. But when the GoZ is not importing and private traders are importing more modest amounts, the expected price transmission effects are present. Michelson et al. (2010) examine the differential impact of which party pays for shipping from traditional markets. When the modern retailer sent trucks to buy at the farmgate, the effect was to offer a degree of price insurance in those markets, which experienced much price volatility.

Regarding land tenure rights, Bellemare (2013) examines the thesis that land with formal title is more productive. Although land titles are available in Madagascar, the institutional support and infrastructure to manage and maintain these records is exceedingly lacking. Farmers have, thus, created community level title systems, which are recognized only at that level. The study included land characteristics and expectations of farmers to determine the factors leading to secure tenure. The study highlights the lack of complementary land tenure/titling institutions.

5.4 Empirical Studies of Zambia

Numerous empirical studies focus on various aspects of Zambia's agricultural marketing chain. Topics range from general economy-wide policy and poverty questions to specific problems encountered by farmers, marketers, and consumers. Taken together, these studies paint a fairly comprehensive picture of the challenges that the Zambian agricultural sector faces. Starting first at the macro level of inquiry, Hausner (1999) was the first to construct a CGE SAM for Zambia. Keyser and Heslop (2001) conduct a strategic analysis of trade and investment opportunities in Zambian agriculture. While new markets in the north, such as Congo, are opening, the sector faces several constraints such as institutional weakness, poor infrastructure, high tariffs on inputs, and difficulty in price discovery. Thurlow et al. (2008) also look at agricultural investment opportunities with an eye for poverty reduction. Using a CGE model, they analyze linkages and tradeoffs between poverty and economic growth, concluding that growth is needed not only in cash crops, but also in other crops. Buffie and Antolia (2008) use a 2001 DGE model to examine how trade policy affects poverty, underemployment, aggregate capital accumulation, and real output. Thurlow and Wobst (2004) use a dynamic and spatially disaggregated model linked to household survey data to examine the potential for future poverty-reduction, concluding that a diversified agriculture led development policy would be more effective at alleviating poverty. While historical government bias has favored the urban populations and maize growers, non-mining urban growth would be more preferable compared to copper led growth.

A number of studies consider marketing channels and their relationship to poverty. Balat and Porto (2005) use propensity score matching to compare the likely choices of subsistence and market farmers. Using Zamstats surveys from the 1990's, they observe the effects of liberalized trade policies such as the removal of subsidies and price controls. Rural incomes increased with increased trade. Industrial maize prices rose with the result that consumers switched to local, cheaper varieties, which benefited poor farmers. Bigsten and Tengstam (2008) argue that success in lowering Zambian rural poverty rates can be achieved first by growth, and then inequality reduction. Since rural incomes are diverse, so too are sources of growth. They recommend increasing endowments, reducing household constraints, and reducing subsidies, which discourage crop diversification. Siegel (2008) seeks to identify the potential smallholder beneficiaries to agricultural commercialization by creating profiles of poverty by examining the spatial dimensions of geography, infrastructure, HH distributions, and livelihood zones. He concludes that some smallholders will not be able to make the transition and instead need other kinds of assistance. Wichern and Hausner (1999) identify institutional constraints, which were changed but incompletely implemented, on the development of the agricultural sector. Such examples of constraints include credit, land, labor markets, price and market information systems, and post-harvest technologies.

Various studies have focused on aspects of Zambian farm level economic performance. Kimhi and Chiwele (1999) analyze the determinants of land allocation and the determinants of maize productivity in Zambia. They identify two areas of policy influence: diversifying crop mix and increasing crop yields. Kimhi (2003) also examines the inverse productivity to plot size relationship for Zambian maize. He finds that, due to market imperfections, the inverse relationship holds for plots up to 3 ha., which constitutes 86% of his sample. For plots greater than 3 ha., positive returns to scale dominate. Saasa et al. (1999) and Saasa (2003) examine the role of policies and comparative advantage in Zambian agriculture. Despite having abundant resources to host a strong agricultural sector, Zambia suffers from a combination of bad policies that have hindered growth. Long-running policies favoring maize have stimulated overproduction while hurting intensification of other crops. Other constraints identified include poor infrastructure and weak credit facilities to accommodate capital investment.

Brambilla and Porto (2011) investigate the dynamic impact of cotton marketing reform on farm output in rural Zambia. Following liberalization and the elimination of the Zambian cotton marketing board, the sector developed an outgrower scheme whereby cotton firms provided credit, access to inputs and output markets, and technical assistance to the farmers. There are two distinctive phases of the reforms: a failure of the outgrower contracts, due to farmers' debt renegation, firm hold up, and lack of coordination among firms and farms, and a subsequent period of success of the scheme, due to enhanced contract enforcement and commitment. During the phase of failure, farmers were pushed back into subsistence and cotton yields per hectare declined. With the improvement of the outgrower scheme, farmers devoted larger shares of land to cash crops, and farm output significantly increased.

Empirical studies also reviewed the effectiveness of Zambia's food marketing channels. Emonger et al. (2004) conduct a comprehensive overview of the food marketing system in Zambia. From the farmer to the retailers, a general survey, with recommendations for improvement, of the situation is given in several markets. Sitko and Jayne (2011) studied the performance of ZAMACE, the Zambian Agricultural Commodities Exchange. They found that ZAMACE floundered because of low trading volumes, lack of enforcement of legal structures, favoritism, and erratic government interventions in grain markets. Hantuba (2003) and Hantuba et al. (2007) examine the link between smallholders and supermarkets in rural areas to determine the nature of opportunities or constraints posed by procurement requirements and practices. Hichaambwa et al. (2006) survey marketing chains for different crops in Zambia. The paper details the marketing chains around Lusaka and Ndola, including market shares by channel and type of market within the open air segment.

Sociologist Karen Tranberg Hansen (2010) discussed how the informal economy has changed since the 1991 market liberalization by the MMD government. The new MMD government declared that informal traders could operate. Many set up tuntembas, meaning zone of operations on sidewalks, etc. which were staffed by mostly young men. Later governments tried to sweep clean the tuntembas for several reasons. Policy was not coherent. Also, politics played a role since for some reason these informal workers were not considered voters. In addition, since, according to the Zambian Constitution, markets are the property of the State, corruption entered the sector. The advantage of the informal vendors was that they did not pay fees and taxes. However, they did not receive protections either. In sum, informal markets existed at the wim of the political winds.

This literature review paints a picture of the broad themes of growth and development down to analyses of specific issues related to a various parts of the marketing channel. Although Zambia has attracted much attention on specific issues in partial equilibrium context, there remains little general equilibrium modeling to summarize economy-wide effects of different scenarios. This dynamic general equilibrium model allows us to begin to understand the direct and indirect effects of policy choices and their related growth paths. A dynamic framework is particularly suited for Zambia's food channels since the time horizon for realizing the effects of various growth scenarios is measured in decades. Many related issues such as labor productivity, capital deepening, and land title evolve at slow rates. This is the first study to place the evolution of Zambia's food marketing channels in a general equilibrium framework of dynamic structural change.

6 The Theoretical Model

6.1 Environment

- The economy produces four final goods, denoted Y_j, a manufactured good, Y_m, a service good, Y_s and two food goods, one of which is provided by modern food retail firms, Y_r, the other by traditional food retail firms, Y_d.

- Two agricultural goods, and their accompanying wholesale - processing - distribution services, are produced that supply the food retail sector. This vertical production - processing - distribution chain is bifurcated, one of which mostly supplies modern food retail markets, the other of which mostly supplies the traditional food retail firms. The modern food retail firms are supplied by the commercial - modern farms - modern food processing and distribution system. Denote this supply by Y_c. Traditional food retail firms are supplied by the more traditional farm-food processing and distribution system. Denote this supply by Y_h.

- The markets for the service good Y_s, retail food Y_r and Y_d are domestic only. That is, international trade does not occur at the retail level for these goods so that their prices, denoted p_s, p_r, p_d, respectively, are endogenous. International trade occurs for the manufactured good Y_m at a given world price p_m, and at the wholesale level for the modern agricultural good Y_c at the given world price p_c. However, it is assumed that the traditional farm-food processing distribution chain is confined to the domestic market only and hence does not engage in foreign trade. Thus, the supply produced by this chain Y_h is traded at a domestic price p_h that is endogenously determined.

- All technologies are neo-classical constant returns to scale, and all markets are competitive.

- The current generation of households behave as though they take into account the welfare and resources of their descendents. Household members are assumed to grow at the rate n over time. Households receive payments w and r^k for the service flows of their stock of labor L and capital K, and rental payments π_c and π_h for the service flows of the land endowments H_c and H_h in modern and traditional agriculture, respectively. They exchange this income stream for expenditures on consumption goods $Q_j, j = m$ (manufactures), r (modern retail food), d (traditional retail food), s (services) and savings.

6.2 Households

Households are represented by an infinitely-lived Ramsey model where preferences for final goods y_m, y_r, y_d, y_s in per worker terms are expressed in the following utility function. Households receive utility from the sequence $\{q_m, q_r, q_d, q_s\}_{t=0}^{t=\infty}$expressed as a weighted sum of all future flows of utility

$$\int_{t=0}^{t=\infty} \frac{u(q_m, q_r, q_d, q_s)^{1-\theta} - 1}{1-\theta} e^{(n-\rho)t} dt \tag{1}$$

The felicity function $u(\cdot)$ is assumed to be of the Stone-Geary form. Households, assumed to be proportional to the number of workers, grow at the rate

$$L(t) = e^{nt} L(0) \tag{2}$$

and discount future consumption at the rate $\rho > 0$. The ratio $1/\theta$ represents the intertemporal elasticity of substitution, where we presume $\theta \geq 1$.

The household's flow budget constraint expresses savings $\dot{K}$ at each instant in time as the difference between income(wages and interest) and expenditure on final goods (see Appendix A for derivation of the expenditure function with Stone Geary framework). Foreign ownership of assets is not allowed so that the stock of capital assets equals the economy's stock of capital K. Its budget constraint is

$$\dot{k} = w + k(r-n) + \pi_c H_c + \pi_h H_h - E \tag{3}$$

where expenditures on final goods is given by

$$E = \varepsilon(p_m, p_r, p_d, p_s)q + \gamma_r p_r + \gamma_d p_d = \underset{\{q_j \geq 0\}}{Min} \left\{ \sum_j p_j q_j \mid q \leq \mu(q_m, q_r - \gamma_r, q_d - \gamma_d, q_s) \right\} \tag{4}$$

The implied no-arbitrage condition between capital and land for each agricultural sector must hold at each instant in time such that the return to capital equals the profits to agricultural land plus appreciation in the price of land where P_{Li} is the price of land.

$$r = \frac{\pi_i}{P_{L_i}} + \frac{\dot{P}_{L_i}}{P_{Li}}, i = c, h \tag{5}$$

The first order conditions obtained from the present-value Hamiltonian yield the Euler equation,

$$\frac{\dot{q}}{q} = \frac{1}{\theta}(r - \rho - \sum_{j=r,d,s} \lambda_j \frac{\dot{p}_j}{p_j}) \tag{6}$$

where λ_i is the share of super numerary expenditure $\varepsilon(p_m, p_r, p_d, p_s)q$ allocated to the $i-th$ good

$$\lambda_i = \frac{\varepsilon_{p_j} p_j}{\varepsilon(\cdot)},\ j = r, d, s$$

where $\varepsilon_{p_j} = \partial\varepsilon(\cdot)/\partial p_j$. This relationship means that households will choose a series of expenditures equal to the difference between the return on their assets r, their rate of time preference ρ, and the weighted change in prices p_j. Households displaying a relatively high time preference (and small $(r - \rho)$) will experience a small growth rate in expenditures; they have little incentive to forgo consumption.

6.3 Firms

6.3.1 Manufacturing and service sector firms

The manufacturing and service producing firms employ neoclassical and constant returns to scale technologies

$$Y_j = Min\left\{\mathcal{F}^j\left(\mathcal{A}L_j, K_j\right), \frac{Y_{mj}}{\sigma_{mj}}, \frac{Y_{sj}}{\sigma_{sj}}, \frac{Y_{c,j}}{\sigma_{c,j}}\right\},\ j = m, s \tag{7}$$

that employ the services of labor L_j and capital K_j, and intermediate factor flows Y_{ij}, where $\mathcal{A} = e^{xt}$ and x is the exogenous rate of factor augmentation. Expressing the technology in intensive form (i.e. in units of effective - economy wide workers $\mathcal{A}L$) yields

$$\hat{y}_j = Min\left\{\mathcal{F}^j\left(l_j, \hat{k}_j\right), \frac{\hat{y}_{mj}}{\sigma_{mj}}, \frac{\hat{y}_{sj}}{\sigma_{sj}}, \frac{\hat{y}_{c,j}}{\sigma_{cj}}\right\},\ j = m, s$$

where $l_j = \mathcal{A}L_j/\mathcal{A}L$ and σ_{ij} are input-output coefficients that determine the amount of intermediate input Y_{ij}required to produce one unit of Y_j output. Firms behave to minimize cost subject to their technology, yielding, for $j = m, s$

$$\left(C^j\left(\hat{w}, r^k\right) + \sum_{i=m,s,c} p_i\sigma_{ij}\right)\hat{y}_j \equiv \underset{l_j, \hat{k}_j, \hat{y}_{mj}, \hat{y}_{sj}, \hat{y}_{c,j}}{Min}$$

$$l_j\hat{w} + r^k\hat{k}_j + \sum_{i=m,s,c} p_j\sigma_{ij}\hat{y}_{ij} \mid \hat{y}_j = Min\left\{\mathcal{F}^j\left(l_j, \hat{k}_j\right), \frac{\hat{y}_{mj}}{\sigma_{mj}}, \frac{\hat{y}_{sj}}{\sigma_{sj}}, \frac{\hat{y}_{c,j}}{\sigma_{c,j}}\right\}$$

6.3.2 The agricultural-food processing distribution chain

The modern agricultural-food processing distribution chain employs a neoclassical and constant returns to scale technology

$$Y_c = Min\left\{\mathcal{F}^c\left(\mathcal{A}L_c, K_c, \mathcal{B}H_c\right), \frac{Y_{mc}}{\sigma_{mc}}, \frac{Y_{sc}}{\sigma_{sc}}, \frac{Y_{cc}}{\sigma_{cc}}\right\} \tag{8}$$

where $\mathcal{B} = e^{\gamma t}$ and γ is the exogenous rate of factor (e.g., land) augmentation due to improvements in agronomic and other practices affecting the productivity of the sector specific factor H_c. Since H_c is specific to the sector, it is convenient to express aggregate firm behavior at the sector level as

$$\pi_c = \pi^c\left(pv_c, \hat{w}, r^k\right)H_c \equiv$$

$$\underset{l_c,k_c}{Max}\left\{\left(p_c - \sum_{i=m,s,c} p_i\sigma_{ic}\right)\hat{y}_c - \hat{w}l_c - r^k\hat{k}_c\right\}$$

subject to (8) expressed in intensive form, i.e., in units of effective economy wide labor. The value added price pv_c is defined as

$$pv_c = pv^c\left(p_c, p_m, p_s\right) \equiv p_c - \sum_{i=m,s,c} p_i\sigma_{i,c}$$

For simplicity at this point, we impose the condition that the rate of factor productivity growth of land equal the rate of labor productivity growth plus the rate of growth of the work force, $n = \dot{L}/L$, i.e., $\gamma = x + n$.

The traditional agricultural-food processing distribution chain behaves in the same manner as the modern chain, albeit with same functional form for technology but different parameters to capture the relatively more labor intensive nature of this chain, and its lessor reliance on service inputs Y_{sh}. Firms in this sector employ a neoclassical and constant returns to scale technology

$$Y_h = Min\left\{\mathcal{F}^h\left(\mathcal{A}L_h, K_h, \mathcal{B}H_h\right), \frac{Y_{mh}}{\sigma_{mh}}, \frac{Y_{sh}}{\sigma_{sh}}, \frac{Y_{hh}}{\sigma_{hh}}\right\} \tag{9}$$

where $\mathcal{B} = e^{\gamma t}$ and γ is the exogenous rate of factor (e.g., land) augmentation due to improvements in agronomic and other practices affecting the productivity of the sector specific factor H_h. Since H_h is specific to the sector, it is convenient to express, aggregate firm behavior at the sector level as

$$\pi^h\left(pv_h, \hat{w}, r^k\right) H_h \equiv$$

$$\underset{l_h,k_h}{Max}\left\{\left(p_h - \sum_{i=m,s,h} p_i\sigma_{ih}\right)\hat{y}_h - \hat{w}l_h - r^k\hat{k}_h\right\} \tag{10}$$

subject to (9) expressed in intensive form, i.e., in units of effective economy wide labor. The value added price pv_h is defined as

$$pv_h = pv^h\left(p_h, p_m, p_s\right) \equiv p_h - \sum_{i=m,s,h} p_i\sigma_{ih}$$

Again, we impose the condition that the rate of factor productivity growth of land equal the rate of labor productivity growth plus the rate of growth of the work force, $n = \dot{L}/L$, i.e., $\gamma = x + n$.

6.3.3 The modern and traditional retail-food firms

Modern retail food firms employ a constant returns to scale neoclassical technology

$$Y_r = Min\left\{\mathcal{F}^r\left(\mathcal{A}L_r, K_r, Y_{cr}\right), \frac{Y_{mr}}{\sigma_{mr}}, \frac{Y_{sr}}{\sigma_{sr}}\right\}$$

employing labor L_r, capital K_r and wholesale-level food Y_{cr}, that we assume initially (and relax later), is only produced by the modern farm - processing - distribution chain of firms. As in the case of manufacturing and service sectors, cost minimization leads to

$$\left(C^r\left(\hat{w}, r^k, p_c\right) + \sum_{i=m,s} p_i\sigma_{i,r}\right)\hat{y}_r$$

Similarly, for the traditional retail food firms, we have the technology

$$Y_d = Min\left\{\mathcal{F}^d\left(\mathcal{A}L_d, K_d, Y_{hd}\right), \frac{Y_{md}}{\sigma_{md}}, \frac{Y_{sd}}{\sigma_{sd}}\right\}$$

which implies the cost function, per effective worker units,

$$\left(C^d \left(\hat{w}, r^k, p_h \right) + \sum_{i=m,s} p_i \sigma_{id} \right) \hat{y}_d$$

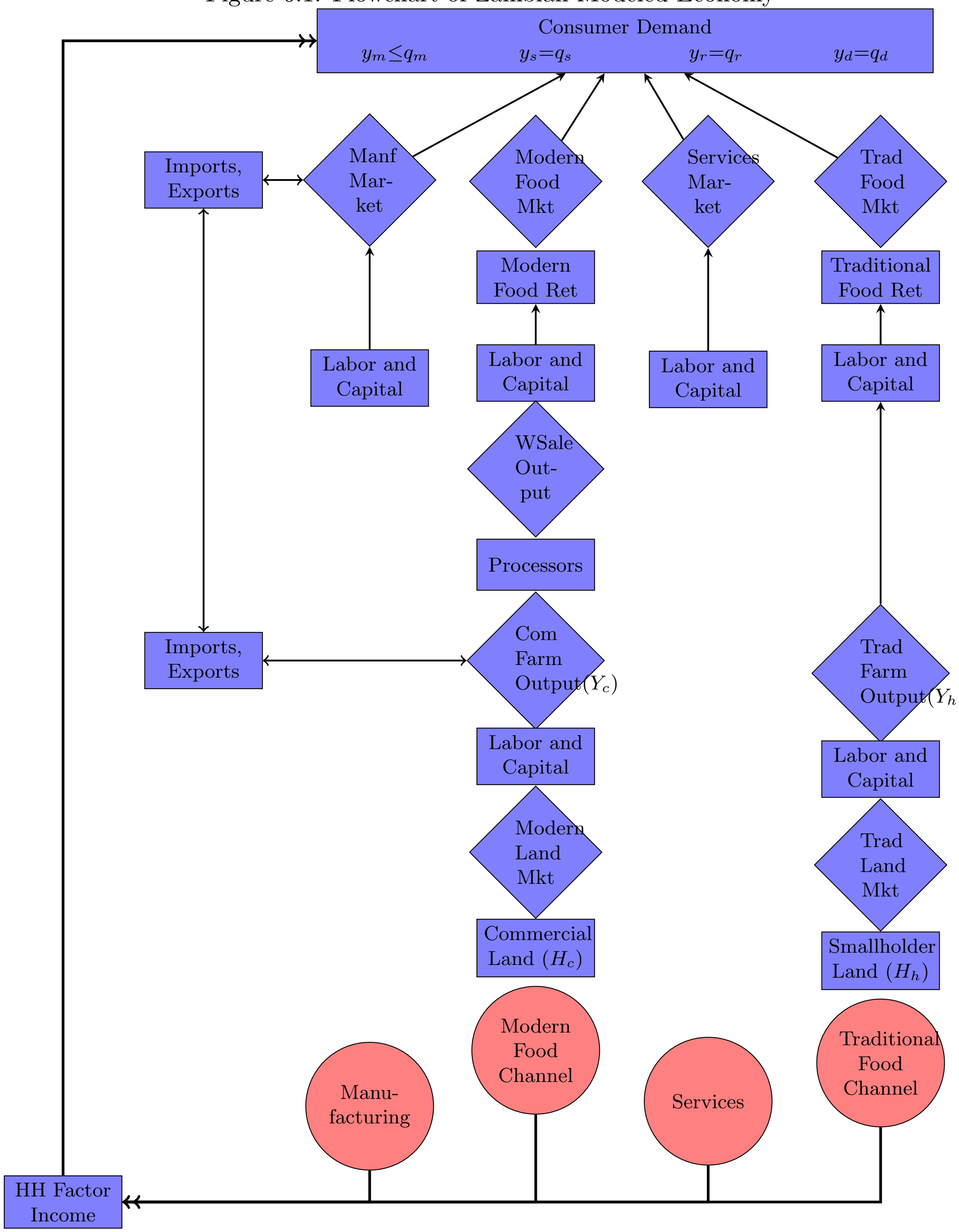
In this case however, p_h is endogenous.

6.3.4 Summary

Figure 6.1 depicts the main features of the modeled six-sector economy. Agricultural food-processing distribution chains, as described above, outline the economic structure of their respective vertical marketing channels as shown in the traditional and modern food channels. At the farm level, output is represented by a production function consisting of labor, capital and land inputs. The particular technology employed in each sector determines the scale of contribution of each of the factors. Cost minimizing firms choose the production process with the most efficient combination of factors. Intermediate inputs are assumed to contribute to production in a Leontief fashion. At the beginning of the chain are the service flows of primary factor inputs. At the end of the agricultural segment of the marketing chain is derived demand for agricultural produce at market-clearing prices. The difference between the price of output and the cost of intermediate inputs is the value added by the firm. As product moves upward from farm to retail, firms add value at each stage of production (Stern 1988). The value added price represents the contribution of the firm to the overall final output value. In various degrees, depending on the levels of technology and the factors employed, food marketing channels add value at each successive stage of production as the product moves further away from its original status as a primary commodity (Kislev and Peterson 1982). At the farm level, food products exhibit characteristics of commodities, while as they move through the marketing channel they acquire other characteristics such as place, time, and form. The modern food marketing channel, as the data presented later shows, tends to be relatively more capital intensive than is the case of the traditional channel. Moreover, due to uniformity of product and resources to assemble and distribute product, the commercial farm-wholesale market is presumed to have access to foreign markets so that a constant and given world market price p_c prevails. The traditional farm-wholesale sector is presumed to supply domestic markets only so that the price p_h endogenous.

This structure causes growth in the rest of the economy to impact the modern and traditional sector in different ways. As capital deepening occurs, the manufacturing and

Figure 6.1: Flowchart of Zambian Modeled Economy



service sectors compete for resources, causing wages relative to capital rents to rise. Since, as the data suggest, the commercial farm-wholesale-retail channel is relatively more capital intensive than the traditional channel, capital deepening can cause unit costs of the traditional relative to the modern channel to rise thus, all else constant, increasing the marketing margin between traditional farm to retail outlet. This increasing margin can depress the price received by traditional farmers relative to the price received by farmers in the modern sector while at the same time increasing the retail price of food in the traditional relative to modern food retail outlets. Effectively, capital deepening can lead to negative terms of trade effects on the traditional sector causing, to the extent resources are mobile, resources to depart the traditional sector.

6.4 Definition and Characterization of Equilibrium

Given the initial prices, $p_s(0), p_h(0), p_r(0), p_d(0)$, resource endowments $\{K(0), L(0), H(0)\}$ and constant world market prices, p_m, p_c, a competitive equilibrium is a sequence of positive prices

$$\{p_s(t), p_h(t), p_r(t), p_d(t)\}_{t\in[0,\infty)}$$

positive household consumption plans

$$\{\widehat{q}_m(t), \widehat{q}_r(t), \widehat{q}_d(t), \widehat{q}_s(t)\}_{t\in[0,\infty)}$$

positive factor rental prices

$$\{\widehat{w}(t), r(t), \widehat{\pi}_c(t), \widehat{\pi}_h(t)\}_{t\in[0,\infty)}$$

for labor, capital, the two types of agricultural land, respectively, and production

$$\{\widehat{y}_m(t), \widehat{y}_r(t), \widehat{y}_d(t), \widehat{y}_s(t), \widehat{y}_c(t), \widehat{y}_h(t)\}_{t\in[0,\infty)}$$

and resource allocation plans

$$\left\{\widehat{k}_m(t), \widehat{k}_r(t), \widehat{k}_s(t), \widehat{k}_d(t), \widehat{k}_c(t), \widehat{k}_h(t), \widehat{l}_m(t), \widehat{l}_r(t), \widehat{l}_s(t), \widehat{l}_d(t), \widehat{l}_c(t), \widehat{l}_h(t)\right\}_{t\in[0,\infty)}$$

such that at each instant of time t, households maximize utility subject to a budget contraint and firms maximize profit subject to technology and resource constraints.

It is convenient to characterize equilibrium in two parts, an intra-temporal and a temporal component.

6.4.1 Intra-temporal equilibrium

Given the sequence $\left\{\widehat{E}\left(t\right), \hat{k}\left(t\right)\right\}_{t\in[0,\infty)}$, intra-temporal equilibrium can be characterized by the following ten equations in ten unknowns

$$\Omega = (\widehat{w}, r^k, p_r, p_d, p_s, p_h, \widehat{y}_m, \widehat{y}_r, \widehat{y}_d, \widehat{y}_s) \tag{11}$$

Firms in the final goods sectors m, r, d, s, earn zero profits

$$c^m(\widehat{w}, r^k) - (p_m - \sigma_{mm}p_m - \sigma_{sm}p_s - \sigma_{cm}p_c) = 0 \tag{12}$$

$$c^r(\widehat{w}, r^k, p_c) - (p_r - \sigma_{mr}p_m - \sigma_{sr}p_s) = 0$$

$$c^d(\widehat{w}, r^k, p_h) - (p_d - \sigma_{md}p_m - \sigma_{sd}p_s) = 0$$

$$c^s(\widehat{w}, r^k) - (p_s - \sigma_{ms}p_m - \sigma_{ss}p_s - \sigma_{cs}p_c) = 0$$

Markets clear for:

Labor

$$c^m_w(\widehat{w}, r^k)\widehat{y}_m + c^r_w(\widehat{w}, r^k, p_c)\widehat{y}_r + c^d_w(\widehat{w}, r^k, p_h)\widehat{y}_d + c^s_w(\widehat{w}, r^k)\widehat{y}_s$$

$$-\pi^c_w(pv_c, \widehat{w}, r^k)\widehat{H}_c - \pi^h_w(pv_h, \widehat{w}, r^k)\widehat{H}_h = 1 \quad (13)$$

Capital

$$c^m_{r^k}(\widehat{w}, r^k)\widehat{y}_m + c^r_{r^k}(\widehat{w}, r^k, p_c)\widehat{y}_r + c^d_{r^k}(\widehat{w}, r^k, p_h)\widehat{y}_d + c^s_{r^k}(\widehat{w}, r^k)\widehat{y}_s$$

$$-\pi^c_{r^k}(pv_c, \widehat{w}, r^k)\widehat{H}_c - \pi^h_{r^k}(pv_h, \widehat{w}_s, r^k)\widehat{H}_h = \widehat{k} \quad (14)$$

and, the supply of the agricultural good produced on traditional farms equals intermediate demand[1]

$$\pi^h_{p_h}(pv_h, \widehat{w}, r^k)\widehat{H}_h - c^d_{p_h}(\widehat{w}, r^k, p_h)\widehat{y}_d = 0 \quad (15)$$

Demand and supply for final retail goods clear, for:

the supermarket retail food market

$$\partial\widehat{E}/\partial p_r = \widehat{y}_r = \frac{\lambda_r \varepsilon(\cdot)\,\hat{q}}{p_r} + \gamma_r \quad (16)$$

the traditional retail food market

$$\partial\widehat{E}/\partial p_d = \widehat{y}_d = \frac{\lambda_d \varepsilon(\cdot)\,\hat{q}}{p_d} + \gamma_d \quad (17)$$

[1]The supply of the commercially produced agricultural good is an inequality because of the possibility of international trade.

and the service good market

$$\partial\widehat{E}/\partial p_s = \frac{\lambda_s \varepsilon\left(\cdot\right) q}{p_s} = \widehat{y}_s - \sigma_{ss}\hat{y}_s - \sigma_{sm}\hat{y}_m - \sigma_{sc}\hat{y}_c - \sigma_{sh}\hat{y}_h \tag{18}$$

where, upon substituting the reduced forms (48) for $\hat{w}$ and r^k, we have the supply functions for commercial and traditional agriculture which, to lower notational clutter, are expressed as a function of the endogenous variables p_s, and p_h only

$$\begin{aligned} \hat{y}_c &= \tilde{y}^c\left(p_s, p_h\right) \equiv \frac{\partial \pi^c(pv_c, \widehat{w}, r^k)\widehat{H}_c}{\partial pv_c} \\ \hat{y}_h &= \tilde{y}^h\left(p_s, p_h\right) \equiv \frac{\partial \pi^h(pv_h, \widehat{w}, r^k)\widehat{H}_h}{\partial pv_h} \end{aligned}$$

To derive the model's equation of motion, it is useful to reduce the dimensionality of the intra-temporal conditions (see Appendix B for details).

6.4.2 The Steady state

We first substitute reduced forms (48) for $\hat{w}$ and r^k, the supply functions,(56) and (58) into the budget constraint to obtain

$$\dot{\hat{k}} = \mathbf{K}\left(p_s, p_h, \hat{k}\right) \equiv \tag{19}$$

$$W\left(p_s, p_h\right) + R\left(p_s, p_h\right)(\hat{k} - x - \delta - n) + \widetilde{\pi}^c\left(p_s, p_h\right) H_c + \widetilde{\pi}^h\left(p_s, p_h\right) H_h -$$

$$\overbrace{\frac{p_s}{\lambda_s}\left(\left(1-\sigma_{ss}\right)\tilde{y}^s\left(p_s, p_h, \hat{k}\right) + \sigma_{sm}\tilde{y}^m\left(p_s, p_h, \hat{k}\right) + \sigma_{sc}\tilde{y}^c\left(p_s, p_h\right) + \sigma_{sh}\tilde{y}^h\left(p_s, p_h\right)\right)}^{=\tilde{\varepsilon}(\cdot)\hat{q}} -$$
$$\gamma_r P^r\left(p_s, p_h\right) - \gamma_d P^d\left(p_s, p_h\right)$$

Substituting for $\hat{y}_d$ from (56) into traditional farm level market clearing (15) yields

$$\tilde{\pi}^h_{p_h}(p_s, p_h))\widehat{H}_i - \tilde{c}^d_{p_h}(p_s, p_h))\tilde{y}^d\left(p_s, p_h, \hat{k}\right) = 0 \tag{20}$$

From Euler (6), we have the steady-state condition

$$R\left(p_s, p_h\right) = \rho + \delta + \theta x \tag{21}$$

If a steady state exists, we find the root $\left(p_h^{ss},\, p_s^{ss}, \hat{k}^{ss}\right)$ satisfying (19) and either (20) and (21). Knowing $\left(p_h^{ss},\, p_s^{ss}, \hat{k}^{ss}\right)$, the remaining endogenous variables can be obtained using the reduced forms (48) and (56).

6.4.3 Differential equations

Our first differential eqution is (19). We need two additional equations. Define the traditional farm level market equation (15) as

$$\Pi^h\left(p_s, p_h, \hat{k}\right) \equiv \tilde{\pi}^h_{p_h}(p_s, p_h))\widehat{H}_i - \tilde{c}^d_{p_h}(p_s, p_h))\tilde{y}^d\left(p_s, p_h, \hat{k}\right)$$

and time differentiate

$$\Pi^h_{p_s}\left(p_s, p_h, \hat{k}\right)\dot{p}_s + \Pi^h_{p_h}\left(p_s, p_h, \hat{k}\right)\dot{p}_h + \Pi^h_{\hat{k}}\left(p_s, p_h, \hat{k}\right)\dot{\hat{k}} = 0 \tag{22}$$

The second differential equation is obtained by time differentiating the home good equation (63). The result is expressed as

$$\tilde{\varepsilon}\left(p_m, p_s, p_h\right) q\left(\sum_{j=r,d,s}\lambda_j\frac{\dot{p}_j}{p_j} + \frac{\dot{q}}{q}\right) = \frac{1}{\lambda_s}\left(\dot{p}_s\bar{Y}^s\left(\cdot\right) + p_s\bar{Y}^s_{p_s}\left(\cdot\right)\dot{p}_s + p_h\bar{Y}^s_{p_s}\left(\cdot\right)\dot{p}_h + p_s\bar{Y}^s_k\left(\cdot\right)\dot{k}\right)$$

where

$$\begin{aligned}\frac{\dot{p_r}}{p_r} &= \frac{P^r_{p_s}\left(p_s, p_h\right)p_s}{P^r\left(p_s, p_h\right)}\frac{\dot{p}_s}{p_s} + \frac{P^r_{p_h}\left(p_s, p_h\right)p_h}{P^r\left(p_s, p_h\right)}\frac{\dot{p}_h}{p_h} \text{ and} \\ \frac{\dot{p_d}}{p_d} &= \frac{P^d_{p_s}\left(p_s, p_h\right)p_s}{P^d\left(p_s, p_h\right)}\frac{\dot{p}_s}{p_s} + \frac{P^d_{p_h}\left(p_s, p_h\right)p_h}{P^d\left(p_s, p_h\right)}\frac{\dot{p}_h}{p_h}\end{aligned} \tag{23}$$

Next, substitute the Euler equation (6) for $\dot{q}/q$ and simplify

$$\begin{aligned}&\tilde{\varepsilon}\left(p_m, p_s, p_h\right) q\left(\frac{\theta-1}{\theta}\sum_{j=r,d,s}\lambda_j\frac{\dot{p}_j}{p_j} + \frac{1}{\theta}\left(r^k - \delta - \rho - \theta x\right)\right) = \\ &\frac{1}{\lambda_s}\left(\dot{p}_s\bar{Y}^s\left(\cdot\right) + p_s\bar{Y}^s_{p_s}\left(\cdot\right)\dot{p}_s + p_h\bar{Y}^s_{p_s}\left(\cdot\right)\dot{p}_h + p_s\bar{Y}^s_k\left(\cdot\right)\dot{k}\right)\end{aligned} \tag{24}$$

We have three non-linear and autonomous differential equations (19), (22) and (24) in unknowns $\left\{\hat{k}, p_s, p_h\right\}$ that are linear in the dot variables $\left\{\dot{\hat{k}}, \dot{p}_s, \dot{p}_h\right\}$. We can use this system to obtain the three differential equations

$$
\begin{aligned}
\dot{\hat{k}} &= K\left(p_s, p_h, \hat{k}\right) \\
\dot{p}_s &= P^s\left(p_s, p_h, \hat{k}\right) \\
\dot{p}_h &= P^h\left(p_s, p_h, \hat{k}\right)
\end{aligned} \tag{25}
$$

7 The Zambia Social Accounting Matrix

This study uses a social accounting matrix (SAM) to organize aggregated data for the base year for the model of the Zambian economy. A SAM is a square matrix that summarizes economic activity across various sectors of an economy with each agent having a column and row. Based on the idea of an input-output table, each transaction in a SAM represents both the seller and the buyer in a double entry format, thus balancing selling and purchasing activity by definition. Across the top margin, the column accounts record disbursements; down the left margin row headings record payments of income received. Thus, each cell in the SAM represents a disbursement and a receipt or, in other words, an expenditure and a source of income for each agent. Total expenditures across the columns must equal total income across the rows.

A SAM is partitioned into a number of accounts, depending on the desired number of sectors and activities in the modeled economy. The first section of a SAM represents production activities, which is a grouping of domestic sectors engaged in the production of goods or services. Expenditures for the employment of factors of production are recorded under the column heading of each production activity. Intermediate factors, listed first, are purchased consumable inputs such as fertilizer and seeds. Next are value-added inputs of labor, capital, and land, which represent the value added by the associated production activity. Thus, across the modeled economy, the aggregate value-added represents GDP. The column total for a production activity is its gross output, the sum of intermediate and value-added inputs.

Commodities, the next grouping of expenditures, is the total supply, domestically produced and imported, of goods and services by sector. For the Zambia SAM, the six sectors produce their own commodities for domestic consumption, export, or intermediate demand.

After commodities are the group of expenditures paid to rent the factors of production–labor, capital, and land. These three columns show the cost of the factors used to add value in the production process. Expenditures on labor are wages paid to workers and expenditures on capital represent the cost of capital. Expenditures for land, which is a fixed factor, represent profits accruing to the agricultural sector. This expense is the return demanded by landowners.

The next column, household expenditures, represents final consumption of goods and services. Notice that households do not directly consume intermediate agricultural products, but only retail-level products. Households may also decide to forego present consumption and instead save a portion of their income in the form of savings expenditures. This supply of savings satisfies the demands for capital from the production activities.

The last column is exports, which is the sale of traded goods into the international market. In the case of the Zambia SAM, only the commercial agriculture and industry sectors have the option of exporting.

We may compute GDP from expenditures with two methods–the value-added and expenditure methods. First, the sum of the value-added components of the production activities gives GDP. Note that we avoid double counting by excluding intermediate inputs because their value-added components have already been counted. Second, the sum of total household expenditures, composed of consumption expenditures and savings, gives us GDP by the expenditure method.

The counterpart to disbursements in the SAM is receipts, which are detailed in the row accounts. Starting from the top, and in corresponding order to disbursements, is production activities. Every production activity receives sales income in exchange for the goods and services it produces from two source–domestic sales and exports.

Next, the commodities grouping shows where products and services are distributed in the economy. Some are sold as intermediate inputs and others are sold for final consumption, of which there are two types–household and government consumption. Also included in the commodities row is investment accumulation or saving, which is the difference between factor income and household consumption expenditures. This is to say that what is not consumed in intermediate or final demand is saved, not that a particular quantity of commodities is stored in inventory.

After commodities, receipts to factors shows the distribution of factor income across production activities. These factor incomes are the source for computing factor shares and the sum of all factor incomes is household income, which is GDP computed by the value-added method.

Following factors is institutions, representing households and governments. The household line details total household income by factor–labor, capital, and land–which also is GDP by the income method. Government income is comprised of import duties and taxes on production activities.

Next, the capital account row shows the amount of capital accumulation or saving by households as they forego current consumption. Trade imbalances show up here, indicating the need for financing to cover the imbalance.

The last row is foreign trade, or imports. For traded goods only, imports may supply the difference between demand and domestic supply. For trade to balance, imports must equal exports.

This Zambia SAM is based on a 1995 SAM of Zambia constructed by Hausner (1999) for the International Food and Policy Research Institute (IFPRI) and incorporated into the Global Trade and Policy (GTAP) database. The Zambia SAM has six production activities–commercial agriculture, smallholder agriculture, modern food retail, traditional food retail, industry, and services–to represent the economy of Zambia. Commercial agriculture in Zambia is characterized by large farms and capital-intensive farming methods including irrigation. Commercial farmers supply the modern retail markets of Zambia and also export surpluses to surrounding countries such as Congo. Export overseas is less common because of the cost of transport and infrastructure constraints. Thus, in the SAM, some of the commercial agricultural output satisfies intermediate demand in the modern retail markets. Smallholder farming is done on small plots with manual labor or sometimes animal traction. Many farmers operate at the subsistence level while others are able to sell their produce in village markets or to itinerate assemblers. By these channels, the smallholder sector supplies the intermediate demands of the traditional retail food sector. In Zambia, the mining and refining of copper and other industrial metals dominates the industrial sector, and the whole economy. The prosperity of Zambia follows the world copper markets.

Hausner's 1995 SAM of Zambia, integrated into the GTAP database, provides the data for this DGE study. Using GTAP software, we extract sector level data to match our theoretic model of the Zambian economy for four of the six sectors–commercial agriculture, modern retail, industry, and services. Further examination of the sector detail reveals how well they match the model. The commercial agriculture sector is composed of farm-level agricultural production activities including grains, fruits, vegetables, and livestock. Forestry and fishing, however, are included in the industrial sector. The industrial sector, known as the manufacturing sector in GTAP, includes industrial activity such as the mining of copper and also downstream activities such as food processing, other manufacturing, construction, and power generation. The modern retail sector includes the higher stages of food processing beyond the commercial agriculture sector. The services sector includes all other service activities not included in the modern retail sector, including general trade as well.

This configuration of GTAP sectors provides the necessary level of aggregation for the theoretical model for the above four sectors. Yet, since GTAP is unable to provide further detail for the two remaining sectors, smallholder agriculture and traditional retail, we must look to other data sources for these sectors. The first task of estimating the size of the smallholder farming sector is problematic because of the lack of data. By definition, the smallholder sector includes not only emerging farmers, but also subsistence farmers who exhibit home production/home consumption patterns, not participating in the formal economy. In Zambia, since maize is the largest crop, it is the subject of a high number of economic studies and can give us a sense of the greater traditional agricultural economy. For instance, Hausner's 1995 SAM dissertation provides detailed data on GDP, production quantities, capital, labor, and land shares for large and small-scale Zambian maize producers. This data gives a measure of the relative size of the two maize sectors in each of the above attributes.

Table 7.1: Composition of GDP, Production, and Factors (maize as % of total economy)

Maize Producers	GDP f.c.	Production	Labor	Capital	Land
Small	3.4	2.3	5.2	0.6	37.7
Large	0.7	0.7	0.6	0.6	6.1
Total	4.1	3.0	5.8	1.2	43.8

Table 7.2: Relative Factor Shares by Producer Size for Zambian Maize

Maize Producers	GDP f.c.	Production	Labor	Capital	Land
Small	0.83	0.77	0.90	0.50	0.86
Large	0.17	0.23	0.10	0.50	0.14

Share of GDP is 0.83 and 0.17 and the share of production is 0.77 and 0.23 for small and large maize producers respectively. For large maize producers, capital, labor, and land shares are 0.50, 0.10, and 0.14 respectively. For small maize producers the shares are 0.50, 0.90, and 0.86 respectively. These data reveal that the smallholder agriculture sector is about three to four times larger than its commercial counterpart.

Yet, although the two sectors employ about the same aggregate amount of capital, at 0.60% each of total economy-wide capital, the capital share of large commercial farms (large maize producers) is 0.60 while the capital share of smallholders is only 0.16. As expected, smallholders employ more labor, with a labor share of 0.68 versus 0.30 for large maize producers. A picture emerges of the two groups using vastly different production technologies.

These derived factor shares are used to disaggregate the commercial farming sector factor inputs received from GTAP. A necessary assumption in this process is that the subsistence farming activities of the smallholder sector are included in the aggregated factor costs and production figures.

An analysis of the orders of production of the modern and smallholder farming methods

Table 7.3: Adjustments to Old GTAP SAM Factors

	GTAP SAM Allocation	Old Factor Share %	New Share % Small	New Share % Large	New Factor Allocation Small	New Factor Allocation Large	New Factor Shares Smallholder	New Factor Shares Commercial
Labor	588.41	0.60	0.90	0.10	527.54	60.87	0.68	0.30
Capital	245.17	0.25	0.50	0.50	122.59	122.59	0.16	0.60
Land	147.10	0.15	0.86	0.14	126.61	20.49	0.16	0.10
							1.00	1.00

is another way of revealing the differences in relative factor intensities. Smallholder production technology is simpler, using less capital-intensive methods. A comparison of the cost of production which illustrates the great differences in methods and technology is found in a study of the costs of maize production (Burke et al 2011) (table S4). This study uses the 2010 crop forecast survey conducted by the Government of Zambia's Central Statistics Office and the Ministry of Agriculture and Cooperatives to estimate the cost of growing maize. Among the estimated costs are agricultural inputs, transportation of inputs and harvested maize, family and hired labor, land rent, and animal or machine traction. The cost rollup summary shows that for a 50 kg bag of maize, labor's share is 75.0%, capital 9.7%, and land 15.3% of total cost.

In Zambia, the land market is not considered competitive because of institutional arrangements including national laws and tribal customs. Smallholders have a right granted by the village chief to freely use land, but do not have the right to rent it to others (Burke et al 2011). However we apportion costs, it becomes apparent that Zambian smallholder agriculture is highly labor intensive.

The 1995 SAM extracted from GTAP reports the retail food sector as an aggregate total, just as the agricultural sector was aggregated. Other data sources allow us to disaggregate this sector into modern and traditional sub-sectors. The modern food retail sector refers to that segment of the food processing chain starting at the farm-gate and ending at the household that employs capital intensive processing and distribution methods. The modern channel uses technology to further differentiate food products in terms of place, time, and form. Stages along the modern channel are characterized by greater capital intensity. The modern channel, for example, has the capacity to distribute perishable goods by means of refrigerated transport and coolers. Moreover, the channel has more stages of intermediate processing compared to the traditional channel, such as sorting, grading, washing, assembly, bundling, packaging, warehousing, and breakbulking. The modern channel employs more capital equipment and requires more working capital. An important aspect of modern channel distribution is the management of inventories through point of sale information technology.

In contrast to the modern retail sector, the traditional retail sector's marketing channel is less complex. From the farm-gate, smallholders may sell a portion of their crop to neighbors, in the local market, or to itinerating assemblers at the terminus of feeder roads accessible to vehicular traffic near their village. Assemblers may transport some produce to regional city markets or even to Lusaka's open air Soweto market. Because of poor transportation and communication infrastructure, more remote farms and smaller supply

Table 7.4: Maize Production Costs for Zambia (ZMK/50kg bag)

Cost Item	Farmer mean	Per 50kg Bag of Maize	% share of Costs	% sh of Ttl Costs	Relative Shares– value added	Relative Shares: value added (excluding land)
Hired animal use	911	536	1.3%	1.2%		
Hired machine/tractor use	77	97	0.2%	0.2%		
Hired labor	3,788	3,438	8.4%	7.6%		
Basal dressing	2,932	3,487	8.6%	7.7%		
Top dressing	3,066	3,576	8.8%	7.9%		
Fertilizer transport to homestead	139	193	0.5%	0.4%		
Transport cost to FRA depot	373	763	1.9%	1.7%		
Transport cost to private buyer	528	2,044	5.0%	4.5%		
Herbicides	33	62	0.2%	0.1%		
Seeds	4,264	4,434	10.9%	9.8%		
Total Cash Expenditures	16,111	18,630	45.7%	41.0%		
Family labor	35,638	19,744	48.5%	43.4%		
Own animal use	2,368	2,304	5.7%	5.1%		
Own machine use	35	61	0.1%	0.1%		
Expenditures + HH Labor & Assets	54,152	40,739	100.0%	89.6%		
				0.0%		
Land annual rent	7,818	4,720		10.4%		
Total Cost including Land	61,970	45,459		100.0%		
Cost Rollup Summary						
Intermediate Inputs	11,335	14,559	35.7%	32.0%		
Labor	39,426	23,182	56.9%	51.0%	75.0%	88.5%
Capital	3,391	2,998	7.4%	6.6%	9.7%	11.5%
Expenditures + HH Labor & Assets	54,152	40,739	100.0%			100.0%
Land	7,818	4,720		10.4%	15.3%	
Total Cost including land	61,970	45,459		100.0%	100.0%	
Cost Rollup Summary by Percent						
Intermediate Inputs				32.0%		
Labor				51.0%	75.0%	
Capital (with land included)				17.0%	25.0%	
Total Cost including land				100.0%	100.0%	

source: Cost of Smallholder Maize Production Zambia, Table 1 quantities, marketing of smallholders' agricultural produce is more difficult than its modern counterpart (Chapoto and Jayne 2011). City markets also serve the role of distribution center for small retail operators such as hawkers and street-side stands or kiosks known as kantembas.

The modern and traditional retail channels are not completely independent of each other, however. Large city markets in Lusaka, for instance, sometimes serve as a supply outlet for surplus or lower quality produce from Shoprite, for example.

Nevertheless, for the purpose of the model, the two retail sectors are treated as if there is no integration. Yet, from the GTAP extract of the 1995 SAM, the modern retail sector sums all food retailing activity. Disaggregating these figures requires additional detail on Zambia's traditional food markets. A study on urban food consumption patterns of four of Zambia's largest cities (Lusaka, Kitwe, Mansa, and Kasama) provides a window into retail market channel shares. The study considers consumption of staple carbohydrate purchases across five outlets–retail grocers, market stalls and stands, ka (kantemba) sector, supermarkets, and other outlets. Retail grocers are small, independent food stores. Markets stalls and stands are found in open air city markets.

As discussed above, kantembas are free standing kiosks in urban estates (neighborhoods). Supermarkets are the typical representation of the modern food retailing sector. For example, Shoprite operates supermarkets of varying sizes across Zambia.

When weighted for city population, urban market shares by outlet are: retail grocers 37.3%, market stalls/stands 21.9%, ka sector 17.3%, supermarkets 10.9%, and other outlets 12.5%.

As these figures are representative of urban populations only, about 36% of total population, we need to account for the rural share of food consumption. A profile on Zambian rural smallholders (Siegel 2008) gives an insight into the mean shares of income by source. Since income results from mutually beneficial exchanges, we can interpret these averages in terms of consumption shares for the rural population. Since rural populations are by definition relatively far from urban centers, they have little chance to visit grocery stores and city markets. In the source survey, the total shares of income sum up to only 0.93.

On average, the Zambian rural population provides an equivalent of 55% of its income from home production/home consumption (HP/HC). HP/HC activities are assumed to be valued in producer prices. Other sources of income are food crop sales, non-food crop sales (tobacco), livestock and other agricultural income, non-farm business, remittances, and other sources, with no identified source over 10%. In other words, only 45% of their income is derived from exchange outside the household.

Table 7.5: Urban Consumption Patterns of Selected Cities in Zambia

	Market Channel Share (%) of Total Value of Staple Carbohydrate Purchases					
	Retail Grocers	Market stalls	ka sector	Supermarkets	Other outlets	Total
Lusaka	39.0	19.6	18.9	11.9	10.6	100.0
Kitwe	38.3	24.2	15.6	5.8	16.1	100.0
Mansa	22.2	31.3	4.8	16.9	24.8	100.0
Kasama	15.1	43.3	6.0	15.1	20.5	100.0
Average	28.7	29.6	11.3	12.4	18.0	100.0

Table 7.6: Population of Selected Cities in Zambia (2010)

	Population	Share
Lusaka	1,742,979	0.72
Kitwe	504,194	0.21
Mansa	55,000	0.02
Kasama	113,779	0.05
Sub-total	2,415,952	1.00
Total Zambia	13,046,508	

With this data, we compute in table 7.9 the nationwide weighted average of consumption shares. Table 7.10 summarizes the data into three categoriesHP/HC, traditional markets, and modern grocers, where the modern grocers category includes the retail grocers group and supermarkets; traditional markets include all other categories except HP/HC. The summarized shares are: HP/HC 35.2%, traditional markets 47.4%, and modern grocers 17.4%.

The question arises regarding the treatment of HP/HC for the purpose for disaggregating retail food sector shares. HP/HC may be considered a subsistence level of living since none of this food enters the market and instead is consumed at some unknown rate until the next harvest. HP/HC is momentary production and does not accommodate the accumulation of capital unless there remains a surplus to exchange for the production and/or acquisition of capital goods. Since HP/HC is valued in producer prices, we may view this state of affairs as if the smallholders were selling produce to themselves at a breakeven price. In this case, it makes more sense to include HP/HC in traditional markets. Based on this interpretation, the nationwide consumption shares now become: traditional markets 82.6% and modern grocers 17.4%. Although the traditional, mostly rural, channels are dispersed, they represent a considerable majority of consumption. These consumption shares are the basis of the weighting of factor shares between the traditional and modern sectors.

These weighted market shares must be adjusted for differing factor intensities since the two channels use different technologies. Starting with the factors from the GTAP extract in table 7.11, we have relative factor shares of 0.38 for capital and 0.62 for labor.

From the above analysis, we have relative market shares for modern and traditional retail that we weight according to each channel's unique factor share. For modern retail, we assume that its factor share remains the same as the GTAP computed result of 0.38 for capital and 0.62 for labor since the data sources for Hausner's 1995 came from the formal economy, of which modern retail is a part (Hausner 1999). For traditional retail, computa-

Table 7.7: Weighted Urban Consumption Patterns of Selected Cities in Zambia

	Weighted Market Channel Share (%) of Total Value of Staple Carbohydrate Purchases					
	Retail Grocers	Market stalls	ka sector	Supermarkets	other outlets	Total
Lusaka	28.1	14.1	13.6	8.6	7.6	72.1
Kitwe	8.0	5.1	3.3	1.2	3.4	20.9
Mansa	0.5	0.7	0.1	0.4	0.6	2.3
Kasama	0.7	2.0	0.3	0.7	1.0	4.7
Totals	37.3	21.9	17.3	10.9	12.5	

Table 7.8: Mean Shares of Income by Source for Rural Households

Profile of Zambian Rural Smallholders	
	Average of all Rural Hholds
Consumption of own production	0.55
Food Crop sales	0.06
Non-food crop sales	0.02
Livestock & other ag inc.	0.02
Non-farm business	0.10
Remittances	0.06
Other	0.12
Total	0.93
Rural Consumption Summary	
Consumption of own production	0.55
Market Stalls/stands	0.45
Total	1.00
	Share
Urban population	0.36
Rural population	0.64

Table 7.9: Weighted Consumption Shares

Whole Country	Weighted Market Channel Share (%) of total value of staple carbo purchases						
	HP/HC	Retail Grocers	Market Stalls	ka Sector	Supermarkets	Other Outlets	Total
Urban	-	13.4	7.9	6.2	3.9	4.5	
Rural	35.2	-	28.8	-	-	-	
Country Total	35.2	13.4	36.7	6.2	3.9	4.5	100.0

Table 7.10: Summary of Weighted Market Channel Shares

	HP/HC	Traditional Markets	Modern Grocers	Total
HP/HC	35.2			
Retail Grocers			13.4	
Market stalls/stands		36.7		
ka sector		6.2		
Supermarkets			3.9	
other outlets		4.5		
Totals	35.2	47.4	17.4	100.0
Totals excluding HP/HC		47.4	17.4	64.8
Totals including HP/HC in Traditional Markets		82.6	17.4	100.0

Note: In this case, HP/HC activities are assumed to be valued in producer prices.

Table 7.11: Retail Sector Factor Values from Housner's 1995 SAM

		Aggregate	Market Weight with HP/HC		
	Value	Factor Share	Ret Modern	Ret Traditional	Total
Capital	107.21	0.38	0.17	0.83	1.00
Labor	174.01	0.62	0.17	0.83	1.00
Total	281.22	1.00			

tion of factor shares is more problematic since data sources are scarce. In line with factor shares of the smallholder agricultural sector, we assume that traditional retail channels downstream employ slightly more capital intensive production structure as traditional food moves to larger city markets. Accordingly, in table 7.12 we apply a factor share of 0.30 for capital and 0.70 for labor for the traditional retail sector.

When we apply these weights, the factor shares now become for modern retail: capital 0.45 and labor 0.55; and for traditional retail: capital 0.37 and labor 0.63, as shown in table 7.13.

Compared to the GTAP factor shares, modern retail is more capital intensive and traditional retail becomes slightly more labor intensive.

Table 7.12: Calculation of Modern and Traditional Food Retail Factor Shares

	Adjusted Factor Shares		Weights			Weighted Averages		New Weighted Factors	
	Ret Modern	Ret Traditional	Ret Modern	Ret Traditional	Total Weight	Ret Modern	Ret Traditional	Ret Modern	Ret Traditional
Capital	0.38	0.30	0.07	0.25	0.31	0.21	0.79	22.54	84.67
Labor	0.62	0.70	0.11	0.58	0.69	0.16	0.84	27.31	146.70
							Total	49.84	231.38

Table 7.13: New Food Retail Factor Shares

	Modern	Traditional
Capital	0.45	0.37
Labor	0.55	0.63
	1.00	1.00

Table 7.14: Zambia Social Accounting Matrix – Activities and Commodities

Expenditures: Receipts:	1. Activities						2. Commodoties					
	AT01 AgCom	AT02 AgShold	AT03 RetMod	AT04 RetTrad	AT05 Ind	AT06 Svcs	CT01 AgCom	CT02 AgShold	CT03 RetMod	CT04 RetTrad	CT05 Ind	CT06 Svcs
1. Activities												
AT01 Ag Com							40.67					
AT02 Ag Shold								427.17				
AT03 Ret Mod									68.08			
AT04 Ret Trad										554.42		
AT05 Ind											762.16	
AT06 Svcs												1,171.21
2. Commodities												
CT01 Ag Com			40.67									
CT02 Ag Shold				427.17								
CT03 Ret Mod												
CT04 Ret Trad												
CT05 Ind												
CT06 Svcs												
3. Factors												
K	67.42	67.42	12.40	46.56	551.74	456.82						
L	33.48	290.12	15.02	80.68	210.42	714.40						
T	11.27	69.63			0.00							
4. Institutions												
HH												
GV	0.00		0.00		0.00	(0.00)	0.00		(0.00)		0.00	0.00
5. Capital Acct. KA												
6. Foreign Trade WT												
							-		0.00		71.49	(0.00)
7. Total GDP TT	112.16	427.17	68.09	554.42	762.16	1,171.21	40.67	427.17	68.08	554.42	833.65	1,171.21
Value Added	112.16	427.17	27.42	127.24	762.16	1,171.22						

Factor Shares	AT01	AT02	AT03	AT04	AT05	AT06	Total Factor Shares: Agriculture	Industry	Services	Total Economy
Ag Commercial	n/a	n/a	0.597	n/a	n/a	n/a				
Ag Smallholder	n/a	n/a	n/a	0.770	n/a	n/a				
K	0.601	0.158	0.182	0.084	0.724	0.390	0.250	0.724	0.390	0.46
L	0.298	0.679	0.221	0.146	0.276	0.610	0.600	0.276	0.610	0.51
T	0.100	0.163	n/a	n/a	n/a	n/a	0.150			0.03
	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Relative Factor Shares for Retail Sectors

	AT03	AT04
K	0.45	0.37
L	0.55	0.63

GDP Shares	
Ag Comm	0.043
Ag Shold	0.163
Ret Modern	0.010
Ret Traditional	0.048
Industry	0.290
Services	0.446
	1.000

Total GDP by:	
Value Added	2,627.37
Income	2,627.37
Expenditure	2,627.37

Table 7.15: Zambia Social Accounting Matrix – Factors, Institutions, Capital, and Trade

Expenditures: Receipts:	3. Factors			4. Institutions		5. Capital Account	6. Foreign Trade	7. Total
1. Activities	K	L	T	HH	GV	KA	WT	TT
AT01 Ag Com							71.49	112.16
AT02 Ag Shold							-	427.17
AT03 Ret Mod							(0.00)	68.08
AT04 Ret Trad								554.42
AT05 Ind							0.00	762.16
AT06 Svcs							0.00	1,171.21
2. Commodities								
CT01 Ag Com				0.00	0.00	(0.00)		40.66
CT02 Ag Shold								427.17
CT03 Ret Mod				68.08	0.00	(0.00)		68.08
CT04 Ret Trad				554.42				554.42
CT05 Ind				660.73	0.00	172.92		833.66
CT06 Svcs				1,171.21	0.00	(0.00)		1,171.21
3. Factors								
K								1,202.36
L								1,344.12
T								80.90
4. Institutions								
HH	1,202.36	1,344.12	80.90					2,627.37
GV								0.00
5. Capital Acct. KA				172.92	(0.01)		(0.00)	172.91
6. Foreign Trade WT								71.49
7. Total GDP TT	1,202.36	1,344.12	80.90	2,627.37	0.00	172.91	71.49	

Consumption Only	2,454.45

Consumption Shares	
RetailModern	0.028
Retail Trad	0.226
Industry	0.269
Services	0.477
	1.000

Export Shares	
Ag Com	1.000
Industry	0.000

Total Expenditure Shares	
RetailModern	0.026
Retail Trad	0.211
Industry	0.251
Services	0.446
Saving	0.066
Total	1.000

Relative Consumption Shares	
RetailModern	0.11
Retail Trad	0.89

8 The Baseline Model

8.1 Introduction

The modeled economy produces four final goods–a manufactured good, a service good, and two retail food goods, one of which is provided by commercial farms and the other provided by smallholder farms. The vertical food marketing channel is bifurcated. In one branch, commercial farmers supply modern grocers, and in the other smallholder farmers supply traditional retail grocers. Thus, owing to different attributes of quality, uniformity and retail outlet, the two food goods are imperfect substitutes. The markets for the service good and both retail food goods are solely domestic, and consequently, the prices of smallholder produce, modern food, and traditional food retail are endogenously determined. The manufacturing and commercial farming sectors, however, participate in international trade with prices determined on the world market.

A representative household receives utility from the consumption of four final goods–manufactured goods, modern food, traditional food, and services. This household has Stone-Geary preferences over the two final food goods whereby the share of all food in consumption expenditures falls as income rises. From the SAM results in the previous section, both modern and traditional food enter the preference function as relative consumption shares of 0.89 and 0.11, respectively. Each share is multiplied by the food budget share of a typical wealthy country, estimated at 0.097. A system of two equations is then used to solve for the unknown minimum modern and traditional food expenditures required under Stone-Geary preferences. See Appendix A for details on the expenditure function. Households also own the factors of production–land, labor, and capital–which they rent to firms in exchange for factor payments.

Manufacturing and service firms employ only labor and capital. Agricultural firms hire labor, capital and land services, with the value of the contribution of land being agricultural profits. Modern and traditional food retail firms purchase intermediate agricultural inputs for their production as well as labor and capital to produce final food-consumption goods. The difference between the gross value of traditional (modern) retail output and its cost of intermediate inputs is the traditional (modern) sector's value added.

8.2 Structure of Production

Model results give insights into the transitional nature of Zambia's structure of production. For the baseline scenario, we assign the following parameter values. The first parameter,

θ, is set to 1.2 so that elasticity of inter-temporal substitution, $1/\theta$, is less than one. Giovannini (1985) estimated that for low income countries, $1/\theta$ is less than one, meaning that consumption smoothing is sensitive to changes in the real interest rate. Second, the rates of time preference ρ, and depreciation δ, are set to 0.04 based on Kydland and Prescott (1982). Next, the annual rate of growth in the workforce is 0.233, computed from WDI data. The beginning period (1980) workforce population from WDI, LL, is 2,086,079. The rate of technical change, x, is set to zero since quasi-homothetic Stone-Geary preferences for the two retail food goods are in effect.

Expenditure shares indicate the relative magnitudes of the final goods sectors. The industrial expenditure share, λ_1, is 0.269 in the base year and projected to grow into the future. The two food sector shares reveal the relative magnitudes of the modern and traditional markets. The modern food sector share, λ_2, is 0.028, compared to the traditional share, λ_3, of 0.226. Thus, in 1995, the traditional food sector was almost ten times the size of the modern food share. Even with high growth rates, the modern food sector would take a number of years to catch up to the traditional food sector. The service sector expenditure share, λ_4, is 0.477, and represents all service activities, including government consumption, outside of food marketing. Since the implementation of economic reforms in 1995, the service sector has shown strong growth.

In table 8.1, factor elasticities for agriculture show that commercial agriculture is more capital intensive than smallholder agriculture. With factor elasticities of capital and labor of 0.601 and 0.298 respectively, commercial agriculture is less sensitive to increasing labor costs than smallholder agriculture. Factor elasticities of smallholder agriculture are 0.158 and 0.679 for capital and labor, respectively. The contrasting factor elasticities of these agricultural sectors show how different are their structures of production.

Table 8.1: Factor Elasticities for Farming Sectors

Factor	Commercial	Smallholder
Labor	0.298	0.679
Capital	0.601	0.158
Land	0.100	0.163

In table 8.2, capital and labor factor elasticities for the food retail sectors show that modern retail employs more labor and capital in its production compared to traditional retail. Factor elasticities of labor for modern and traditional food retail are 0.221 and 0.146 respectively; for capital they are 0.182 and 0.083 respectively. With the smaller value added component, the elasticity of intermediate inputs is greater for traditional retail at 0.770 versus 0.597 for modern retail. The modern channel adds more value through labor and capital inputs, which provide enhanced product attributes such as consistency, timeliness, and packaging.

Table 8.2: Factor Elasticities for Food Retail Sectors

Factor	Modern	Traditional
Labor	0.221	0.146
Capital	0.182	0.084
Intermediate Inputs	0.597	0.770

Source: Zambia SAM

Zambia's industrial sector is more capital intensive with factor elasticity of labor of only 0.276. The high capital intensity is due to the nature of Zambia's copper and base metal mining operations, which behave like an enclave economy within Zambia's broader, agrarian economy.

The service sector, excluding the two retail food sectors, has a factor elasticity of labor of 0.600, showing the labor-intensive nature of the sector.

Factor intensities for the agricultural and retail sectors show the relative strength of labor and capital (labor factor elasticity/(1-labor factor elasticity)), not including land or intermediate inputs. The sector intensity of commercial farming is 0.425 compared to 2.117 for smallholder farming, indicating that commercial farming is more capital intensive than smallholder farming.

For the retail sectors, sector intensity of modern food retail is 0.283 compared to traditional food retail of 0.170. Although these intensities are relatively close, one would perhaps expect modern food retail to be more capital intensive.

These differences in relative factor intensity suggest that as capital deepening (implying that the stock of capital grows at a faster rate than growth of the work force) occurs, the marginal product of labor, all else constant, will tend to increase more rapidly in the capital intensive sectors relative to the more labor intensive sectors of the economy. All else constant, the more capital intensive sectors' unit costs will fall relative to the other sectors, causing them to pull labor from the other sectors. As household income increases, the demand for all goods increase, thus causing the domestic market for the non-internationally traded, and relatively labor intensive sector to clear at rising prices. These forces feed-back down the food marketing chain causing changes in the terms of trade between the modern and traditional farm sector. Together with capital deepening, they become the major source of inducing structural change between the modern and traditional farm sector.

8.3 Baseline Model Results: An Overview

Results from the baseline scenario suggest that the economic sectors of Zambia behave very differently because of their contrasting structures of production. The industrial sector is the most capital intensive, followed by the commercial farming sector and the service sector, which excludes the retail food sectors. Overall, the modeled economy of Zambia has four home good sectors involved in domestic trade. The capital intensity of the smallholder farming sector is low, meaning that these farmers rely heavily on labor inputs. For the modern and traditional food sectors, the value of agricultural inputs dominates both capital and labor value added. Traditional food retail, however, is relatively more capital intensive than modern food retail.

As the economy grows, capital accumulates, resulting in a series of adjustments to the structure of production across the economy. Capital deepening allows firms that use capital intensively to expand output in a fashion similar to that explained by the Rybczynski Theorem. This theorem states that for a two sector and two good economy, if the endowment of a factor increases, the sector which uses the resource intensively will expand, and expand more than proportionately to the percentage increase in the factor. However, in the case of the Zambian modeled economy with more than two sectors, the result is ambiguous because several combinations of factor elasticities could emerge. Nonetheless, the capital intensive sector tends to expand with the increase in its intensive factor. This expansion also requires additional complementary labor. Consequently, across the economy, the supply of capital increases, resulting in a fall in its capital rental rate, and the demand for labor increases, resulting in higher labor costs. With the falling price of capital and the rising price of labor, the net benefit to the capital intensive sectors is positive while the more labor intensive sectors face tighter labor supply conditions. Terms of trade begin to turn in favor of capital intensive sectors and against labor intensive sectors. Since labor intensive sectors such as smallholder farming and services use relatively more labor than capital, their unit costs rise and margins are squeezed. They have no choice but to offer higher wages to retain labor in their sectors causing their product market to clear at rising prices. Simultaneously, households experience higher incomes as demand for capital and labor services increases. In the case of capital, the increasing quantity effect beneficially dominates the effect of falling rental rates.

Given Zambia's six sector model, structural adjustment manifests itself in the comparative performance of these sectors. The industrial sector, the capital intensive giant of the Zambian economy, benefits from the process of capital deepening by employing more capital at lower rental rates. The labor intensive sectors, however, experience higher labor costs in response to the increased demand for labor in the industrial sector. As for the farming sectors, the capital intensive commercial farming sector also expands due to capital deepening, but the labor-intensive smallholder sector also realizes higher costs for labor. Thus, the labor-intensive nature of the smallholder farming sector dampens growth prospects relative to the commercial farm sector. Regarding the two retail sectors, the effects of capital deepening may be muted because their factor elasticities are relatively close, and because labor and capitals share of total cost is relatively small. Similarly, the labor intensive service sector experiences higher labor costs as well.

From the perspective of households, growth in factor earnings, a result of capital deepening, leads to growth in final home good demands, which include retail food and services, and consequently higher prices for home goods. Thus, over the course of time traditional retail food and service prices rise to a market-clearing price. Industrial final good prices and commercial agriculture prices, which are set on the world market, are not affected. Commercial agricultural input prices are set on the world market, while modern food retail prices are set domestically, as are other home goods. Accordingly, prices of modern food retail may rise slightly due to increased demand. Traditional food retail prices rise while smallholder farmers experience tighter margins. The differential between modern and traditional food prices tends to widen as a result.

The Zambian growth model projects economic performance over 100 years from 1980, and uses 1994 as the base year. To provide insights into the forces causing structural change in agriculture, we are interested in economic growth since 1994, the year economic reforms were implemented.

In table 8.3, macro-economic ratios show the Zambian economy accumulating capital. GDP, saving, and capital stock per worker reveal gradual increasing trends with diminishing growth rates in the later years. The index of the ratio of capital stock to GDP shows a consistent increasing pattern, rising from 1.07 in 1995 to 1.21 in 2055. The time from 1980 for GDP per worker to double is 200 years. While GDP is doubling in about 21 years, the supply of workers is also growing, but not quite as fast. The half-life of adjustment to long run equilibrium is about 75 years, in the year 2055.

The growth and composition of Zambian GDP may be examined from a few perspectives. From table 8.4, in 1995, capital rents made up the largest share of GDP by income at 0.555, followed by wages, smallholder farming profits, and commercial farming profits with

Table 8.3: Macroeconomic Baseline Data per Worker*

Year	GDP	Savings/ GDP	Capital/GDP Index
1980	1,159,373	0.450	1.00
1985	1,231,944	0.450	1.03
1990	1,300,489	0.450	1.05
1995	1,364,916	0.449	1.07
2000	1,425,216	0.449	1.09
2005	1,481,443	0.449	1.11
2010	1,533,700	0.448	1.12
2015	1,582,124	0.448	1.13
2020	1,626,882	0.448	1.15
2025	1,668,156	0.447	1.16
2030	1,706,141	0.447	1.17
2035	1,741,035	0.447	1.18
2040	1,773,037	0.447	1.19
2045	1,802,346	0.446	1.20
2050	1,829,152	0.446	1.20
2055	1,853,642	0.446	1.21

*1994 Zambian Kwacha; Index: 1980 = 1.00

respective shares of 0.421, 0.020, and 0.004. By the time the Zambian economy reaches the half-way point to the steady state (2055), real GDP will have increased by 450%. Captial's share of income increases 0.004 or 0.7% while the other income shares fell. Labor's share falls by -0.001, smallholder farming profits by -0.001, and commercial farming profits by -0.002.

Table 8.4: GDP by Income*

Year	Capital Rent	Wage Income	Smallholder Farm Profit	Commercial Farm Profit
1980	1,336	1,020	49	14
1985	1,599	1,216	58	15
1990	1,900	1,441	68	16
1995	2,243	1,698	79	17
2000	2,635	1,992	92	19
2005	3,081	2,325	107	21
2010	3,587	2,704	124	23
2015	4,160	3,133	142	25
2020	4,809	3,619	164	27
2025	5,543	4,168	187	30
2030	6,373	4,789	214	34
2035	7,310	5,490	245	37
2040	8,367	6,282	279	41
2045	9,559	7,174	318	46
2050	10,902	8,180	361	51
2055	12,416	9,313	410	57

*billions of 1994 Zambian Kwacha

In table 8.5, GDP by final good expenditures reveals that, after saving, services represents the largest expenditure share at 0.252, followed by traditional food, industry, and modern food with respective shares of 0.173, 0.104, and 0.021. Over the first 55 years from 1995, expenditure share for industrial goods increases by 0.028, while modern food, traditional food, and service shares fall by -0.003, -0.034, and -0.011, respectively.

In table 8.6, GDP by value added at the final goods stage reveals how much each sector contributes to the growth of the Zambian economy. In 1995, respective value-added shares of industry, modern food, traditional food, and services were 0.554, 0.021, 0.173, and 0.252. Sixty years later, the model predicts that the share of industry will rise by 0.048, and the shares of modern food, traditional food, and services will fall by -0.003, -0.034, and -0.011 respectively. Although the value-added shares of both food sectors fall, the modern

Table 8.5: GDP by Expenditure*

Year	Industrial Goods	Modern Food	Traditional Food	Services	Saving
1980	216	57	483	642	1,087
1985	275	65	546	751	1,298
1990	343	74	617	876	1,540
1995	421	84	696	1,017	1,815
2000	510	95	786	1,177	2,128
2005	612	108	887	1,358	2,483
2010	729	122	1,000	1,562	2,886
2015	861	138	1,127	1,793	3,343
2020	1,011	157	1,270	2,053	3,859
2025	1,181	177	1,431	2,347	4,443
2030	1,373	200	1,612	2,678	5,102
2035	1,591	226	1,816	3,051	5,846
2040	1,837	255	2,044	3,470	6,685
2045	2,114	288	2,301	3,943	7,630
2050	2,428	324	2,590	4,475	8,696
2055	2,781	366	2,914	5,074	9,896

*billions of 1994 Zambian Kwacha

food sector gains relative to the traditional food sector. While the modern food channel is capital intensive, it begins from a small position. Although the traditional food channel is large, it lacks the capital to improve labor productivity. For the modern food channel, the negative effect of Stone-Geary preferences may counterbalance the positive effects of capital deepening.

Table 8.6: GDP by Value Added*

Year	Modern Food	Traditional Food	Industry	Services
1980	57	483	1,303	642
1985	65	546	1,573	751
1990	74	617	1,883	876
1995	84	696	2,236	1,017
2000	95	786	2,638	1,177
2005	108	887	3,096	1,358
2010	122	1,000	3,615	1,562
2015	138	1,127	4,204	1,793
2020	157	1,270	4,870	2,053
2025	177	1,431	5,624	2,347
2030	200	1,612	6,475	2,678
2035	226	1,816	7,437	3,051
2040	255	2,044	8,522	3,470
2045	288	2,301	9,745	3,943
2050	324	2,590	11,124	4,475
2055	366	2,914	12,678	5,074

*billions of 1994 Zambian Kwacha

In table 8.7, prices under the baseline scenario indicate that the spread between traditional and modern food retail widens. Smallholder farm-gate prices, in equivalent traditional retail units, and traditional retail prices increase by about 23% from 1995 to 2055 while modern retail prices only increase by 4.7%. While the modern retail price spread increases only slightly, the greater increase in the traditional food marketing margin shows that traditional retailers capture most of the increase in retail prices. This difference between the two sectors is caused by the rise in labor wage having a more cost increasing effect on the relatively more labor intensive traditional food marketing chain than the modern marketing chain. Smallholder farmers continue to add relatively little additional value to traditional food retail. The aggregate price index rises by 10.4% over this period.

Under the baseline scenario, the distinction between commercial and smallholder farming

Table 8.7: Agricultural Food Price Indices

Year	Smallholder Farm*	Traditional Retail	Modern Retail	Aggregate Price Index
1980	0.187	0.813	0.959	0.912
1985	0.195	0.848	0.968	0.930
1990	0.202	0.879	0.976	0.947
1995	0.209	0.909	0.983	0.962
2000	0.215	0.936	0.989	0.975
2005	0.221	0.961	0.995	0.987
2010	0.226	0.984	1.000	0.999
2015	0.231	1.006	1.005	1.009
2020	0.235	1.025	1.009	1.018
2025	0.239	1.043	1.013	1.026
2030	0.243	1.059	1.016	1.034
2035	0.246	1.074	1.019	1.041
2040	0.250	1.087	1.022	1.047
2045	0.252	1.100	1.025	1.052
2050	0.255	1.111	1.027	1.058
2055	0.257	1.121	1.029	1.062

*Smallholder farm-gate price in traditional retail equivalents is apparent. In table 8.8, commercial farming employs about 8.7 times as much capital per worker as does Smallholder farming although in aggregate commercial output is smaller.

Table 8.8: Capital per Agricultural Worker*

Year	Commercial Farms	Smallholder Farms
1980	9,834,306	1,134,728
1985	10,679,840	1,232,289
1990	11,496,695	1,326,542
1995	12,280,172	1,416,943
2000	13,026,878	1,503,101
2005	13,734,563	1,584,757
2010	14,401,948	1,661,763
2015	15,028,567	1,734,065
2020	15,614,616	1,801,686
2025	16,160,819	1,864,710
2030	16,668,312	1,923,267
2035	17,138,534	1,977,523
2040	17,573,148	2,027,671
2045	17,973,961	2,073,919
2050	18,342,871	2,116,485
2055	18,681,814	2,155,594

*1994 Zambian Kwacha

In table 8.9, in 1995, commercial farm output per farm worker was 200% higher than smallholder farm output. By 2055, commercial farm output per farm worker increases to 250% of smallholder farm output. However, differences in profit per farm worker are smaller. In 1995, commercial farm profit per farm worker was ZMK193,225 while smallholder farms generated ZMK137,764 in profits, a difference of 40%. By 2055, the difference in profits remains unchanged. Thus, although commercial farms have access to more capital per farm worker and have greater output, growth in per worker profit lags behind.

Supply per worker by food channel shows how much domestic supply is flowing through the farm and retail channels per worker(table 8.10). The initial lower supplies for the commercial farming and modern retail stages is an indication of how much output is exported. By 2055 commercial farming domestic supply surpasses the smallholder channel while at the retail level the modern channel still falls behind traditional retail supply. This result indicates that commercial farms are responsible for most of the increase in value-added in the modern channel. Traditional channel growth in value-added remains less dynamic.

Table 8.9: Output and Profit per Agricultural Worker*

	Output		Profit	
Year	Commercial	Smallholder	Commercial	Smallholder
1980	1,637,631	903,229	164,526	117,303
1985	1,738,391	916,924	174,649	124,520
1990	1,833,659	929,320	184,220	131,344
1995	1,923,292	940,538	193,225	137,765
2000	2,007,259	950,685	201,661	143,779
2005	2,085,618	959,864	209,533	149,392
2010	2,158,500	968,164	216,855	154,612
2015	2,226,085	975,669	223,645	159,453
2020	2,288,594	982,455	229,925	163,931
2025	2,346,271	988,591	235,720	168,062
2030	2,399,380	994,138	241,056	171,867
2035	2,448,192	999,153	245,960	175,363
2040	2,492,979	1,003,686	250,459	178,571
2045	2,534,013	1,007,785	254,582	181,510
2050	2,571,557	1,011,490	258,354	184,199
2055	2,605,869	1,014,839	261,801	186,657

*1994 Zambian Kwacha

Table 8.10: Supply per Worker by Food Channel*

	Farm Stage		Retail Stage	
Year	Commercial	Smallholder	Modern	Traditional
1980	396,093	903,229	2,310,124	4,128,829
1985	447,301	916,924	2,430,227	4,206,015
1990	498,870	929,320	2,542,819	4,276,149
1995	550,230	940,538	2,647,946	4,339,827
2000	600,880	950,685	2,745,756	4,397,608
2005	650,391	959,864	2,836,478	4,450,011
2010	698,412	968,164	2,920,396	4,497,518
2015	744,658	975,669	2,997,834	4,540,571
2020	788,918	982,455	3,069,138	4,579,575
2025	831,036	988,591	3,134,671	4,614,902
2030	870,913	994,138	3,194,799	4,646,893
2035	908,498	999,153	3,249,883	4,675,856
2040	943,778	1,003,686	3,300,280	4,702,073
2045	976,772	1,007,785	3,346,333	4,725,803
2050	1,007,526	1,011,490	3,388,372	4,747,278
2055	1,036,107	1,014,839	3,426,710	4,766,711

*1994 Zambian Kwacha

In table 8.11, a comparison of supply per sector worker in the two agricultural channels shows the modern food channel, starting at the farmgate, adding greater value than the traditional channel. For the modern channel, value-added per worker is ZMK 285,925 in 1995 and rises 52.3% by 2055. For the traditional channel on the other hand, value-added per worker is ZMK 208,355 in 1995 and rises only 16.7% over the same period. This difference highlights the importance of marketing channel stages to overall product value.

Table 8.11: Channel Value Added per Worker*

Year	Modern	Traditional
1980	227,273	191,637
1985	247,616	197,717
1990	267,205	203,277
1995	285,925	208,355
2000	303,695	212,987
2005	320,468	217,208
2010	336,220	221,050
2015	350,948	224,545
2020	364,667	227,722
2025	377,403	230,608
2030	389,192	233,228
2035	400,076	235,606
2040	410,101	237,763
2045	419,318	239,720
2050	427,776	241,493
2055	435,525	243,101

*1994 Zambian Kwacha

At the retail level, the modern food sector has more capital to work with than does the traditional food sector, according to the baseline scenario. From 1995 to 2055, capital per retail worker increases by 52.1% for both sectors(table 8.12). Accordingly, the modern retail sector is able to maintain its edge in capital per worker, which sustains its lead in productivity over the traditional retail sector. Recall that capital and labor contributions for the two retail sectors are relatively close, and a small proportion compared to intermediate inputs.

Growth rates are projected to converge toward the steady state growth rate of about 0.023 over the next 100 years. Approaching from below, commercial agriculture starts to grow at about 0.015 per year. This growth trajectory raises the question of why it is growing so slowly compared to the other sectors. Commercial farms have more capital per worker,

Table 8.12: Capital per Retail Worker*

Year	Modern	Traditional
1980	4,030,178	2,818,327
1985	4,376,684	3,060,641
1990	4,711,438	3,294,737
1995	5,032,513	3,519,266
2000	5,338,519	3,733,259
2005	5,628,534	3,936,068
2010	5,902,034	4,127,327
2015	6,158,827	4,306,905
2020	6,398,995	4,474,855
2025	6,622,834	4,631,387
2030	6,830,808	4,776,825
2035	7,023,509	4,911,582
2040	7,201,617	5,036,134
2045	7,365,873	5,150,999
2050	7,517,056	5,256,722
2055	7,655,958	5,353,857

*1994 Zambian Kwacha

which contributes to higher production and profits per worker compared to smallholder farms.

8.4 Interpretation of Baseline Model Results

As the modeled Zambian economy unfolds, each sector displays a different growth story as the processes of capital deepening and rising incomes slowly transform the structure of production and relative prices. As the economy grows, the increasing supply of capital induces capital-intensive sectors, such as industry and commercial farming, to increase output. With output and the supply of capital increasing, these sectors benefit from a falling cost of capital. As output expands, complementary labor demand increases, causing upward pressures on wages throughout the economy. As a consequence of rising demand, wages rise in order to attract workers from other sectors. However, the effect of this increase in demand is mitigated by an increasing labor supply. Thus, labor costs increase for all sectors, although capital-intensive sectors still maintain a net cost advantage since labor represents a relatively small share of costs. However, labor intensive sectors such as smallholder farming and services face increasing costs for labor as they must match wage increases to retain labor. Higher labor costs make these sectors less competitive compared to the capital-intensive sectors. Model results project the share of workers in traditional agriculture to slowly fall about 1% over the next 70 years.

Rising factor incomes also increase household demand for final goods and services. In the case of home goods like smallholder farming and traditional retail, increased demand leads the market to clear at a higher price, thus dampening some of the negative effects of higher labor costs.

The ratio of capital per worker confirms that capital deepening is driving the divergent growth paths of Zambia's economic sectors. The amount of capital per agricultural worker is 8.7 times as great for commercial farming as it is for smallholder farming. In this environment, capital intensive sectors hold an advantage over labor intensive sectors that is manifested in higher output and labor productivity.

9 Sector Growth Accounting

9.1 Introductory Discussion of Elasticity

The economic growth model of Zambia can tell us the separate effects of changes in factor prices and endowments on outputs. In dynamic general equilibrium models, the information transmitted through elasticity is particularly important because several direct and indirect effects are occurring simultaneously. Elasticity not only indicates the sign of the change, but also in some cases estimates of magnitude.

Dynamic growth models employ two common types of elastic relations in discussions of comparative statics. First, the Stopler-Samuelson Theorem states, in the case of a two-sector, two-good economy, that if the relative price of a good increases, the factor used intensively in the production of that good will experience an increase in income more than proportionate to the percentage change in relative price. The other factor will experience a decrease in income which is more than proportionate than the percentage fall of its relative price. The second relation, the Rybczynski Theorm, states that if the supply of a factor increases, the sector which employs that factor will increase production more than proportionately to the percentage increase in the factor. The other sector will experience a decrease in production. Although these theorems apply strictly to a two-sector, two-good problem, they can serve as general guides for understanding how competing sectors behave in multi-sector models. Other elasticity relations may be useful as well, but these two are particularly useful to understanding the dynamics of the Zambia growth model.

The foundational economic story imbedded in the Zambia growth model is that capital deepening drives changes in the relative cost of factors and sector outputs. In this analysis, we are interested in understanding the forces which affect growth of output by sector. According to the output supply equations (see equation 7 of the theoretical model), output for all six sectors is a function of wages, w, the cost of capital, r, and output price, p_j. The two farming sectors also include the fixed resource of land, H_c and H_h. The two food retail sectors also include the price of agricultural inputs from their respective upstream suppliers. Theory can suggest likely effects of these factors on sector supply.

Starting with the capital-intensive industrial sector, output is a function of p, w, and r. As capital accumulates across the economy and its price, expressed in r, falls, the industrial sector benefits from the lower cost of capital. This increase in the capital endowment creates Rybczynski-like effects as the capital intensive sectors expand. Output grows more than proportional compared to the percentage increase in capital. The rental rate of capital, r, also falls as supply increases. As output expands, industrial demand for labor rises, pushing up the equilibrium price. The cost of labor is now more expensive across the economy. However, since the industrial sector is capital intensive, the cost of capital represents a larger cost component than labor. The net effect on industry is a reduction in cost and an expansion of output. The output price of industry is set on the world market, and as such is an exogenous factor.

Since this Zambia growth model has only one capital and one labor market, factor costs also affect the other sectors. The labor-intensive services sector responds in the opposite manner from that of the capital-intensive sector. As capital intensive sectors drive up the cost of labor, the service sector experiences deterioration in its terms of trade. The costly rise in labor inputs outweighs the beneficial fall in the rental rate of capital since services is labor intensive.

Households, as owners of the factors, receive factor income. Overall, capital holds a slight edge in GDP share of income compared to labor, and thus, in capital deepening, the net volume and price effect on income to households should be moderately positive, depending on the elasticity of capital with respect to its price. This moderate rise in income suggests that demand for home-sector goods such as services will be stronger, thus dampening the negative effects on margins of rising labor costs.

The effect of capital deepening on the farming sectors mainly depends on their capital intensity. The commercial farming sector is strongly capital intensive compared to the smallholder sector, although it is just a fraction of the size. Thus, theory tells us that the commercial sector will expand just as industry does. Greater supplies of capital lead to lower rental rates and greater demand for labor. With output prices set on the world market, commercial farmers accept these prices as exogenous. A significant difference to note for the farming sectors is that the fixed resource of land creates diminishing returns to capital and labor inputs. Profits and output will slightly trail comparable returns in the industrial or service sectors.

The much larger labor-intensive smallholder farming sector will experience negative terms of trade effects similar to the services sector. The magnitude of the effect will be stronger since the labor share of cost is so great. Unit costs of production increase for smallholders. As for smallholder income, higher household factor revenues will lead to greater demand for food, and higher retail prices. The magnitude of the increase in farm-gate prices is difficult to assess because the demand for traditional retail food is inversely related to income. We know from the theoretical model that traditional retail intermediate demand is equal to smallholder output supply. Thus, retail price changes should be transmitted to the smallholder market since the traditional marketing channel is limited in scope to the domestic market.

The retail food sectors respond to capital deepening in similar ways to the other sectors, except that labor and capital cost shares are very small compared to the intermediate goods cost share. The cost of intermediate agricultural inputs dominates retails value added inputs of labor and capital.

9.1.1 Commercial Farm Sector Elasticity

Growth in commercial farm output can be decomposed into wage and capital cost components, which in turn can be broken down into price effects. As table 9.1 shows below, the price of smallholder agriculture contributes positive, but diminishing effects to growth in commercial farm output. As described in the Stopler-Samuelson section above, the elasticity of wages with respect to the smallholder farm-gate price is positive with a large magnitude. Model results tell us that smallholder prices increase through the forecast period. Thus, the combined effect of elasticity and the smallholder farm price change on wages is positive and large.

$$y_c = y_c[p_c, W(p_s, p_h), R(p_s.p_h)H] \tag{26}$$

The other effect of smallholder farm prices on commercial farm output growth runs through cost of capital effects. As described in the Stopler-Samuelson section above, the elasticity of cost of capital with respect to the smallholder farm price is negative with a small magnitude. Model results tell us that smallholder prices increase through the forecast period. Thus, the combined effect of elasticity and the smallholder farm price change on the cost of capital is negative and small.

In addition to smallholder farm prices, the price of services also affects growth in commercial farm output through associated wage and capital cost components. The price of services contributes negative, but diminishing effects to growth in commercial farm output. As described in the Stopler-Samuelson section above, the elasticity of wages with respect to the price of services is positive with a large magnitude. Model results tell us that the price of services also increases through the forecast period. Thus, the combined effect of elasticity and the change in the price of services on wages is positive and large.

The other effect of the price of services on commercial farm output growth runs through cost of capital effects. As described in the Stopler-Samuelson section above, the elasticity of cost of capital with respect to the price of services is negative with a small magnitude. Model results tell us that the price of services increases through the forecast period. Thus, the combined effect of elasticity and the change in the price of services on the cost of capital is negative, but small.

Smallholder farming prices and the price of services interact with wage and cost of capital effects to influence commercial farming output. Starting with the elasticity of commercial farm output with respect to wages, recall from the theoretical discussion of elasticity that since commercial farming is capital intensive, the positive effects of lower capital costs will outweigh the small, but negative effects of higher labor costs. Accordingly, the elasticity of commercial farm output with respect to wages is negative, but small. Thus, when we combine the elasticity of commercial farm output with respect to wages with the positive effects of the price of services and the smallholder price, the overall labor cost effect on commercial farming output becomes negative. Though difficult to judge, the magnitude of this negative effect is likely to be small since commercial farming is capital intensive.

We now consider the second effect, the elasticity of commercial farm output with respect to the cost of capital. From the theoretical discussion of elasticity, since commercial farming is capital intensive, one of the benefits of capital deepening is a lower cost of capital. Accordingly, the elasticity of commercial farm output with respect to the cost of capital is negative and large. Thus, when we combine the elasticity of commercial farm output with respect to the cost of capital with the two negative price effects discussed previously, the overall cost of capital effect on commercial farming output becomes positive. Though difficult to judge, the magnitude of this positive effect is likely to be large since commercial farming is capital intensive.

The last effect on commercial farm output is the price elasticity of commercial farm output. As expected with normal goods, this price elasticity of supply is positive, with an unknown magnitude. Since commercial farm output is traded on the world market, we assign it, as the numeraire, the price of unity. Thus, in the Zambia growth model, commercial farm prices do not change, and the combined effect of price elasticity of supply is zero.

The fixed factor of land does not affect the growth of commercial farm output since its area is assumed to be unchanging. Although it is obviously an important factor of production, commercial farmland's contribution to output growth does not change.

The summation of these four effects accounts for the change in commercial farming output. Since land and price elasticity of supply have no effect, the cumulative wage and cost of capital effects provide the elasticity story. For commercial farming, the wage elasticity effect turns out to be negative and weak in magnitude. The cost of capital elasticity effect is positive with a magnitude stronger than that of the wage effect since the sector is capital intensive. The conclusion, then, is that the smallholder farm price and services price effects, working through wage and cost of capital effects, have an overall positive effect on commercial farming output. According to the data in the table below, the growth rate of commercial farming output slows down slightly at a diminishing rate. Perhaps the magnitude of change is not as strong as the analysis suggests. Nonetheless, this analysis provides useful insights into the dynamics of commercial farming through the theoretical and data linkages described here.

Table 9.1: Growth in Commercial Farm Output and Factor Contributions

		Contributions to Growth		
Year	Growth in Output	Price of Trad Agric	Price of Service Goods	Effective Land
1980	0.0276	0.0462	(0.0418)	0.0233
1985	0.0273	0.0424	(0.0384)	0.0233
1990	0.0269	0.0388	(0.0352)	0.0233
1995	0.0266	0.0355	(0.0322)	0.0233
2000	0.0263	0.0324	(0.0294)	0.0233
2005	0.0261	0.0296	(0.0268)	0.0233
2010	0.0258	0.0269	(0.0244)	0.0233
2015	0.0256	0.0245	(0.0222)	0.0233
2020	0.0254	0.0223	(0.0202)	0.0233
2025	0.0252	0.0202	(0.0183)	0.0233
2030	0.0250	0.0184	(0.0166)	0.0233
2035	0.0249	0.0167	(0.0151)	0.0233
2040	0.0247	0.0151	(0.0137)	0.0233
2045	0.0246	0.0137	(0.0124)	0.0233
2050	0.0245	0.0124	(0.0113)	0.0233
2055	0.0244	0.0113	(0.0102)	0.0233

9.1.2 Smallholder Farm Sector Elasticity

Growth in smallholder farm output can be decomposed into wage and capital cost components, which in turn can be broken down into price effects. Growth in output price has a positive direct effect and a negative indirect effect through its effect on causing wages to rise. The direct effect dominates the indirect wage effect. As table 9.2 shows below, the price of smallholder agriculture contributes positive, but diminishing effects to growth in smallholder farm output. As described in the Stopler-Samuelson section above, the elasticity of wages with respect to the smallholder farm-gate price is positive with a large magnitude. Model results tell us that smallholder prices increase through the forecast period. Thus, the combined effect of elasticity and the smallholder farm price change on wages is positive and large.

$$y_h = y_h[p_h, W(p_s, p_h), R(p_s.p_h)H] \tag{27}$$

The other indirect effect of smallholder farm prices on smallholder output growth runs through cost of capital effects. As described in the Stopler-Samuelson section above, the elasticity of cost of capital with respect to the smallholder farm price is negative with a small magnitude. Model results tell us that smallholder prices increase through the forecast period. Thus, the combined effect of elasticity and the smallholder farm price change on the cost of capital is negative but small.

In addition to smallholder farm prices, the price of services also affects growth in smallholder farm output through associated wage and capital cost components. The price of services contributes negative, but diminishing effects to growth in smallholder farm output. As described in the Stopler-Samuelson section above, the elasticity of wages with respect to the price of services is positive with a large magnitude. Model results tell us that the price of services also increases through the forecast period. Thus, the combined effect of elasticity and the change in the price of services on wages is positive and large. Effectively, this indirect effect on cost in traditional agriculture depicts the two sectors competition for economy-wide resources of labor and capital.

The other effect of the price of services on smallholder output growth runs through cost of capital effects. As described in the Stopler-Samuelson section above, the elasticity of cost of capital with respect to the price of services is negative with a small magnitude. Model results tell us that the price of services increases through the forecast period. Thus, the combined effect of elasticity and the change in the price of services on the cost of capital is negative, but small.

Smallholder farming prices and the price of services interact with wage and cost of capital effects to influence smallholder farming output. Starting with the elasticity of smallholder farm output with respect to wages, recall from the theoretical discussion of elasticity, that since smallholder farming is labor intensive, the negative effects of higher labor costs will be greater than the small, but positive effects of higher capital costs. Accordingly, the elasticity of smallholder farm output with respect to wages is negative, but large. Thus, when we combine the elasticity of smallholder farm output with respect to wages with the two positive price effects discussed previously, the overall labor cost effect on smallholder farming output becomes negative. Though difficult to judge, the magnitude of this negative effect is likely to be large since smallholder farming is labor intensive.

We now consider the second effect, the elasticity of smallholder farm output with respect to the cost of capital. From the theoretical discussion of elasticity, since smallholder farming is labor intensive, the benefit of capital deepening, a lower cost of capital, is weak. Accordingly, the elasticity of smallholder farm output with respect to the cost of capital is negative and small. Thus, when we combine the elasticity of smallholder farm output with respect to the cost of capital with the two negative price effects discussed previously, the overall cost of capital effect on smallholder farming output becomes positive. Though difficult to judge, the magnitude of this positive effect is likely to be small since smallholder farming is labor intensive.

The last effect on smallholder farm output is the price elasticity of smallholder farm output. As expected with normal goods, this price elasticity of supply is positive, with an unknown magnitude.

The fixed factor of land does not affect the growth of smallholder farm output since its area is assumed to be unchanging. Although it is obviously an important factor of production, smallholder farmland's contribution to output growth does not change.

The summation of these four effects accounts for the change in smallholder farming output. Since land has no effect, the cumulative wage and cost of capital effects and the price elasticity of supply effect provide the elasticity story. For smallholder farming, the wage elasticity effect turns out to be negative and large in magnitude. The cost of capital elasticity effect is positive with a magnitude weaker than that of the wage effect since the sector is labor intensive. However, the price elasticity of smallholder farm output is positive, with a relatively small magnitude because the smallholder farming sector is not as integrated as the commercial farming sector. The conclusion, then, is that the smallholder farm price and services price effects, working through wage and cost of capital effects, and the price elasticity of output probably have an overall negative effect on smallholder farming output. According to the data in the table below, the growth rate of smallholder farming output slows down slightly at a diminishing rate. Perhaps the magnitude of change is not as strong as the analysis suggests. Nonetheless, this analysis provides useful insights into the dynamics of smallholder farming through the theoretical and data linkages described here.

Table 9.2: Growth in Smallholder Farm Output and Factor Contributions

		Contributions to Growth		
Year	Growth in Output	Value Added Price	Price of Service Goods	Effective Land
1980	0.0238	0.0485	(0.0480)	0.0233
1985	0.0238	0.0433	(0.0428)	0.0233
1990	0.0238	0.0388	(0.0383)	0.0233
1995	0.0237	0.0347	(0.0343)	0.0233
2000	0.0237	0.0311	(0.0307)	0.0233
2005	0.0237	0.0279	(0.0275)	0.0233
2010	0.0236	0.0250	(0.0247)	0.0233
2015	0.0236	0.0225	(0.0222)	0.0233
2020	0.0236	0.0202	(0.0199)	0.0233
2025	0.0236	0.0182	(0.0179)	0.0233
2030	0.0235	0.0163	(0.0161)	0.0233
2035	0.0235	0.0147	(0.0145)	0.0233
2040	0.0235	0.0132	(0.0131)	0.0233
2045	0.0235	0.0119	(0.0118)	0.0233
2050	0.0235	0.0108	(0.0106)	0.0233
2055	0.0234	0.0097	(0.0096)	0.0233

9.1.3 Modern Food Retail Sector Elasticity

Growth in modern food retail output can be decomposed into wage and capital cost components, which in turn can be broken down into price effects. The model results do not include the price of smallholder agriculture's effect on growth in modern food retail output. However, as described in the Stopler-Samuelson section above, the elasticity of wages with respect to the smallholder farm-gate price is positive with a large magnitude. Model results tell us that smallholder prices increase through the forecast period. Thus, the combined effect of elasticity and the smallholder farm price change on wages is positive and large.

$$y_r = y_r[p_r, W(p_s, p_h), R(p_s.p_h)] \tag{28}$$

The other effect of smallholder farm prices on modern food retail output growth runs through cost of capital effects. As described in the Stopler-Samuelson section above, the elasticity of cost of capital with respect to the smallholder farm price is negative with a small magnitude. Model results tell us that smallholder prices increase through the forecast period. Thus, the combined effect of elasticity and the smallholder farm price change on the cost of capital is negative and small.

In addition to smallholder farm prices, the price of services also affects growth in modern food retail output through associated wage and capital cost components. From table 9.3 below, the price of services contributes negative, but diminishing effects to growth in modern food retail output. As described in the Stopler-Samuelson section above, the elasticity of wages with respect to the price of services is positive with a large magnitude. Model results tell us that the price of services also increases through the forecast period. Thus, the combined effect of elasticity and the change in the price of services on wages is positive and large.

The other effect of the price of services on modern food retail output growth runs through cost of capital effects. As described in the Stopler-Samuelson section above, the elasticity of cost of capital with respect to the price of services is negative with a small magnitude. Model results tell us that the price of services increases through the forecast period. Thus, the combined effect of elasticity and the change in the price of services on the cost of capital is negative, but small.

Smallholder farming prices and the price of services interact with wage and cost of capital effects to influence modern food retail output. Starting with the elasticity of modern food retail output with respect to wages, recall from the theoretical discussion of elasticity that since modern food retail is slightly labor intensive, the negative effects of higher labor costs will outweigh the positive, but weak effects of lower capital costs. Accordingly, the elasticity of modern food retail output with respect to wages is negative, with an unknown magnitude. Thus, when we combine the elasticity of modern food output with respect to wages with the two positive price effects discussed previously, the overall labor cost effect on modern food retail output becomes negative. Though difficult to judge, the magnitude of this negative effect is likely to be small since modern food retail is just slightly labor intensive.

We now consider the second effect, the elasticity of modern food retail output with respect to the cost of capital. From the theoretical discussion of elasticity, since modern food retail is slightly labor intensive, the benefit of capital deepening, a lower cost of capital, is weak. Accordingly, the elasticity of modern food retail output with respect to the cost of capital is negative and small. Thus, when we combine the elasticity of modern food retail output with respect to the cost of capital with the two negative price effects discussed previously, the overall cost of capital effect on modern food retail output becomes positive. Though difficult to judge, the magnitude of this positive effect is likely to be small since modern food retail is slightly labor intensive.

The next effect on modern food retail output is the price elasticity of modern food retail output. As expected with normal goods, this price elasticity of supply is positive, with a magnitude near 1, based on observation of changes in the table below.

The last effect on modern food retail output is the price of the intermediate commercial farm input. The expected sign of this elasticity is negative. In the model output, the price of commercial farm inputs is set at unity, and thus is unchanging, cancelling any elasticity effect.

The summation of these three remaining effects accounts for the change in modern food retail output. The cumulative wage and cost of capital effects, along with the elasticity of supply, provide the elasticity story. For modern food retail, the wage elasticity effect turns out to be negative and weak in magnitude. The cost of capital elasticity effect is positive with a magnitude weaker than that of the wage effect since the sector is labor intensive. The elasticity of supply effect is positive with a magnitude near 1. The conclusion, then, is that the smallholder farm price and services price effects, working through wage and cost of capital effects, and the supply elasticity effect, have offsetting negative and positive effects on modern food retail output. The net effect is uncertain without more information. According to the data in the table below, the growth rate of modern food retail output slows down considerably at a diminishing rate.

Table 9.3: Growth in Modern Food Retail Output and Factor Contributions

		Contributions to Growth	
Year	Growth in Output	Value Added Price	Price of Service Goods
1980	0.0024	0.0462	(0.0437)
1985	0.0023	0.0424	(0.0401)
1990	0.0021	0.0388	(0.0367)
1995	0.0020	0.0355	(0.0335)
2000	0.0018	0.0324	(0.0306)
2005	0.0017	0.0296	(0.0279)
2010	0.0015	0.0269	(0.0254)
2015	0.0014	0.0245	(0.0231)
2020	0.0013	0.0223	(0.0210)
2025	0.0012	0.0202	(0.0190)
2030	0.0011	0.0184	(0.0173)
2035	0.0010	0.0167	(0.0157)
2040	0.0009	0.0151	(0.0142)
2045	0.0008	0.0137	(0.0129)
2050	0.0008	0.0124	(0.0117)
2055	0.0007	0.0113	(0.0106)

9.1.4 Traditional Food Retail Sector Elasticity

Growth in traditional food retail output can be decomposed into wage and capital cost components, which in turn can be broken down into price effects. The model results do not include the price of smallholder agricultures effect on growth in traditional food retail output. However, as described in the Stopler-Samuelson section above, the elasticity of wages with respect to the smallholder farm-gate price is positive with a large magnitude. Model results tell us that smallholder prices increase through the forecast period. Thus, the combined effect of elasticity and the smallholder farm price change on wages is positive and large.

$$y_d = y_d[p_d, W(p_s, p_h), R(p_s.p_h), y_h(p_h)] \tag{29}$$

The other effect of smallholder farm prices on traditional food retail output growth runs through cost of capital effects. As described in the Stopler-Samuelson section above, the elasticity of cost of capital with respect to the smallholder farm price is negative with a small magnitude. Model results tell us that smallholder prices increase through the forecast period. Thus, the combined effect of elasticity and the smallholder farm price change on the cost of capital is negative and small.

In addition to smallholder farm prices, the price of services also affects growth in traditional food retail output through associated wage and capital cost components. From the table 9.4 below, the price of services contributes negative, but diminishing effects to growth in traditional food retail output. As described in the Stopler-Samuelson section above, the elasticity of wages with respect to the price of services is positive with a large magnitude. Model results tell us that the price of services also increases through the forecast period. Thus, the combined effect of elasticity and the change in the price of services on wages is positive and large.

The other effect of the price of services on traditional food retail output growth runs through cost of capital effects. As described in the Stopler-Samuelson section above, the elasticity of cost of capital with respect to the price of services is negative with a small magnitude. Model results tell us that the price of services increases through the forecast period. Thus, the combined effect of elasticity and the change in the price of services on the cost of capital is negative, but small.

Smallholder farming prices and the price of services interact with wage and cost of capital effects to influence traditional food retail output. Starting with the elasticity of traditional food retail output with respect to wages, recall from the theoretical discussion of elasticity that since traditional food retail is labor intensive, the negative effects of higher labor costs will outweigh the positive, but weak effects of lower capital costs. Accordingly, the elasticity of traditional food retail output with respect to wages is negative, with an unknown magnitude. Thus, when we combine the elasticity of traditional food output with respect to wages with the two positive price effects discussed previously, the overall labor cost effect on traditional food retail output becomes negative. Though difficult to judge, the magnitude of this negative effect is likely to be larger than that of the modern food retail sector since traditional food retail is more labor intensive.

We now consider the second effect, the elasticity of modern food retail output with respect to the cost of capital. From the theoretical discussion of elasticity, since traditional food retail is labor intensive, the benefit of capital deepening, a lower cost of capital, is weak. Accordingly, the elasticity of traditional food retail output with respect to the cost of capital is negative and small. Thus, when we combine the elasticity of traditional food retail output with respect to the cost of capital with the two negative price effects discussed previously, the overall cost of capital effect on traditional food retail output becomes positive. Though difficult to judge, the magnitude of this positive effect is likely to be small since traditional food retail is labor intensive.

The next effect on traditional food retail output is the price elasticity of traditional food retail output. As expected with normal goods, this price elasticity of supply is positive, with a magnitude near 1, based on observation of changes in the table below.

The last effect on traditional food retail output is the price of the intermediate smallholder farm input. The expected sign of this elasticity is negative and the magnitude close to one since it is such a large share traditional retail food cost.

The summation of these four effects accounts for the change in traditional food retail output. The cumulative wage and cost of capital effects, along with the elasticity of supply and the elasticity with respect to smallholder input prices, provide the elasticity story. For traditional food retail, the wage elasticity effect turns out to be negative and weak in magnitude. The cost of capital elasticity effect is positive with a magnitude weaker than that of the wage effect since the sector is labor intensive. The elasticity of supply effect is positive with a magnitude near one. The elasticity of smallholder input price is negative. The conclusion, then, is that the smallholder farm price and services price effects, working through wage and cost of capital effects, and the supply elasticity effect, have an overall negative effect on traditional food retail output, based on the available data. According to the data in table 9.4 below, the growth rate of traditional food retail output slows down considerably at a diminishing rate.

Table 9.4: Growth in Traditional Food Retail Output and Factor Contributions

	Contributions to Growth		
Year	Growth in Output	Value Added Price	Price of Service Goods
1980	0.0013	0.0507	(0.0494)
1985	0.0012	0.0453	(0.0441)
1990	0.0011	0.0405	(0.0394)
1995	0.0010	0.0363	(0.0353)
2000	0.0009	0.0325	(0.0316)
2005	0.0008	0.0291	(0.0284)
2010	0.0007	0.0261	(0.0254)
2015	0.0006	0.0235	(0.0228)
2020	0.0006	0.0211	(0.0205)
2025	0.0005	0.0190	(0.0185)
2030	0.0005	0.0171	(0.0166)
2035	0.0004	0.0154	(0.0149)
2040	0.0004	0.0138	(0.0134)
2045	0.0004	0.0125	(0.0121)
2050	0.0003	0.0112	(0.0109)
2055	0.0003	0.0101	(0.0098)

9.1.5 Industrial Sector Elasticity

Growth in industrial output can be decomposed into wage and capital cost components, which in turn can be broken down into price effects. From table 9.5 below, the price of smallholder agriculture contributes positive, but small and diminishing, effects to growth in industrial output. As described in the Stopler-Samuelson section above, the elasticity of wages with respect to the smallholder farm-gate price is positive with a large magnitude. Model results tell us that smallholder prices increase through the forecast period. Thus, the combined effect of elasticity and the smallholder farm price change on wages is positive, but small.

$$y_m = y_m[p_m, W(p_s, p_h), R(p_s.p_h)] \tag{30}$$

The other effect of smallholder farm prices on industrial output growth runs through cost of capital effects. As described in the Stopler-Samuelson section above, the elasticity of cost of capital with respect to the smallholder farm price is negative with a small magnitude. Model results tell us that smallholder prices increase through the forecast period. Thus, the combined effect of elasticity and the smallholder farm price change on the cost of capital is negative but small.

In addition to smallholder farm prices, the price of services also affects growth in industrial output through associated wage and capital cost components. The price of services contributes negative, but diminishing effects to growth in industrial output. As described in the Stopler-Samuelson section above, the elasticity of wages with respect to the price of services is positive with a large magnitude. Model results tell us that the price of services also increases through the forecast period. Thus, the combined effect of elasticity and the change in the price of services on wages is positive and large.

The other effect of the price of services on industrial output growth runs through cost of capital effects. As described in the Stopler-Samuelson section above, the elasticity of cost of capital with respect to the price of services is negative with a small magnitude. Model results tell us that the price of services increases through the forecast period. Thus, the combined effect of elasticity and the change in the price of services on the cost of capital is negative, but small.

Smallholder farming prices and the price of services interact with wage and cost of capital effects to influence industrial output. Starting with the elasticity of industrial output with respect to wages, recall from the theoretical discussion of elasticity that since industry is capital intensive, the positive effects of lower capital costs will outweigh the small, but negative effects of higher labor costs. Accordingly, the elasticity of industrial output with respect to wages is negative, but small. Thus, when we combine the elasticity of industrial output with respect to wages with the two positive price effects discussed previously, the overall labor cost effect on industrial output becomes negative. Though difficult to judge, the magnitude of this negative effect is likely to be small since industry is capital intensive.

We now consider the second effect, the elasticity of industrial output with respect to the cost of capital. From the theoretical discussion of elasticity, since industry is capital intensive, one of the benefits of capital deepening is a lower cost of capital. Accordingly, the elasticity of industrial output with respect to the cost of capital is negative and large. Thus, when we combine the elasticity of industrial output with respect to the cost of capital with the two negative price effects discussed previously, the overall cost of capital effect on industry output becomes positive. Though difficult to judge, the magnitude of this negative effect is likely to be large since industry is capital intensive.

The last effect on industrial output is the price elasticity of industrial output. As expected with normal goods, this price elasticity of supply is positive, with an unknown magnitude. Since industrial output is traded on the world market, we assign it, as the numeraire, the price of unity. Thus, in the Zambia growth model, industry sector prices do not change, and the combined effect of price elasticity of supply is zero.

The summation of these three effects accounts for the change in industrial output. Since price elasticity of supply has no effect, the cumulative wage and cost of capital effects provide the elasticity story. For industry, the wage elasticity effect turns out to be negative and weak in magnitude. The cost of capital elasticity effect is positive with a magnitude stronger than that of the wage effect since the sector is capital intensive. The conclusion, then, is that the smallholder farm price and services price effects, working through wage and cost of capital effects, have an overall positive effect on industrial output. According to the data in the table below, the growth rate of industrial output slows down slightly at a diminishing rate. Perhaps the magnitude of change is not as strong as the analysis suggests. Nonetheless, this analysis provides useful insights into the dynamics of industry through the theoretical and data linkages described here.

In table 9.5 below are additional contributions to growth–capital stock and effective labor. The sign of these factors reflect the effects of capital deepening on the industrial sector. With the cost of capital falling and capital stock growing, industrial output experiences a positive contribution. On the other hand, wages increase, cutting into profitability and thus growth to a limited degree.

In summary, this analysis of elasticity shows that capital deepening generates various

Table 9.5: Growth in Industrial Output and Factor Contributions

		Contributions to Growth			
Year	Growth in Output	Price of Smallh Agric	Price of Service Goods	Capital Stock	Effective Labor
1980	0.0387	0.0069	(0.0256)	0.0777	(0.0203)
1985	0.0367	0.0061	(0.0226)	0.0733	(0.0200)
1990	0.0351	0.0053	(0.0200)	0.0695	(0.0197)
1995	0.0337	0.0047	(0.0178)	0.0663	(0.0194)
2000	0.0325	0.0041	(0.0159)	0.0635	(0.0192)
2005	0.0315	0.0036	(0.0141)	0.0610	(0.0191)
2010	0.0306	0.0032	(0.0126)	0.0589	(0.0189)
2015	0.0298	0.0029	(0.0113)	0.0570	(0.0188)
2020	0.0291	0.0026	(0.0101)	0.0554	(0.0187)
2025	0.0285	0.0023	(0.0091)	0.0539	(0.0187)
2030	0.0279	0.0020	(0.0081)	0.0526	(0.0186)
2035	0.0275	0.0018	(0.0073)	0.0515	(0.0185)
2040	0.0270	0.0016	(0.0066)	0.0505	(0.0185)
2045	0.0266	0.0015	(0.0059)	0.0495	(0.0185)
2050	0.0263	0.0013	(0.0053)	0.0487	(0.0184)
2055	0.0260	0.0012	(0.0048)	0.0480	(0.0184)

kinds of effects on Zambia's sectors, according to their degree of capital intensity. These effects are more pronounced when a sector's value-added is a relatively high share of total cost, as in the case of the industrial and commercial farming sectors. The negative effects of capital deepening are illustrated in the smallholder farming sector, where higher labor costs hurt output, even in the face of other positive effects. Other effects, such as the elasticity of output with respect to price and the elasticity of output with respect to intermediate inputs, may dominate other effects, as in the case of the retail food sectors.

9.2 Validation of the Baseline Model

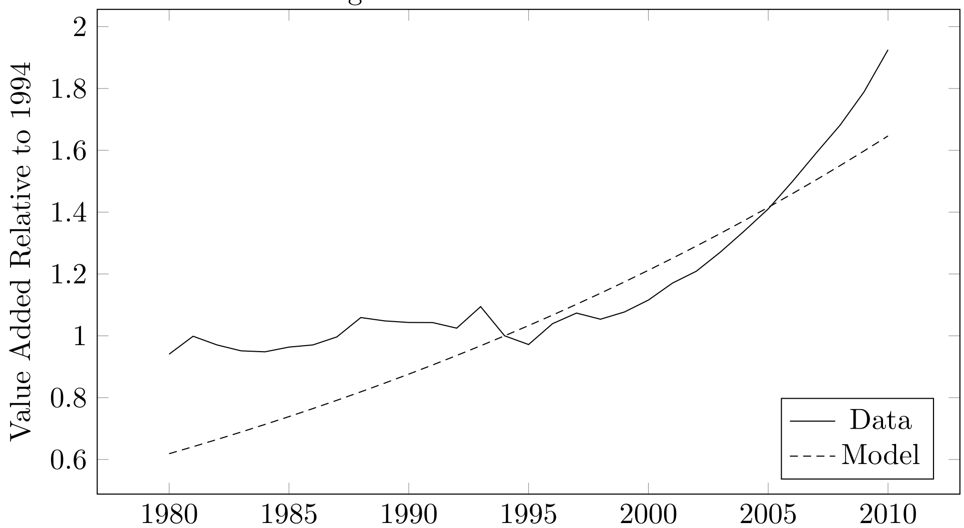
Comparison of the Zambia growth model's projected results against historical data validates the effectiveness of the model. The model's replication of recent historical economic activity gives us the confidence to conclude that it is useful for the study of the effects of various economic policies and conditions into the future. We validate the growth model over six selected variables: Zambia GDP, capital stock, workforce, industrial value added, total agricultural value added, and total services value added, including the two food retail sectors.

Direct comparison of projected trends with data sometimes reveals gaps that are difficult to interpret due to differences in scale. While general trends may be discerned, normalization to a selected base year may reveal more insights into the predictive power of the model. In the case of Zambia, the validation exercise is normalized to the year 1994, the fifteenth year in the data series. The advantage of normalizing to 1994 is that this is the year before economic reforms were effectively implemented in the economy. Going forward from 1994, we observe how effectively the model validates the new policy environment, especially since the subsequent years represent accelerating growth coming out of the reforms.

In figure 9.1, validation shows that Zambian GDP tracks sideways in the late 1990's before taking off in the 2000's. The main reason for this sluggishness is that, in the late 1990's, the copper mining industry was still suffering due to low prices and a lingering lack of capital investment. Once commodity prices began to recover, GDP picked up and exceeded the projected growth path starting in 2005.

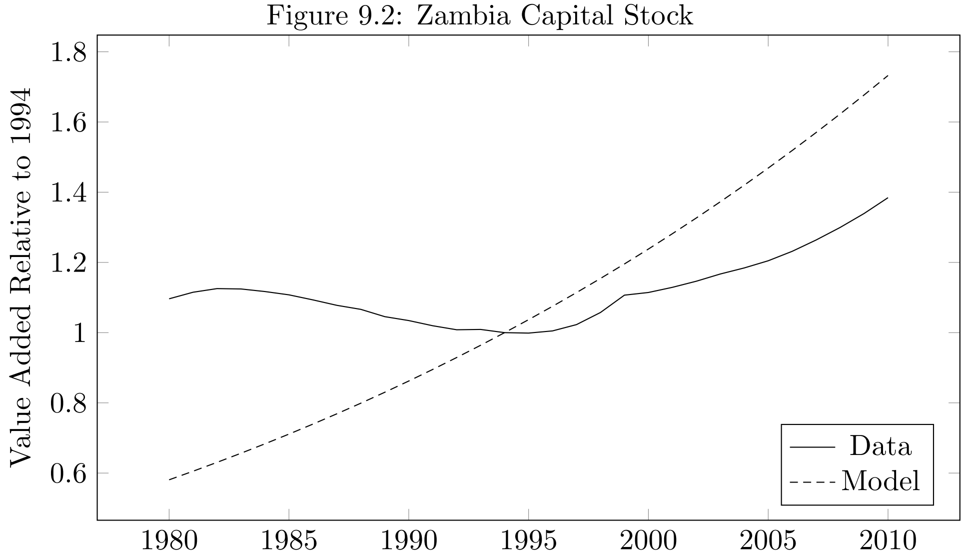
In figure 9.2, projections of capital stock compared to historical data show the significance of copper mining to the Zambian economy. Years of low copper prices and a lack of capital equipment maintenance took a toll on capital stock, with levels finally making post-1980 highs around 2004. The relatively flat levels of capital stock finally begin to follow the projected growth rates by 2008. It is evident that capital stock changes slowly and with

Figure 9.1: Zambia GDP



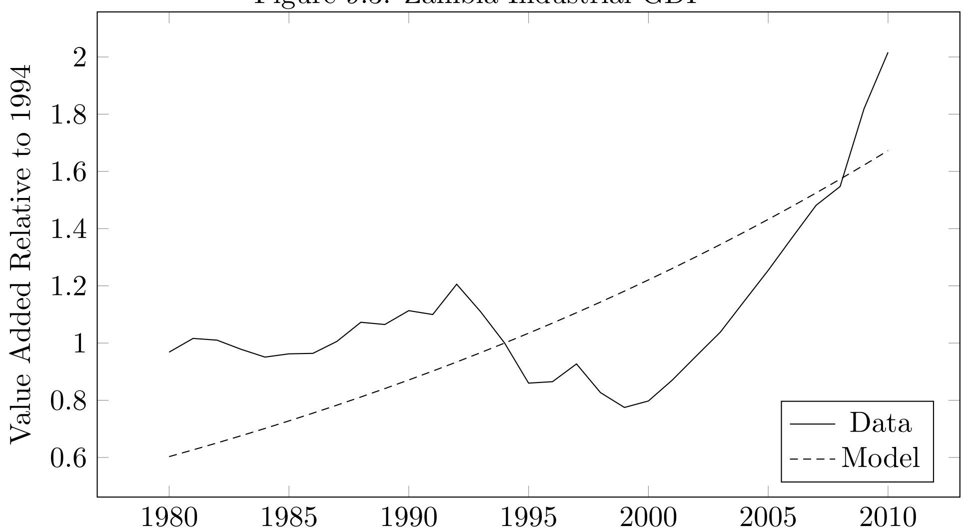
a lag in response to changing prospects for the economy.

Figure 9.2: Zambia Capital Stock



As shown in figure 9.3, validation of normalized industrial value-added reveals that the modeled trend roughly follows the data with all its variation due to the nature of the base metal business. The sector finally hits bottom in 1999 and rides the incipient bull market after two decades of slightly falling output. Industrial value added breaks above the projected growth trend by 2008, reflecting improved economic fundamentals, especially for the copper mining industry.

Figure 9.3: Zambia Industrial GDP



For the purpose of validation, the commercial and smallholder agricultural sectors are combined and compared with aggregate agricultural data. In figure 9.4, the modeled trend follows the historical data relatively well throughout the period. The data trends slightly above the forecast trend for except for a sharp fall in 1992 and modest decline starting in 2007. In contrast to industry, agricultural value added is experiences shorter durations of falling production mainly due to weather-related shocks.

In figure 9.5, services value added, which includes both food retail sectors, shows a slight decline in the first fifteen years of data, before the implementation of economic reforms. However, post reform growth in services is remarkably strong. The forecast slowly converges from below with pre-reforms growth and then undershoots growth in services from 1995. Since the data includes all of services, it is not an exact representation of the food retail sectors.

The forecasted workforce trend, also normalized to 1994, closely follows the data in figure 9.6. A slight rise around 2000 may be due to the resumption of copper mining operations when new capital was invested in the industry.

The validation exercise requires us to rank the six different variables, GDP, labor, capital stock, industry, agriculture, and services, in terms of significance to the success of the model. For the Zambia growth model, the most important measure of validation is agriculture, and then GDP, and capital stock. While the modeled projections do not perfectly match the

Figure 9.4: Zambia Agrcultural GDP

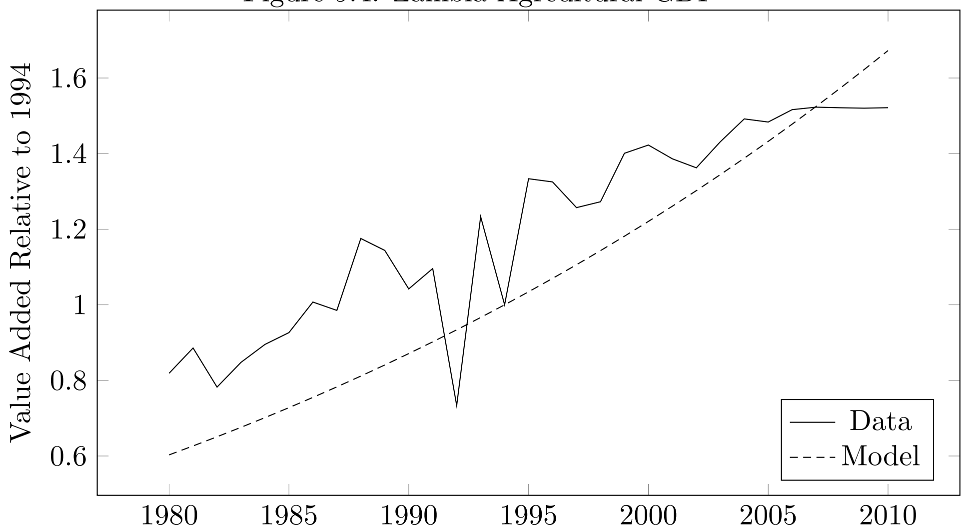
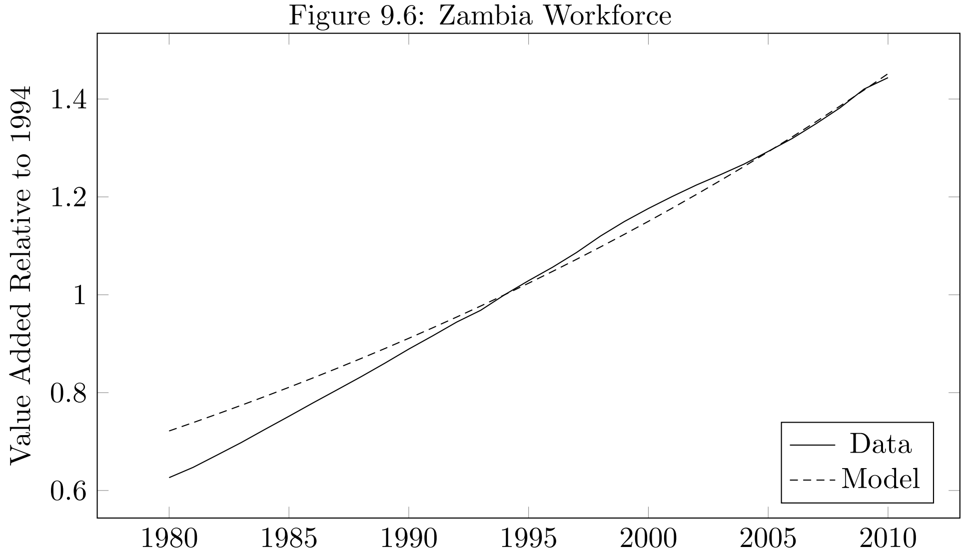


Figure 9.5: Zambia Total Services and Food Retail GDP

historical data, they do provide a sufficient level of confidence for using the model to explore various scenarios.

Figure 9.6: Zambia Workforce



10 Policy Experiments

10.1 Introduction

The baseline scenario tells the story of Zambia's multi-sector growth path. At the farm level, smallholder farming remains distinct from commercial farming. Smallholder land title is not easily transferred to freehold status. Further down the marketing channel, cross-channel marketing is not possible in the modeled framework. These two areas of concern include the focus of many micro-econonomic studies of Zambian smallholder agriculture. The following two sections explore the effects of loosening these constraints.

10.2 Agricultural Land Market Integration

The purpose of this analysis is to evaluate returns to smallholder farmers from changes in the size of the smallholder and commercial farmland areas. The baseline model structures two separate land markets in which title transfers are very difficult to complete in terms of time and expenditure for smallholder farmers. Effectively, the two land markets are not integrated. This separation reduces the opportunity for asset allocation for smallholders. Since only freehold land can be mortgaged, smallholders holding customary title have greater difficulty accessing credit facilities.

The analysis uses a one period adjustment to agricultural land market shares occurring in the beginning year, 1980. The model is subsequently solved going forward into future years. A comparison of results against the baseline model indicates how farming output and profits change with various degrees of market integration.

This exercise simulates the transfer of traditional lands to freehold title. The effect of this transfer is to reallocate a portion of smallholder land to the commercial farming sector. This reallocation does not imply that smallholders lose control or possession of their land. Rather, smallholders retain ownership and rights to profits, but now operate with commercial farming technologies and access to modern food retail markets.

The magnitude of adjustment for this land integration analysis is based on historical estimates. In order to better understand the long-term impact of changes in land shares, we increase the magnitude of the simulated changes in land area, finding that the trends are similar to those of smaller magnitudes in line with historical estimates. Thus, we settle on a 25% change in smallholder land area.

Among other measures of profit, farm profit per hectare provides insight into the productivity of farmland. Determining farm area is more difficult for Zambia due to data limitations. Type of land title can give an idea of the relative size of the farming sectors. By this measure, 93% of land is customary title and 7% is freehold title. However, Siegel (2008) finds that only about half of the freehold titled land is used in agriculture. Table 10.1 describes Zambia's usage of land.

Table 10.1: Zambia Land Use Summary, 1994

	Hectares	
Surface Area	75,261,000	
Land Area	74,339,000	
Agricultural Area	21,473,000	
Arable Land and Permanent Crops	2,873,000	
Arable / Agricultural Land	0.1338	
Arable / Land Area	0.0386	
Land by Title	Hectares	
Land with Title Deeds	3,700,000	
Traditional Lands	47,900,000	
Total	51,600,000	
Share based on Title	Share	
Traditional (customary title) Land Share	0.928	
Freehold title land share (non farming land)	0.036	
Freehold title - commercial farming share	0.036	
source: Seigel (2005)		
Allocation of Arable Land	Hectares	Share
Traditional Farm Share of Arable Land	2,666,990	0.963
Commercial Farm Share of Arable Land (about 0.036)	103,005	0.037
Total Arable Land	2,769,995	1.000
source: WDI		

Although Zambia's agricultural area, which includes arable land and pastures, is 21.4 million hectares, only 2.9 million ha. is arable land, about 13%. Additionally, although 47.9 million ha are classified as traditional lands, only 2.9 million is arable. Based on title, 92.8% is customary land and only 3.6% is freehold commercial farmland. Allocation of arable land according to the above shares implies that traditional farms account for 2,666,990 ha. and commercial farms 103,005 ha.

Siegel (2008) uses survey data to create a distribution of farms by size categories. Small-scale producers are the most numerous at about 800,000. Their average farm size is just over 3 ha. Emergent farmers average about 12.5 ha. Large-scale commercial and corporate farms make up the commercial farm sector, which is very small in terms of number of operations and total area. Aggregated totals give an average smallholder farm size of 3.58 ha, constituting a 0.957 share of arable land, 3,041,995 ha. The commercial farm share is 0.0431 representing 137,005 ha. The profit per hectare equation uses these totals.

From the baseline model, per hectare profits for commercial farms are 153,155 ZKW in 1995, about 5.9 times as great as smallholder per hectare profits. By the 55th period, in 2035, commercial farm per hectare profit rises to 329,376 ZKW and the ratio falls to about 4.1. Over time, per hectare profits continue to increase with smallholder farms slowly approaching commercial farm profits.

10.2.1 Conversion of 25% of Smallholder Farmland to Commercial Farms

This analysis, which represents a one-time shift in the distribution of farmland between customary and freehold tenure, compares the alternative scenario to the baseline as a normalized departure from the baseline in percent terms. Because this shift is a one-time event, model results generally show immediate adjustments followed by convergence toward the long-term baseline values. Moreover, since the following charts show the difference between the analysis and baseline, it is not apparent which statistic is changing. Movement of the difference is relative to the state of the two measures.

The conversion of 25% of existing smallholder, customary tenure agricultural land (about 760,499 ha) to commercial, freehold title status, amounts to a 282.7% increase in commercial land area. The essence of this conversion is the reclassification of 25% of smallholder lands to the commercial farming sector. Smallholders retain ownership of this land and continue to earn profits and land rents from it. Significantly, this newly converted land now employs more capital-intensive production technologies. The output of this land may now be marketed to modern retail food channels or exported. The objective is to observe the impact of such a conversion on the structure of the economy and thus understand the benefits of land market integration. Although the decline in customary land is 25%, the percentage increase in freehold title land is more than eleven times greater because the commercial farming sector is proportionately much smaller. The conversion of land tenure also adjusts the share of technology between customary and freehold lands, which in turn affects the productivity of land. However, land share is the only factor adjusted in this exogenous fashion. The model adjusts complementary supplies of labor and capital

Table 10.2: Distribution of Farm Area in Zambia

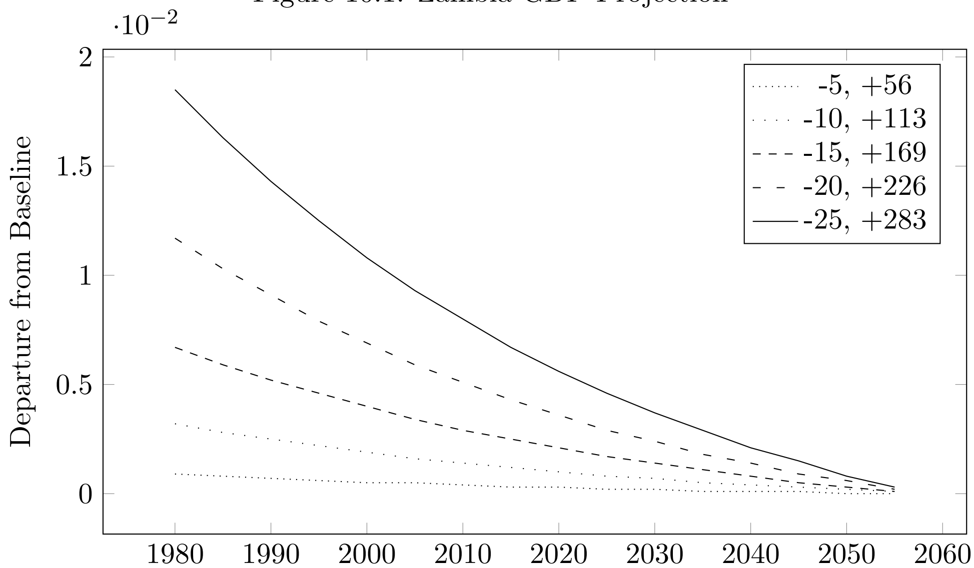
	Approximate N. of Producers	Approximate Farm Size (ha)	Total Area (ha)	Share of Area
Small-scale producers	800,000	3.05	2,440,000	0.737
Emergent Farmers	50,000	12.50	625,000	0.189
Large-scale Commercial Farms	700	100.00	70,000	0.021
Large corporate operations	22	8,000.00	176,000	0.053
Total	850,722		3,311,000	1.000
Aggregated Totals (adjusted to agree with title deed estimate)				
Smallholder Farms	850,000	3.58	3,041,995	0.919
Commercial Farms			269,005	0.081
Total Farm Area			3,311,000	1.000

source: Seigel (2005)

through the factor market equations. In the following charts, the orange line represents this simulation. The (25) means a 25% decrease in customary tenure land and the 283 means a corresponding 283% increase in freehold tenure farmland.

Starting with economy-wide effects, we observe that Zambian GDP initially increases by about 1.8% compared to the baseline. This effect dissipates overtime as simulation model converges with the steady state.

Figure 10.1: Zambia GDP Projection



In the five figures below(figures 10.1, 10.2, 10.3, 10.4, and 10.5), decomposition of GDP into income by source reveals that labor and smallholder farms capture most of this increase while capital rents fall. Commercial farm income also rises just over 200% on a 283% increase in land area. Commercial farm profit shows persistence in contrast to smallholder profit. With reduced land area, smallholder income actually increases at a rate of about 2.2% due to a combination of higher prices received and more productivity. As we will see later, capital rents fall mainly from a related fall in industrial production.

A decomposition of GDP by expenditure shows that the representative household spends a larger share of income on food of both types, and services, while industrial goods and savings shares fall. The reason for rising food expenditures is specific to the sector. In the case of traditional food, the positive variance from baseline of about 0.55% is due to higher prices in an inelastic demand environment (see figure 10.6). Alternatively, the 0.7% increase in modern food expenditures is attributed to higher production volumes in figure

Figure 10.2: GDP by Income: Capital Rent

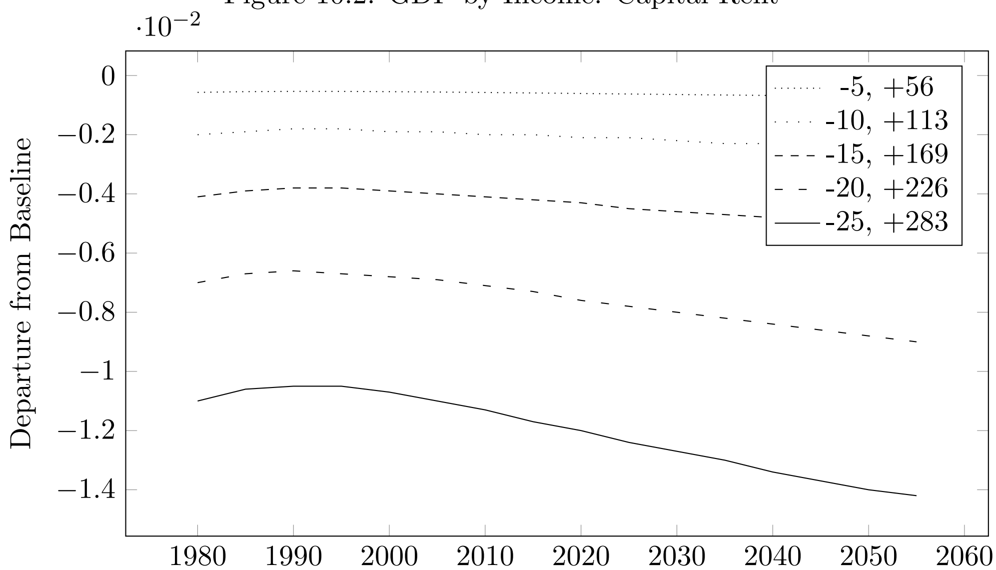
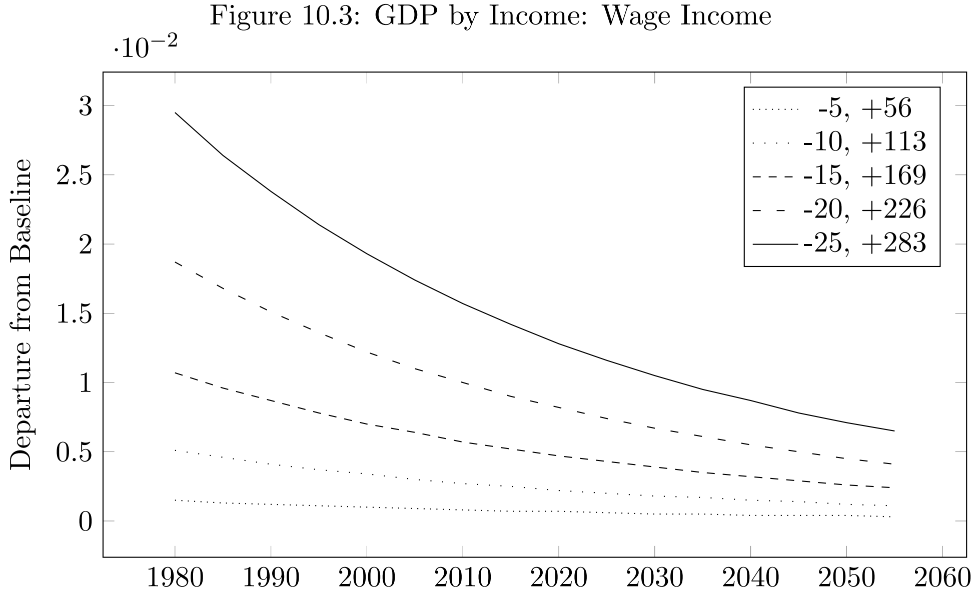


Figure 10.3: GDP by Income: Wage Income



10.7. Service expenditures also increase, perhaps due to a lower price of labor resulting from falling smallholder output (see figure 10.9).

Industrial goods, however, register the largest change in expenditures in figure 10.8. Specifically, in the modeled economy, international trade in industrial goods and the commercial farm intermediate good must balance. In this analysis, commercial farm production

Figure 10.4: GDP by Income: Smallholder Farm Profit

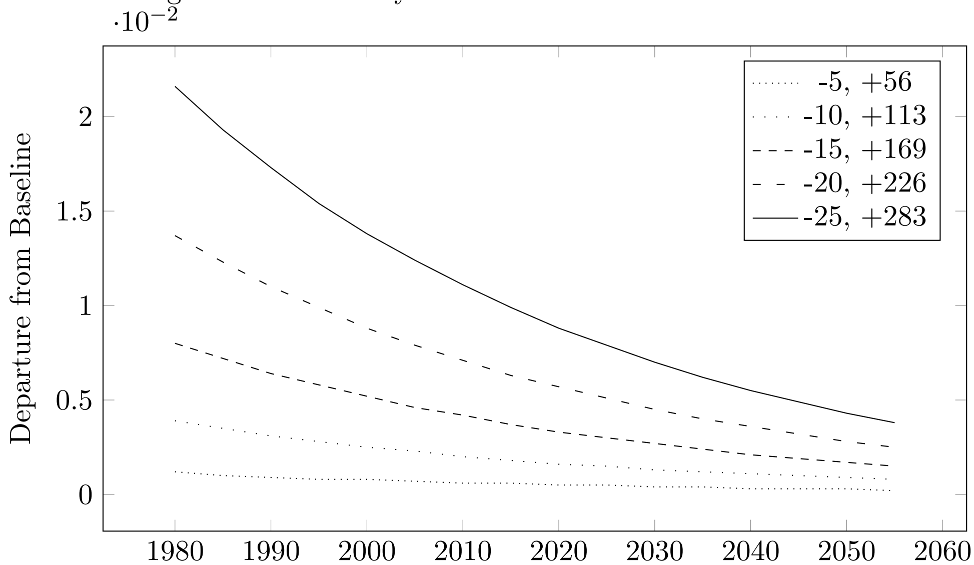
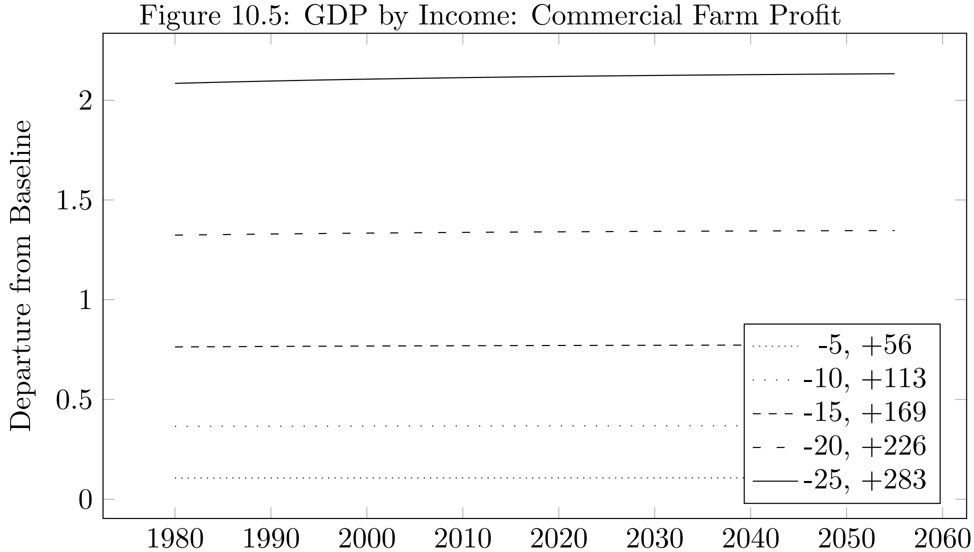


Figure 10.5: GDP by Income: Commercial Farm Profit



increases with the surplus exported to the rest of the world. This expansion of commercial farm exports, by definition, calls for an offsetting increase in industrial good imports. At the same time, consumption of industrial final goods rises against the baseline. Together, these effects make excess demand for industrial goods even more negative. Moreover, savings expenditures also fall in figure 10.10, but with increasing magnitudes. By the time the half-life to the steady state is reached, saving expenditures are running about 1.4% below the baseline. The expenditure story suggests that households compensate for increased expenditures for food and industrial goods by trimming back on residual savings while depending on increased imports to satisfy their industrial demands.

Figure 10.6: GDP by Expenditure: Traditional Food

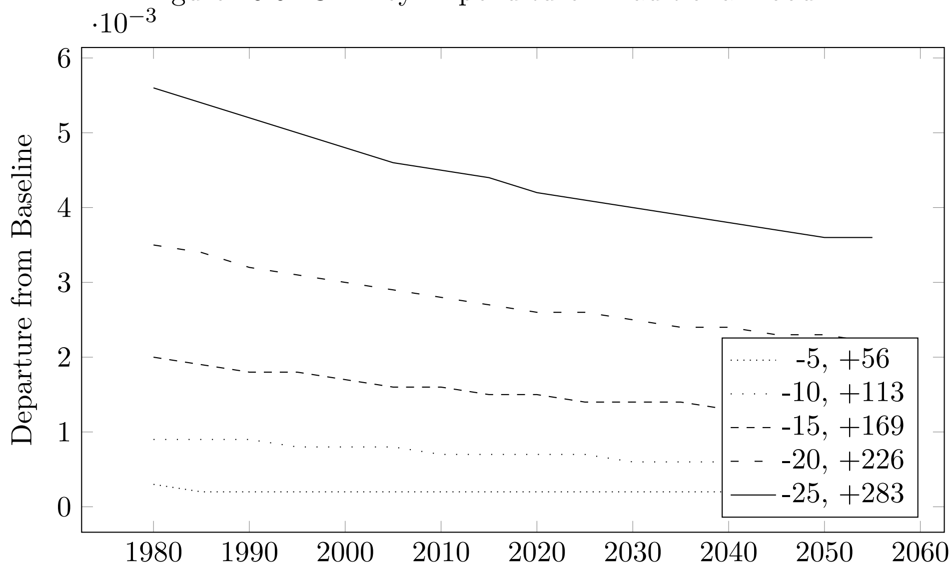


Figure 10.7: GDP by Expenditure: Modern Food

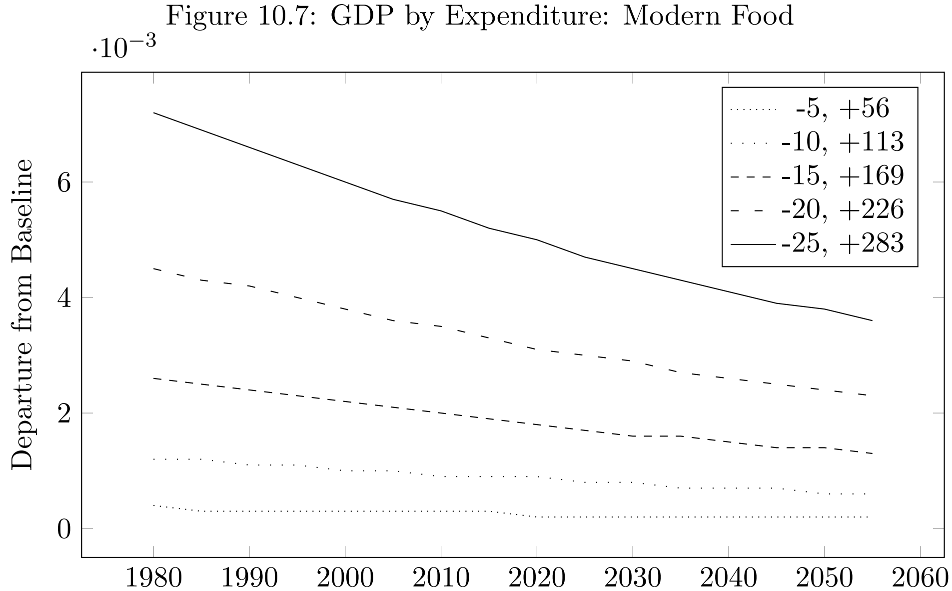


Figure 10.8: GDP by Expenditure: Industrial Goods

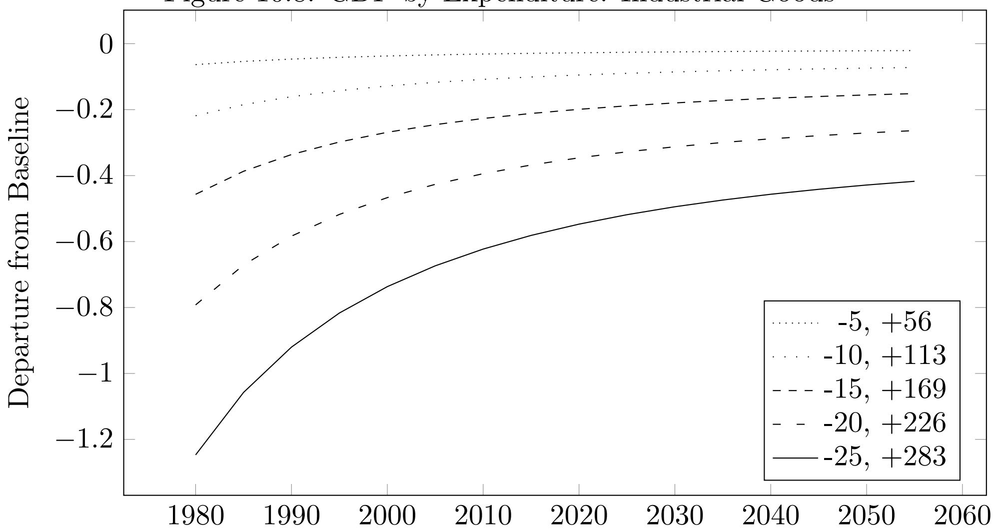
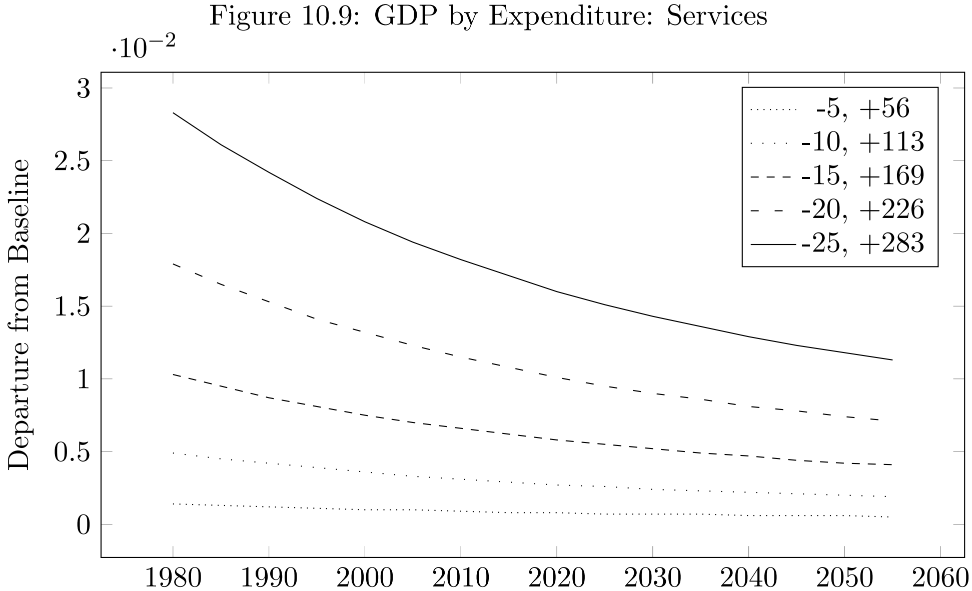
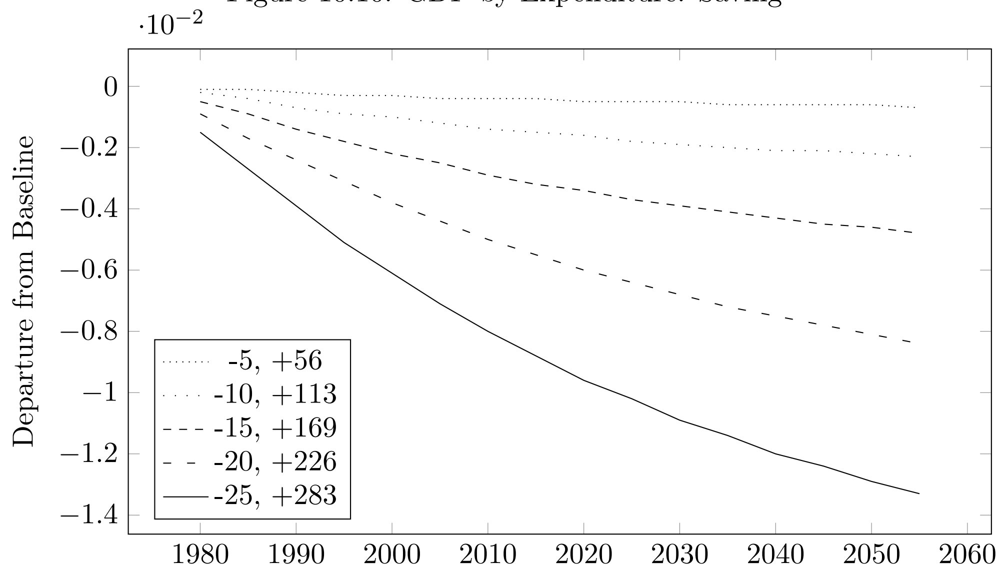


Figure 10.9: GDP by Expenditure: Services



In figure 10.11, the drop in the ratio of savings to GDP per worker, which measures the rate of savings flows, confirms the change in expenditures. The ratio initially falls 2.0% from the baseline, indicating that the rate of saving relative to GDP drops slightly. In addition, the decrease in the savings/GDP ratio appears to only slowly revert to the long-run growth, baseline growth path.

Figure 10.10: GDP by Expenditure: Saving



In contrast to the savings/GDP per worker ratio, the capital/GDP per worker index (see figure 10.12) continues to rise at a sustaining rate, reflecting the increased deployment of capital in the farming sectors. This index measures the stock of capital to GDP per worker, and as such, continues to register a slight increase even as the flow of savings eases up a little. The increase, though, only shows a 0.6% increase from the baseline at the half-life to the steady-state. Although industrial production falls, commercial farming manages to use more capital, thus generating a slight net increase in the ratio.

In figure 10.13, the alternative model predicts that prices will increase against the baseline with an initial jump of 0.9%, reflecting the increased demand for resources resulting from the simulated transfer of land. The details by sector reveal that all prices increase against the numeraire, industrial goods.

In response to the transfer of farmland, the cost of labor rises almost 3.0% and the return to capital falls about 1.1%, relative to the baseline (see figure 10.14). This result implies that the marginal productivity of labor in Zambia increases. The reduction in smallholder farmland has a proportionately smaller effect on its labor force. In addition, the shrinking industrial sector has a relatively small effect on the labor market. Although commercial farming output grows, the effect on labor is relatively small because its technology is more capital intensive than smallholder farming. The largest positive factor for labor demand appears to originate in the growth of the labor-intensive services sector.

Figure 10.11: Ratio of Savings to GDP

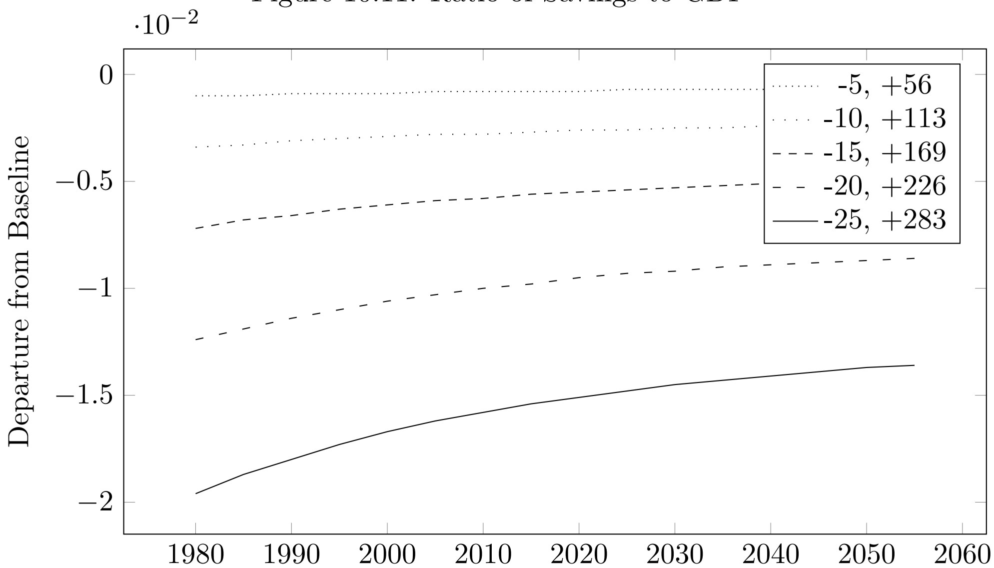
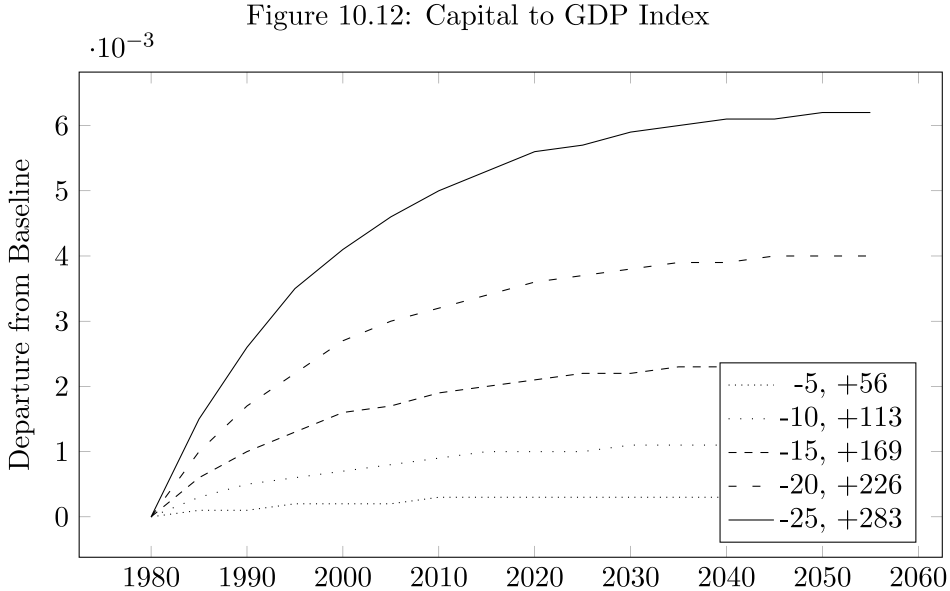


Figure 10.12: Capital to GDP Index



It is interesting to note that the rise in labor cost is more than double the fall in the cost of capital, suggesting that labor faces a greater shock than capital (see figure 10.15). This contrast would imply that labor becomes relatively more scarce compared to capital.

Smallholder farm-gate prices initially jump 1.6% while commercial farm-gate prices rise only 0.44% (see figures 10.16 and 10.17). This variance may be explained by increased sup-

Figure 10.13: General Price Index

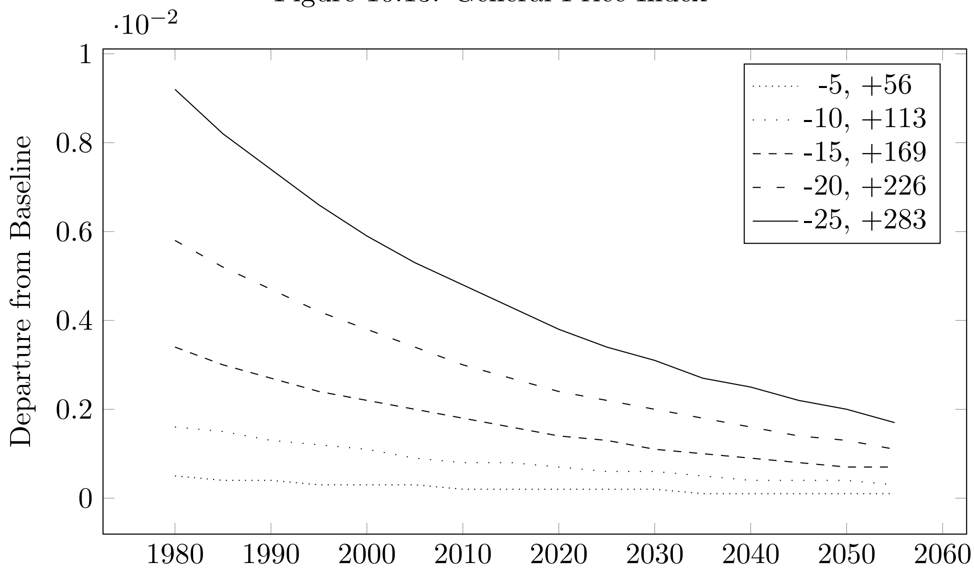
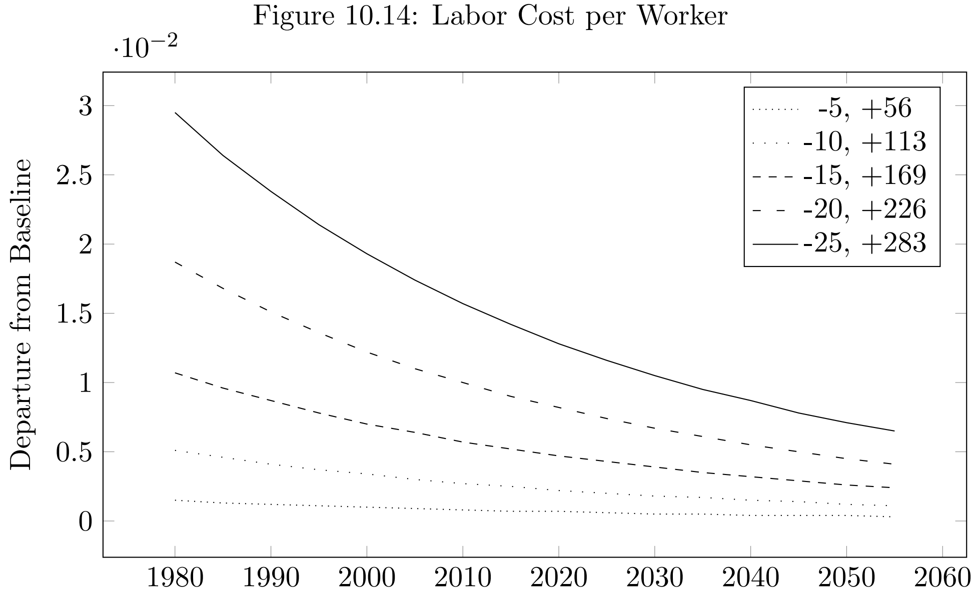
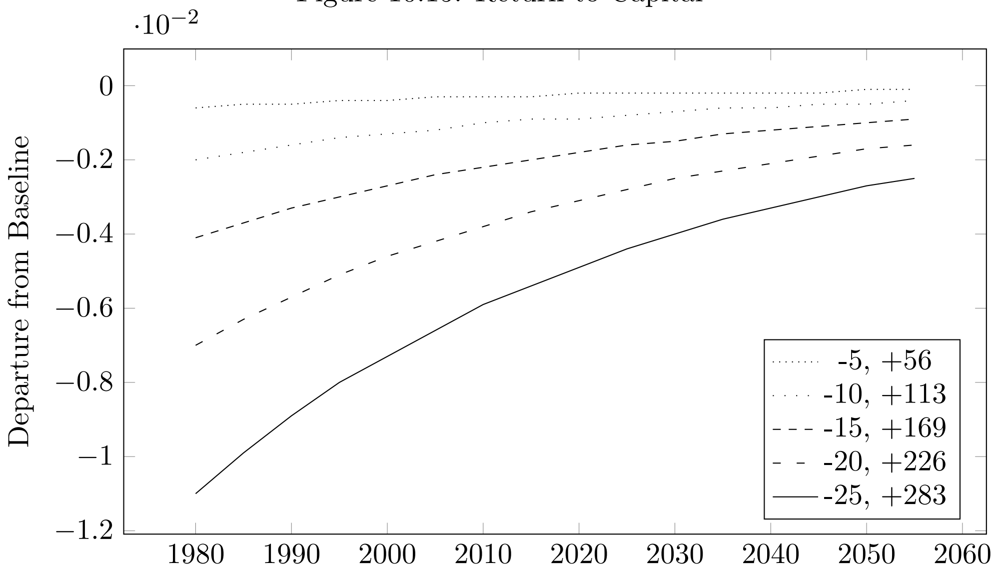


Figure 10.14: Labor Cost per Worker



plies due to more cultivated land. The question of why all prices rise may be approached by considering the influence of relative factor prices. The increase in land allows the commercial farming sector to expand, increasing complementary demand for capital and labor, while the smallholder sector releases more labor than capital. This increased demand for capital increases capital rental income to households and simultaneously raises the cost of

Figure 10.15: Return to Capital



capital, the intensive factor of industry. The new demand for capital also places pressure on the labor market, as the modern food retail channel can afford to pay higher wages. The result, a higher maket clearing wage, places pressure on the labor-intensive services sector, forcing it to raise prices to cover higher labor costs (see figure 10.20).

Traditional retail food prices also initially jump 1.6% while modern retail food only rises 0.44% in figures 10.18 and 10.19. This variance may be explained by increased supplies due to more cultivated land. Similarly, the traditional channel supply is now constrained, resulting in a higher price increase.

Simulated farm output rises for both sectors compared to the baseline in figure 10.21. Smallholder farm output unexpectedly rises a modest 1.3% against baseline results. With 25% less smallholder farm area, one would expect output to fall. This result suggests, as described below, that smallholders respond to the reduced land holdings and higher farm gate prices by shifting to more capital-intensive production.

Commercial farming output rises almost 3.0% above the baseline based on a 283% gain in land holdings (see figure 10.22). The weak response in commercial farm output reflects lands relatively small degree of factor productivity compared to labor and capital.

Supplies of final goods respond similarly to expenditures. Industrial supply suffers by falling 20.0%. Modern food, traditional food, and services register modest gains of about 0.71%, 0.55%, and 2.8%, respectively. Traditional retail supplies follow through from

Figure 10.16: Price of Smallholder Agr. Good (Traditional Retail Equivalent Price)

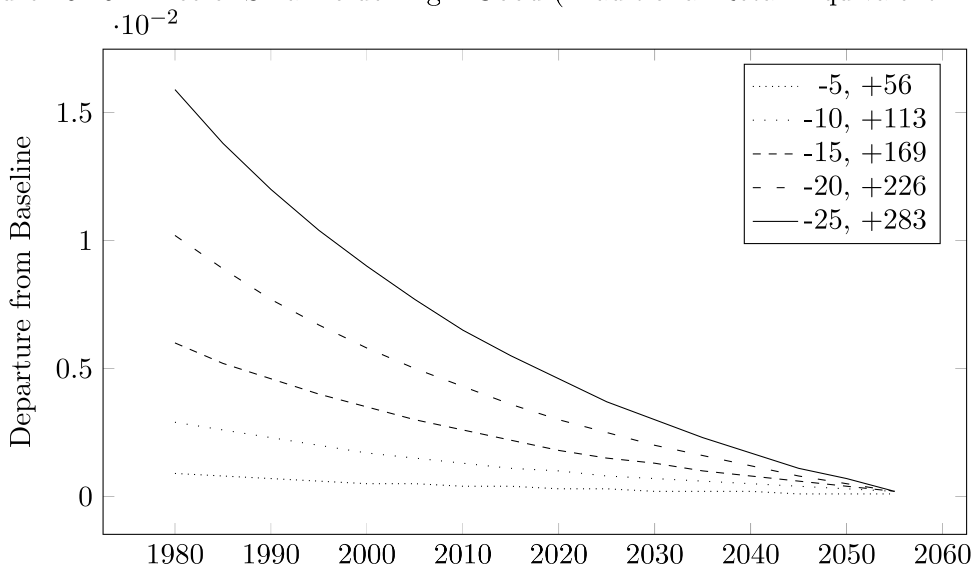
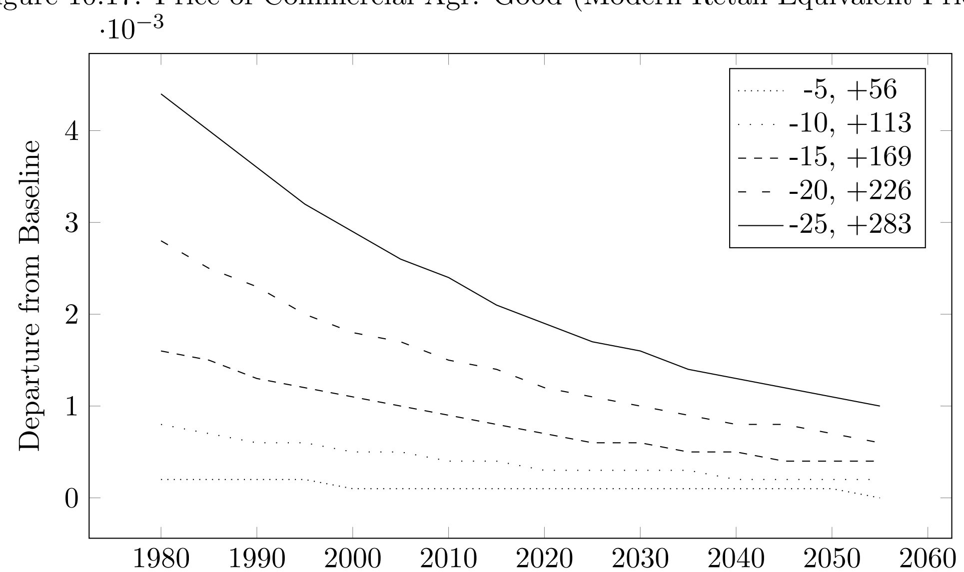


Figure 10.17: Price of Commercial Agr. Good (Modern Retail Equivalent Price)



increased productivity in the intermediate smallholder sector (see figures 10.23, 10.24, 10.25, and 10.26).

In figure 10.27, farm profit per hectare sums up the effects of transitioning a quarter of smallholder farmland to the commercial farming sector. Not surprisingly, smallholder

Figure 10.18: Price of Traditional Food Retail Final Good

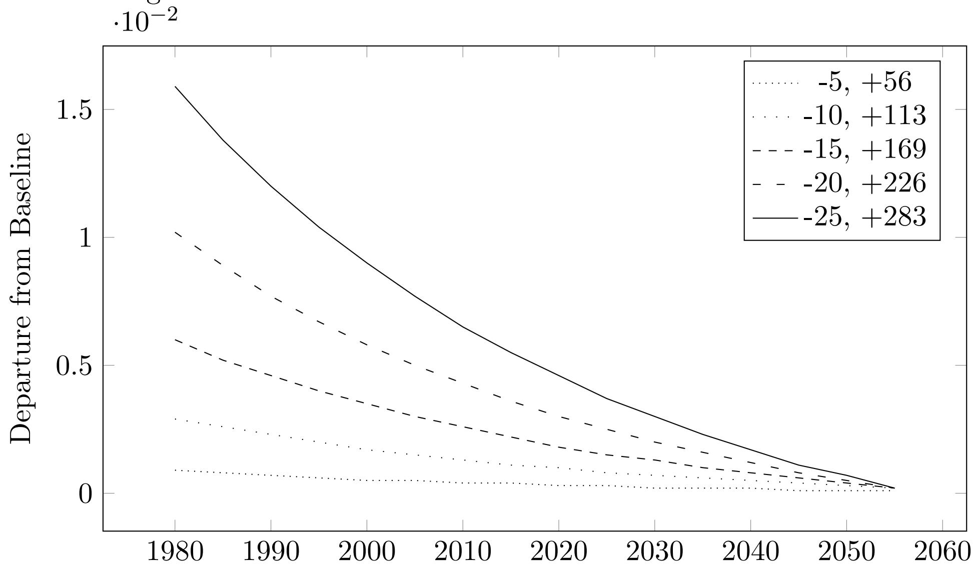
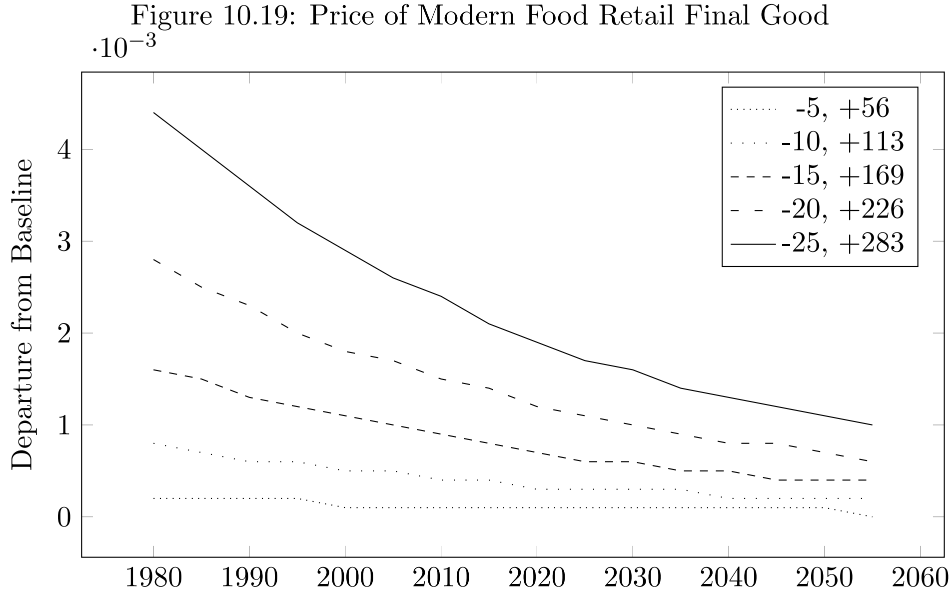


Figure 10.19: Price of Modern Food Retail Final Good



profit per hectare rises about 36% compared to the baseline result. The obvious factor is the reduction in farmland area, the denominator of this statistic. In addition, another factor, probably higher farm gate prices, causes profit per hectare to increase an additional 11%.

As for commercial farms, profit per hectare displays an interesting U-shaped pattern

Figure 10.20: Price of Services

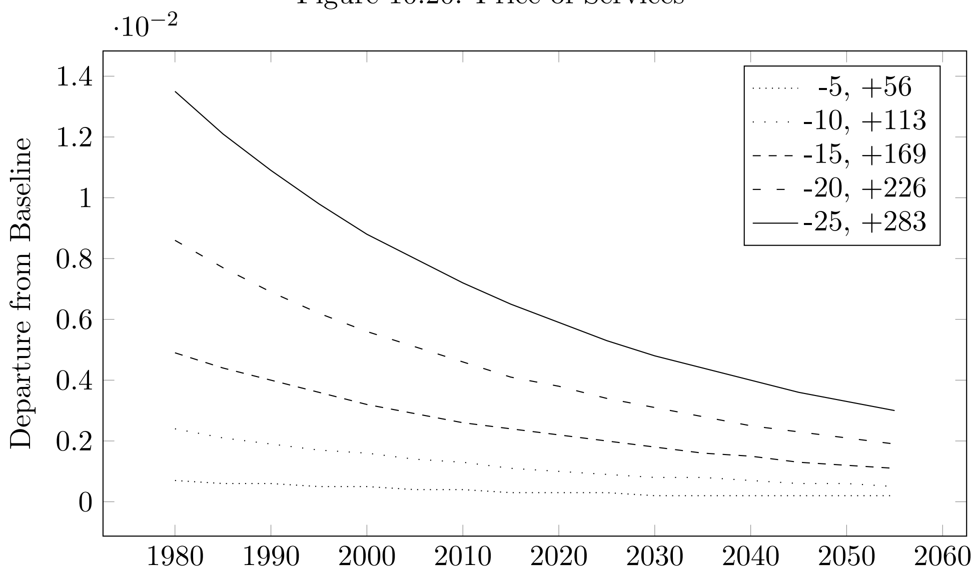
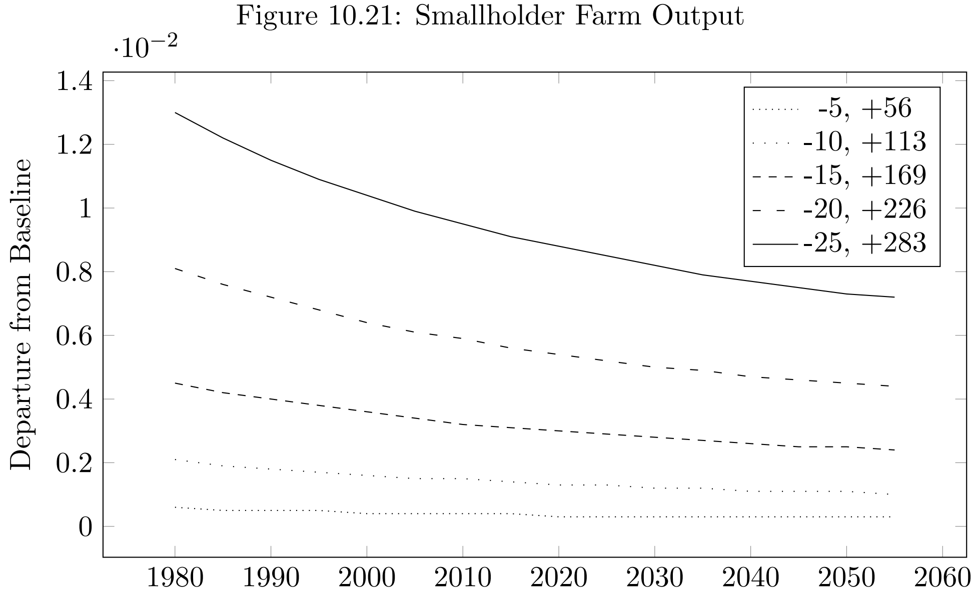


Figure 10.21: Smallholder Farm Output



in figure 10.28. As additional amounts of land are transferred from the smallholder sector, profits per hectare first fall by 35% and then recover to a decrease of about 20% compared to the baseline. This trend suggests that two opposing factors are at work. Commercial farm profit is the only statistic to display such a reversing trend. On the one hand, as land area increases, profit per hectare falls. On the other hand, commercial farming experiences a

Figure 10.22: Commercial Farm Output

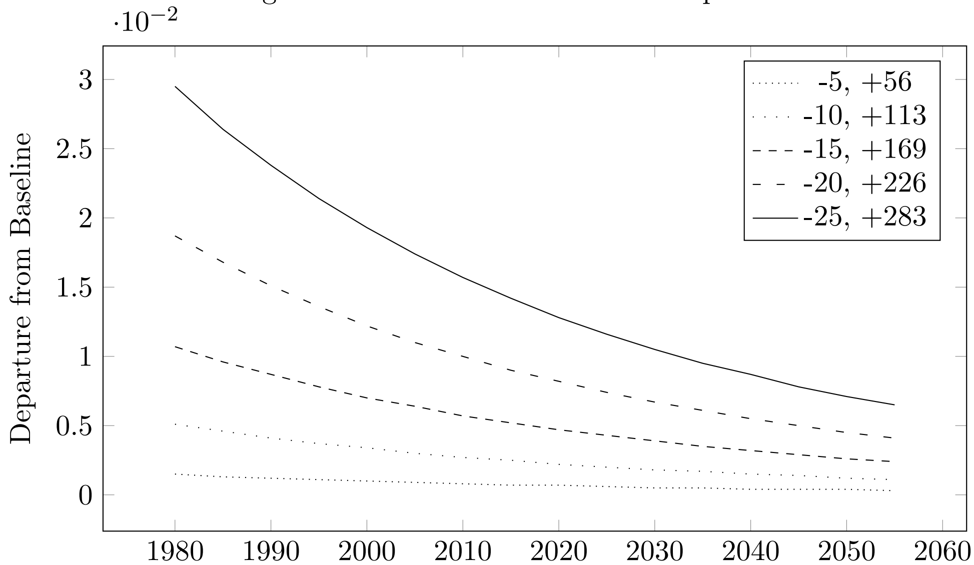
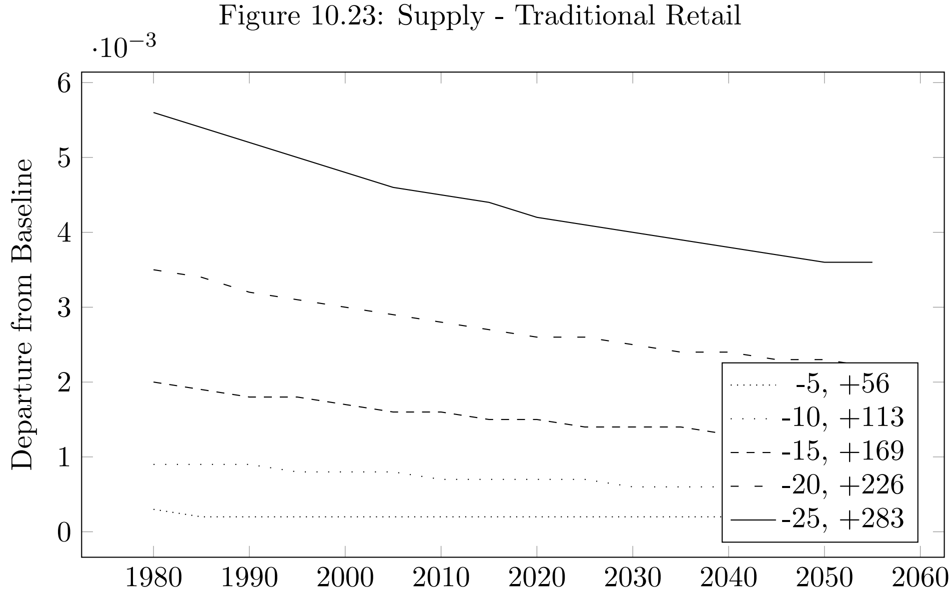


Figure 10.23: Supply - Traditional Retail



scale advantage which begins to outweigh the land area effect starting after a 113% increase in land area.

Another interesting feature of both farm profit trends is their remarkable stability in the projection. While the alternative output (see next paragraph below) drifts back toward the baseline, both farming sectors protect their profit margins. This suggests that the

Figure 10.24: Supply - Modern Retail

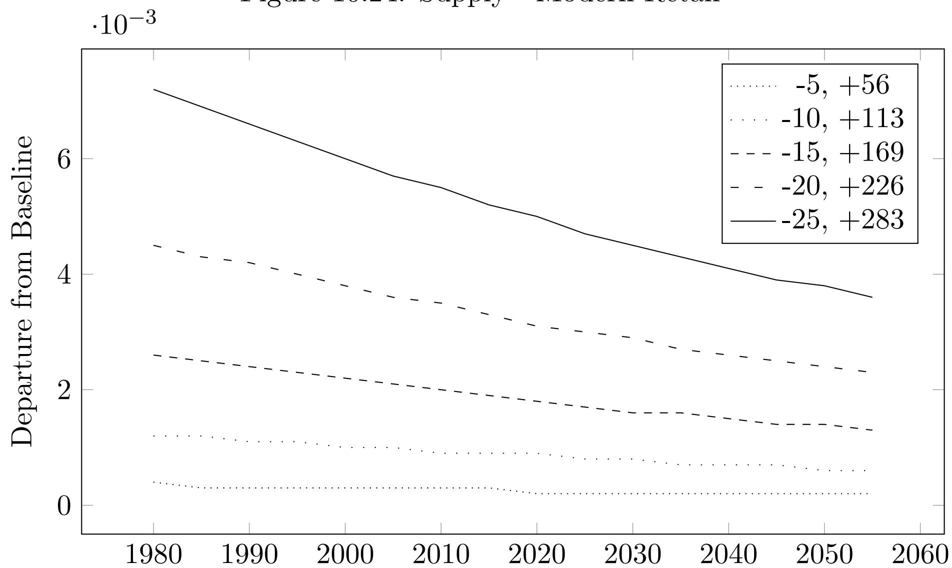
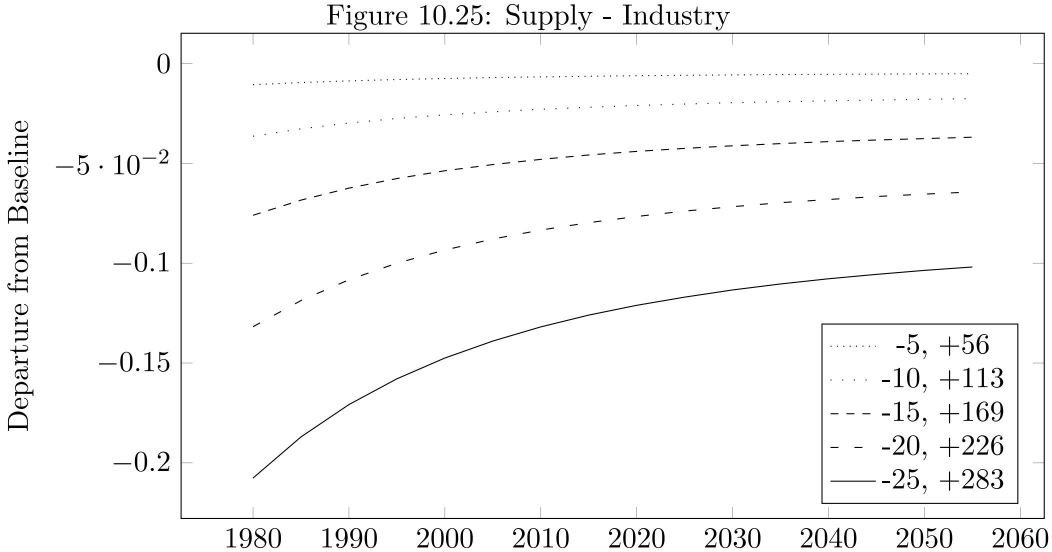


Figure 10.25: Supply - Industry



alternative allocation of farmland is superior to the constrained, baseline allocation.

Farm labor productivity also rises with output for both sectors in figures 10.29 and 10.30. Smallholder farmers become about 1.35% more productive compared to the baseline while commercial farmers are about 3.0% more productive. The rise in labor productivity indicates the presence of capital deepening. As the industrial sector scales back output,

Figure 10.26: Supply - Services

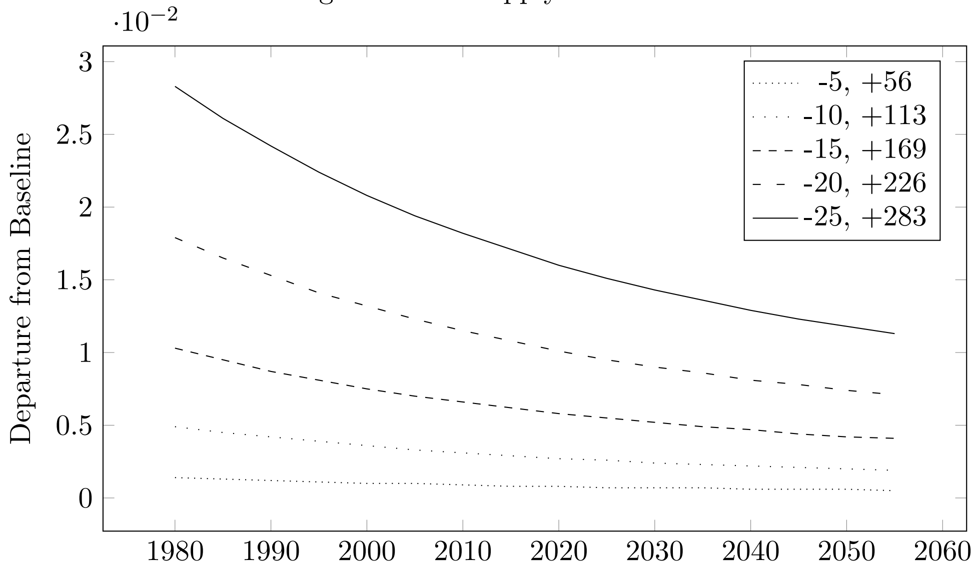
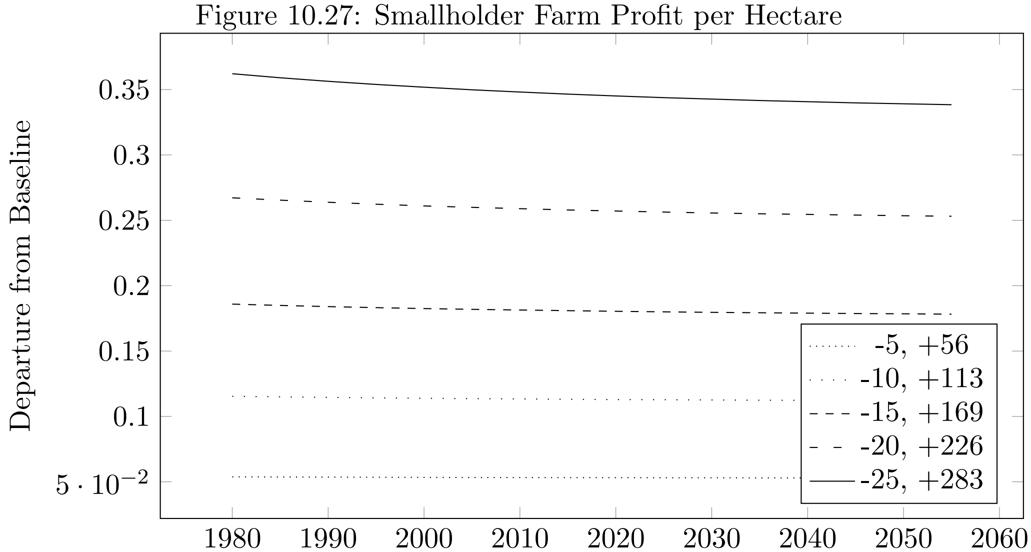


Figure 10.27: Smallholder Farm Profit per Hectare



industrial demand for capital falls. As the rental rate of capital falls, its lower relative price increases the demand of the two farming sectors. The shift in land resources and related relative factor prices leads smallholder farmers to employ more capital in intensive production. Commercial farmers, on the other hand, increase demand for capital as they put newly acquired land into extensive production.

Figure 10.28: Commercial Farm Profit per Hectare

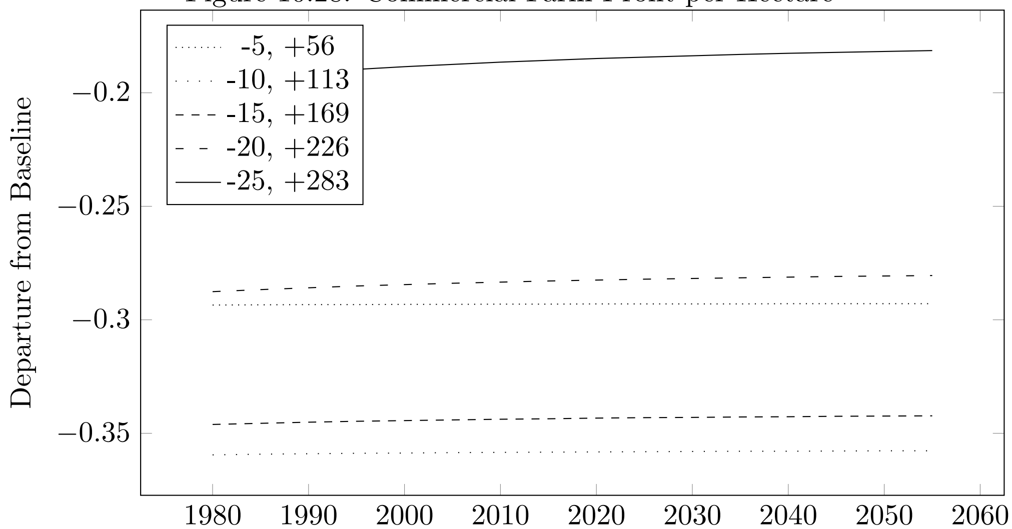
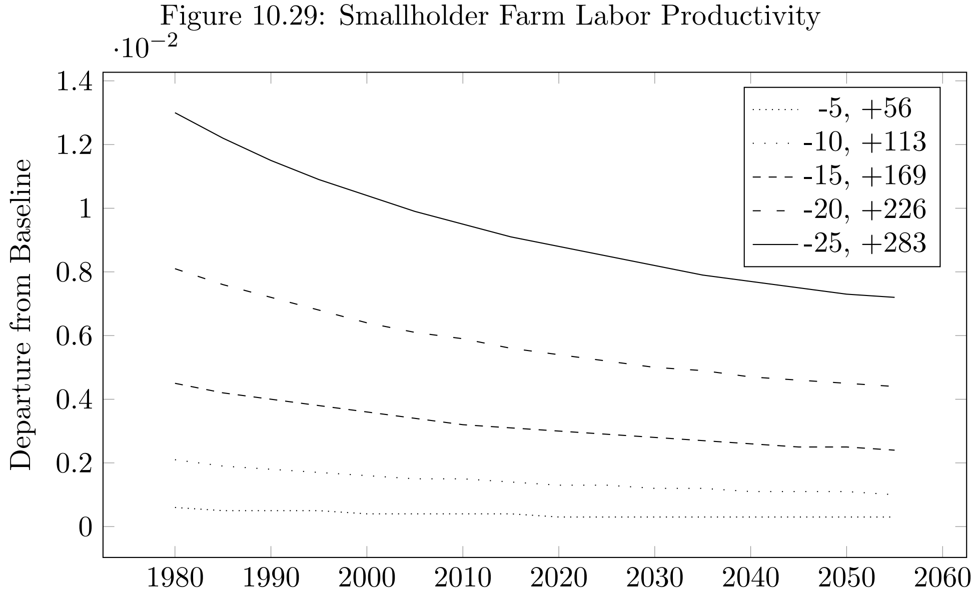
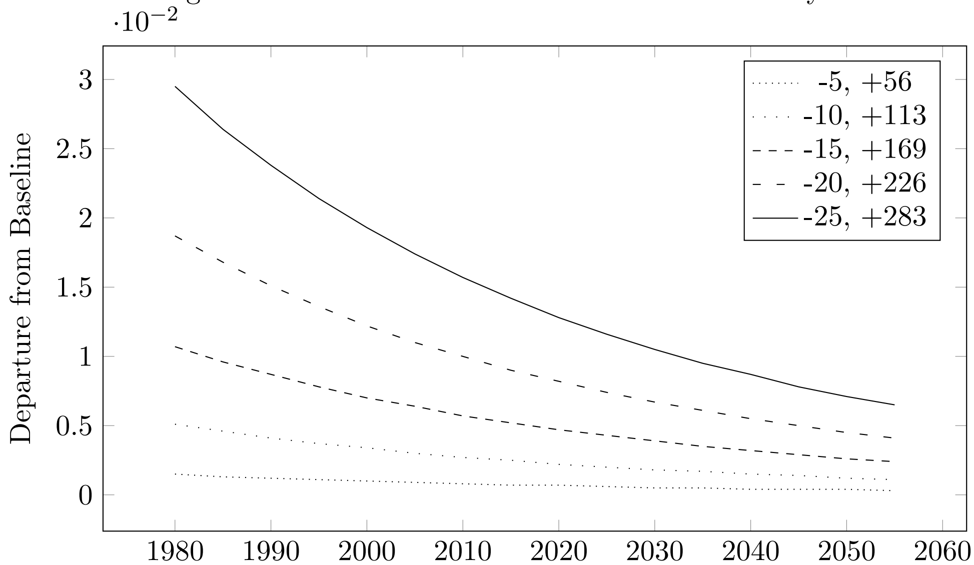


Figure 10.29: Smallholder Farm Labor Productivity



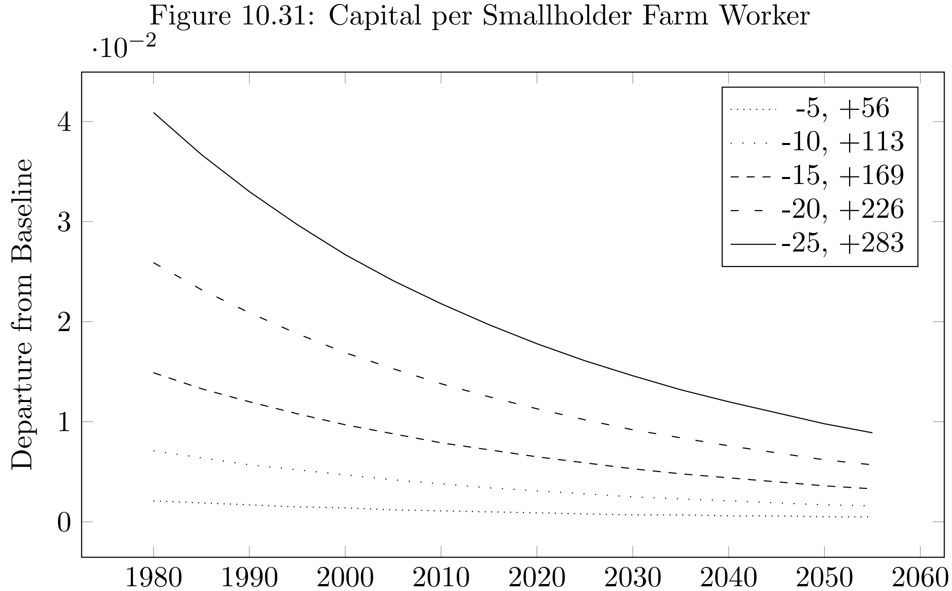
Compared to the baseline, an increase in capital per farm worker of 4.0% for both sectors confirms that they are experiencing capital deepening, as shown in figures 10.31 and 10.32. The responsiveness of labor productivity is interesting to note. While both sectors register the same 4.0% increase, the commercial sector converts this increased deployment of capital into more production per labor unit than does the smallholder sector. The difference

Figure 10.30: Commercial Farm Labor Productivity



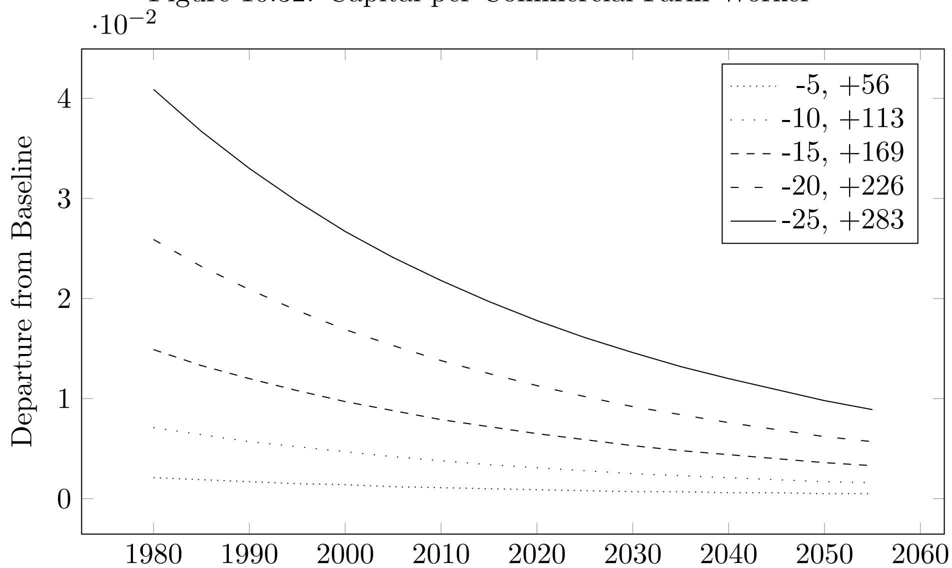
is attributable to commercial farming's greater relative factor productivity of capital.

Figure 10.31: Capital per Smallholder Farm Worker



Agricultural labor shares show the impact of the simulated transfer of smallholder land to the commercial farming sector (see figures 10.33 and 10.34). Relative to the proportion of land converted, the share of smallholder labor following to the commercial sector is less

Figure 10.32: Capital per Commercial Farm Worker



than 1.0% compared to the baseline. On the commercial farming side, labor share increases from the baseline a sustained 200%. Note that compared to the baseline, much of the loss in the smallholder labor share is made up over the course of the projection. However, the increase in commercial farming workforce numbers is sustained, meaning that commercial farming can continue to profitably employ these workers with its current technology.

The loss in the labor-intensive smallholder labor share is relatively small, revealing just how large the smallholder farming sector is. The more capital-intensive commercial farming sector experiences a relatively large inflow of labor. This result shows the relatively weak effect of land as a factor of production. Since the relative factor intensity of land is relatively small compared to labor and capital, the effect of marginal changes in the quantity of land is subdued. Also, the dissipating fall in smallholder labor share indicates that the sector is receiving most of the labor force growth. Commercial farming also receives a small proportion of the smallholder labor force growth.

The next two charts (figures 10.35 and 10.36) detail the effect of the land transition on the downstream stages of the two food channels. Both the traditional and modern retail sectors lose about 0.8% in labor share compared to the baseline. The interpretation of this trend is that the relatively small retail sectors cannot compete for labor with the growing commercial farming sector.

Figure 10.33: Labor Share - Smallholder Agriculture

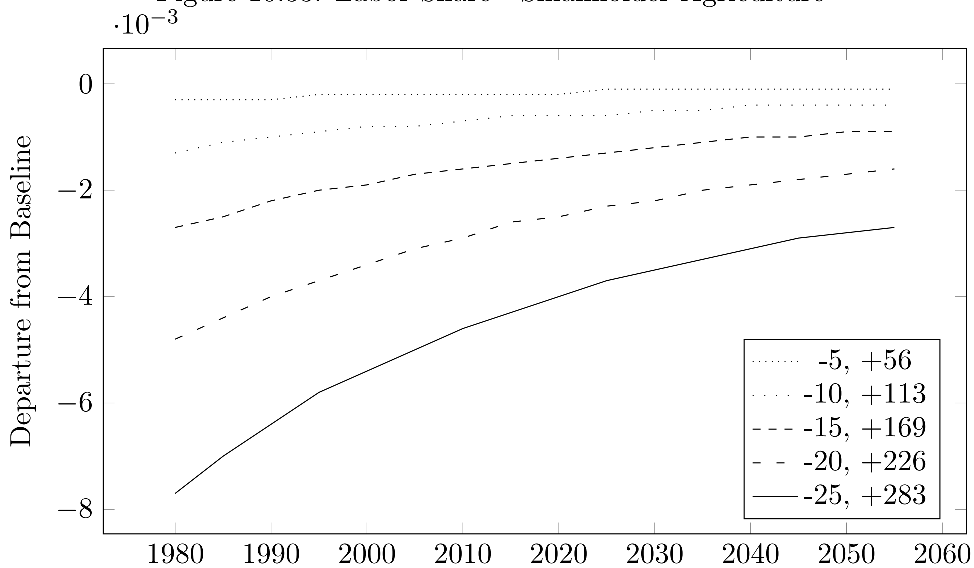
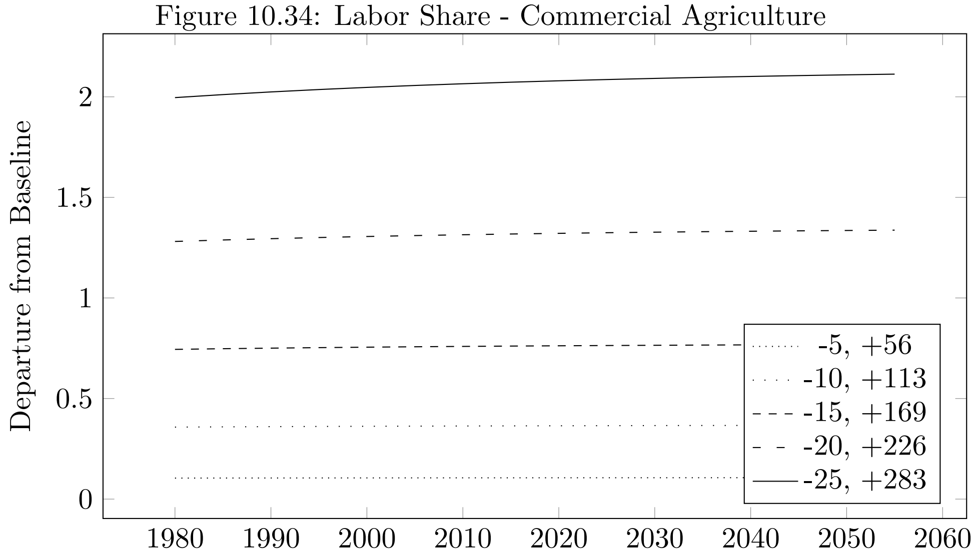


Figure 10.34: Labor Share - Commercial Agriculture



10.2.2 Comparison of the Land Conversion Case with the Baseline

The purpose of the alternative case is to evaluate returns to smallholder farmers from limited integration of smallholder and commercial farmland areas. The extended purpose of this analysis is to understand the impact of these changes on the structure of the Zambian economy. In this analysis, 25% of Zambia's smallholder sector land is converted to the

Figure 10.35: Labor Share - Traditional Retail

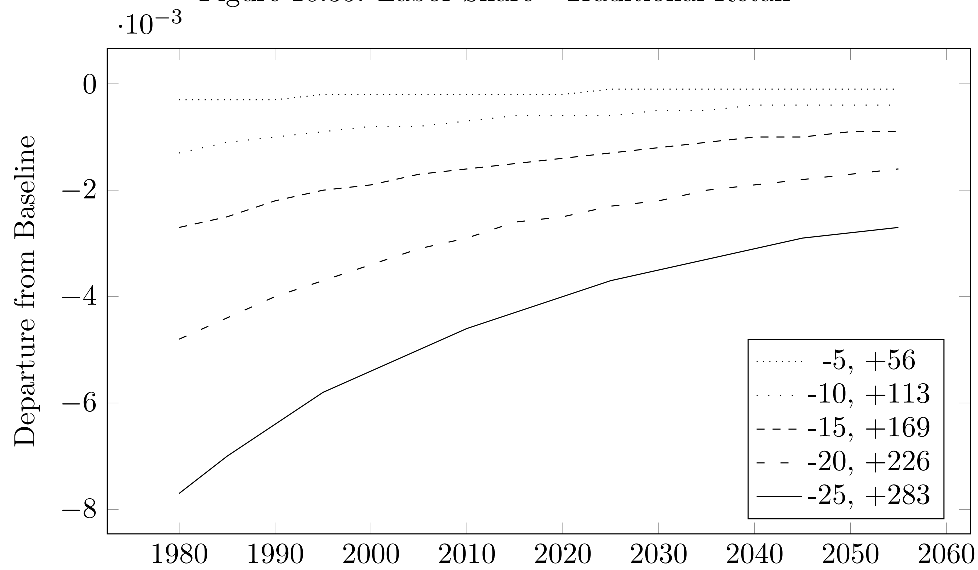
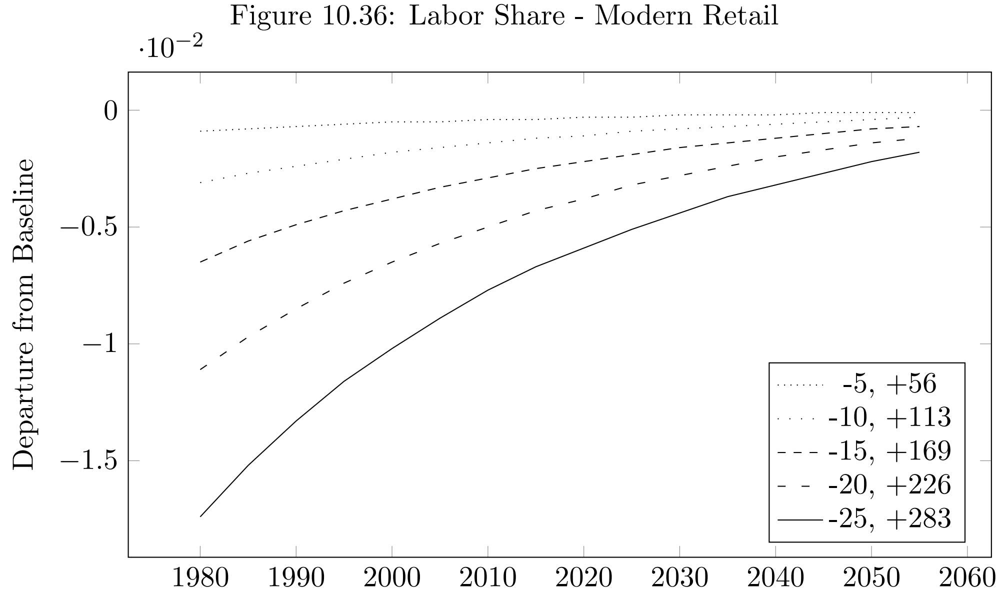


Figure 10.36: Labor Share - Modern Retail



commercial farming sector. This 25% exchange of smallholder land is effectively a change in agricultural sectors where smallholder farmers continue to own their farms. Commercial farming technology now replaces former smallholder technology, along with associated revenues and expenses.

A general observation of this exercise is that changes in factor endowments, such as in this case of agricultural land, generate economy-wide effects all along the production and marketing chain. Since factor endowments help shape the nature of production from the earliest stages until final consumption, they have a strong influence in the design of production chains and marketing channels.

A second observation is that as the alternative and baseline models advance in time, most, but not all indicators converge with most gains and losses from the one-time change in land endowments dissipating. In the long-run, both the alternative and the baseline trend toward the steady-state, albeit from different starting points. However, it is not readily apparent which model–baseline or alternative–adjusts to make up the difference.

In summary, table 10.3 lists the dominant value for each departure statistic of the analysis. Next to each value is a description of the values trend (up or down) and whether it is converging or diverging in relation to the baseline trend. A - indicates if a trend tapers off in the future. A - - indicates a relatively flat trend.

A comparison of statistics highlights major departures from the baseline. In the first section, GDP by income shows the expense paid by capital income in exchange for the advance of the other sectors. Overall, GDP advances about 1.8% with differences to baseline dissipating. Important for this study, smallholder farm profit advances 2.2% while commercial farm profit surges 208%.

For final goods expenditures, modern food advances a small 0.7% while traditional food is slightly behind. Services advance the most at 2.8%, most likely a result of higher incomes. Expenditures on industrial goods dropped, a result of the function of the balanced trade assumption in the model. As commercial agriculture exports increased, imports of the other traded good, industrial goods, rise to automatically balance trade. This adjustment resulted in the simultaneous effects of slashing domestic production and stimulating consumption of imported goods.

The ratio of Savings/GDP and the index of capital/GDP show a one-time reduction of savings and a small rise in the capital stock relative to GDP. The two statistics almost appear to offset one another. The fall in Savings/GDP is slowly made up over time, but the capital/GDP ratio slowly diverges, reaching 0.6% towards the half-life of the projection. Savings and capital accumulation appear to take a negative shock from which they slowly recover over 50 years.

Prices tell a story of an immediate shock that diminishes over time. The general price index rises 0.9% against the baseline. Labor and capital factor prices each experience similar shocks reflecting the relatively more scarce labor supply. The price of the smallholder agricultural good rises 1.6% while the commercial agricultural good rises only 0.4%. Following the marketing channel, the price rise for the retail traditional good is 1.6%. Modern food prices remain more stable, about 1.2% behind traditional food prices. This result shows that price transmission appears to exist along the traditional marketing channel, although the direction of causation is not evident.

In a surprising result, smallholder output advances 1.3% against the baseline in spite of losing 25% of its land endowment while commercial farming output grows by 3.0%.

Further down the marketing channels, retail supplies roughly follow their intermediate goods producers. Note that commercial farm output rises 2.9% while modern retail supply increases only 0.7%, which allows for increased exports. Smallholder output rises 1.3%, slightly higher than traditional retail expenditure, which rises only 0.6%, for an unknown reason, perhaps relating to Stone-Geary preferences. In the modeled economy, traditional retail purchases all the smallholder output.

Profits per hectare clearly reflect the adjustment in land endowments. Commercial profits per hectare fall 19.4% on the increase in agricultural land area. Smallholder profits are more robust than commercial profits, losing proportionately less land than commercial farming gains, but registering a larger magnitude growth in profit per hectare, 36.0% versus (19.4%). The trend in smallholder profits is more stable than the U-shaped pattern of commercial profits. Smallholder farm profit, reviewed above, provides a complete picture of profitability, including volume and price effects.

Labor productivity on commercial farms increases 2.9% versus only 1.3% for smallholder farms. Under the alternative case, smallholders now have less farmland over which to apply capital and labor. However, the percentage loss in the smallholder labor force is relatively small compared to the large labor gains for commercial farming. In addition, some smallholder labor migrates to the commercial farming sector, reducing smallholder labor supply.

Across both sectors the increase in capital per farm worker remains stable at 4.1% compared to the baseline, indicating the presence of capital deepening. As capital deepening is a ratio of capital to labor, changes to either or both factors may affect it. This result supports the idea of increasing labor productivity in the preceding paragraph. The smaller gains in smallholder labor productivity confirm the effect of differing starting points for capital intensity.

Table 10.3: Land Market Integration Analysis Summary Statistics

Magnitude and Direction of Change from Baseline		
Chart	**Departure**	**Trend**
GDP	0.019	converge ↓
GDP-Income: Capital Rent	(0.011)	diverge ↓
GDP-Income: Wage Income	0.029	converge ↓
GDP-Income: Smallholder Farm Profit	0.022	converge ↓
GDP-Income: Commercial Farm Profit	2.084	converge ↓
GDP-Expenditure: Traditional Food	0.006	converge ↓
GDP-Expenditure: Modern Food	0.007	converge ↓
Capital/GDP Index	0.006	diverge ↑ -
Labor Cost/Worker	0.029	converge ↓
Return to Capital	(0.011)	diverge ↑
Price of Smallholder Good	0.016	converge ↓
Price of Commercial Good	0.004	converge ↓
Smallholder Farm Profit per Hectare	0.362	–
Commercial Farm Profit per Hectare	(0.194)	–
Smallholder Farm Labor Productivity	0.013	converge ↓
Commercial Farm Labor Productivity	0.029	converge ↓
GDP by Expenditure: Industrial Goods	(1.247)	converge ↑
GDP by Expenditure: Services	0.028	converge ↓
GDP by Expenditure: Saving	(0.001)	diverge ↓
Savings/GDP Ratio	(0.020)	converge ↑ -
General Price Index	0.009	converge ↓
Price of Traditional Retail Final Good	0.016	converge ↓
Price of Modern Retail Good	0.004	converge ↓
Price of Services	0.013	converge ↓
Smallholder Output	0.013	converge ↓
Commercial Output	0.029	converge ↓
Supply: Traditional Retail	0.006	converge ↓
Supply: Modern Retail	0.007	converge ↓
Supply: Industry	(0.208)	converge ↑
Supply: Services	0.028	converge ↓
Capital per Smallholder Farm Worker	0.041	converge ↓
Capital per Commercial Farm Worker	0.041	converge ↓
Number of Smallholder Farm Workers	(0.008)	converge ↑
Number of Commercial Farm Workers	1.996	–
Labor Share: Smallholder Farming	(0.008)	converge ↑
Labor Share: Commercial Farming	1.996	–
Labor Share: Traditional Retail	(0.008)	converge ↑
Labor Share: Modern Retail	(0.017)	converge ↑
Capital Share: Traditional Retail	0.033	converge ↓
Capital Share: Modern Retail	0.023	converge ↓

Notes: – = flat trend; - = trend tapers off

10.2.3 Land Market Integration Policy Discussion

In conclusion, the results of the land market integration analysis illustrate the interactive nature of the intermediate goods sectors and their factors. This analysis tells a story of Rybczynski-like growth resulting from an increase in the endowment of commercial farmland. The expansion of commercial farmland increases derived demand for capital and labor, resulting in increased household income. Other sectors cannot afford to match the higher wages and release labor to commercial farming. In this modeled economy of balanced trade, increased commercial output and exports lead to higher imports of industrial goods, thus reducing demand for domestic industrial goods. Commercial farming experiences growth and profitability as it draws additional labor and capital resources into production.

These results highlight the importance of a sound institutional framework to the Zambian economy. In the context of the larger, national economy, factor markets benefit from clearly defined property rights and minimal transaction costs. These features have the additional benefit of enabling smallholders to participate in modern food marketing channels, if they so desire. The government of Zambia should seek to strengthen the legal and institutional infrastructure supporting land markets. In addition, it should streamline the policies and procedures for the processing and recording of land titles. Moreover, the model allows for considerable freedom in the design and implementation of legal and trade policies, a task Zambians will have to work through. Lastly, these results show that simultaneous policies of targeting the poorest of the poor and encouraging emerging and commercial farming to thrive can be complementary objectives.

10.3 Smallholder Access to Zambia's Modern Food Channel

Smallholder farmers face the difficulty of marketing their produce in modern food channels for several reasons previously discussed. One of the goals of this study is to measure the structural effect of marketing a portion of smallholder produce in modern, domestic marketing channels. This alternative scenario simulates the effect of smallholder farmers gaining access to supermarkets across Zambia. Under the baseline scenario, smallholders face demand limited only to traditional retail markets. However, under this scenario, ten percent of smallholder production is diverted from traditional market channels and marketed to modern channels. Although smallholders face many specific barriers to entry to modern food channels, we are interested in assessing the structural effect on the food sectors and the rest of the economy regardless of the specific policy intervention or change in the market.

In table 10.4, macro-level variables paint a picture of decreased capital formation and savings with the 10% shift in smallholder production. GDP initially rises, and then settles lower than the baseline. Both the stock of capital and savings fall since the commercial farming sector, which generates a large part of household income, now faces more competition from the new supplies of smallholder farmers. Thus, the rate of capital accumulation slows as households have less residual savings.

Table 10.4: Macro Data per Worker: Departure from Baseline to Smallholders With Access to Modern Retail Channel

Year	GDP	Savings/ GDP	Capital/GDP Index
1980	0.0015	(0.0041)	-
1985	0.0008	(0.0041)	(0.0003)
1990	0.0001	(0.0041)	(0.0005)
1995	(0.0004)	(0.0041)	(0.0007)
2000	(0.0009)	(0.0040)	(0.0009)
2005	(0.0013)	(0.0040)	(0.0010)
2010	(0.0017)	(0.0040)	(0.0012)
2015	(0.0021)	(0.0040)	(0.0013)
2020	(0.0024)	(0.0039)	(0.0014)
2025	(0.0026)	(0.0039)	(0.0015)
2030	(0.0028)	(0.0039)	(0.0016)
2035	(0.0030)	(0.0039)	(0.0016)
2040	(0.0032)	(0.0039)	(0.0017)
2045	(0.0034)	(0.0038)	(0.0017)
2050	(0.0035)	(0.0038)	(0.0018)
2055	(0.0037)	(0.0038)	(0.0018)

*Index: 1980 = 1.00; thus no change

Foreign trade also initially increases as excess supplies of agricultural produce overflow as exports.

Prices of inputs, intermediate goods, and final goods respond as expected according to theory, as shown in table 10.5. As supplies of smallholder produce fall in traditional channels with demand remaining constant, smallholder farmgate prices and traditional retail prices rise. However, in the later years of the projection, smallholder farm-gate prices fall back towards the baseline price. The rise in prices across the traditional channel stimulates additional smallholder production, which in turn puts upward pressure on wages, since smallholder farming is relatively labor intensive. The price of capital falls as it is the factor less intensively used in smallholder agriculture. The price of services must rise to allow the sector to compete for higher cost labor, which was bid higher by the smallholder farming sector.

Input shares also reflect structural changes between sectors. In response to the higher cost of labor, commercial and smallholder labor shares fall, and capital share rises in smallholder agriculture. However, capital shares in commercial agriculture do not rise because of relatively lower modern retail prices.

Table 10.5: Intermediate and Final Prod. Price Indices: Change from Baseline to 10% Smallholder Access

Smallholder Farm-gate*	Traditional Retail	Modern Retail	General Price Index
0.0046	0.0046	0.0010	0.0022
0.0040	0.0040	0.0009	0.0019
0.0036	0.0036	0.0008	0.0017
0.0032	0.0032	0.0007	0.0015
0.0028	0.0028	0.0006	0.0014
0.0025	0.0025	0.0006	0.0012
0.0022	0.0022	0.0005	0.0011
0.0019	0.0019	0.0004	0.0010
0.0017	0.0017	0.0004	0.0008
0.0015	0.0015	0.0004	0.0008
0.0014	0.0014	0.0003	0.0007
0.0012	0.0012	0.0003	0.0006
0.0011	0.0011	0.0002	0.0005
0.0009	0.0009	0.0002	0.0005
0.0008	0.0008	0.0002	0.0004
0.0007	0.0007	0.0002	0.0004

*converted to equivalent units of Traditional Retail

In the modern food channel, the commercial farm price remains unchanged as the numeraire, and the retail price of modern food rises, but less than the traditional retail price.

In response to the 10% reduction of smallholder produce to the traditional channel, smallholder profits increase on nearly constant output as farmers now receive higher output prices (see table 10.6). On the other hand commercial farming sector output falls, even though per worker output rises, as supplies from smallholder farming have a large impact on this small sector. Input shares fall along with output and profits. Although commercial farmers have access to export markets at a constant price, the impact on their domestic supermarket channel is too great to overcome.

Table 10.6: Output and Profit per Ag Worker: Departure from Baseline to Smallholder Access to Modern Retail

	Output		Profit	
Year	Commercial	Smallholder	Commercial	Smallholder
1980	0.0068	0.0018	0.0068	0.0068
1985	0.0060	0.0016	0.0060	0.0060
1990	0.0053	0.0014	0.0053	0.0053
1995	0.0047	0.0013	0.0047	0.0047
2000	0.0042	0.0011	0.0042	0.0042
2005	0.0037	0.0010	0.0037	0.0037
2010	0.0033	0.0009	0.0033	0.0033
2015	0.0029	0.0008	0.0029	0.0029
2020	0.0026	0.0008	0.0026	0.0026
2025	0.0023	0.0007	0.0023	0.0023
2030	0.0021	0.0006	0.0021	0.0021
2035	0.0018	0.0006	0.0018	0.0018
2040	0.0017	0.0005	0.0017	0.0017
2045	0.0015	0.0005	0.0015	0.0015
2050	0.0013	0.0004	0.0013	0.0013
2055	0.0012	0.0004	0.0012	0.0012

In table 10.7, traditional channel value-added figures reveal the effect of the loss of volume on downstream operations. Yearly traditional value-added falls by almost 8%. The modern channel also suffers a fall in value added of a slightly lower magnitude.

Table 10.7: Channel Value Added per Worker: Departure from Baseline to Smallholders Accessing Modern Retail

Year	Modern	Traditional
1980	(0.0608)	(0.0767)
1985	(0.0629)	(0.0771)
1990	(0.0646)	(0.0775)
1995	(0.0661)	(0.0778)
2000	(0.0673)	(0.0780)
2005	(0.0684)	(0.0782)
2010	(0.0693)	(0.0784)
2015	(0.0701)	(0.0786)
2020	(0.0708)	(0.0788)
2025	(0.0713)	(0.0789)
2030	(0.0718)	(0.0790)
2035	(0.0723)	(0.0791)
2040	(0.0726)	(0.0792)
2045	(0.0730)	(0.0793)
2050	(0.0732)	(0.0794)
2055	(0.0735)	(0.0794)

Supplies of intermediate and final goods fall in response to tighter household budget constraints, which result from higher traditional food prices.

Overall, the diversion of 10% of smallholder output to the modern food channel has an impact on the ability of households to save and accumulate capital. With a reduction in smallholder supply, households must pay a higher clearing price for traditional food, even though smallholders receive better farm-gate prices for that portion of output sent to the modern channel. This increase in output price increases demand for the intensive factor in smallholder agriculture, namely labor. Other firms now must pay the higher price for labor, and thus now demand less capital, resulting in a decrease in the cost of capital. This change in relative factor prices induces smallholders to employ more capital. Thus, this diversion has opposing effects. For smallholders, the beneficial effect is realized in higher farmgate prices. Households, on the other hand, face higher prices for traditional food now that a tenth of smallholder supply has been diverted to modern channels. The benefit of greater supplies of intermediate food goods in the modern channel is offset by the option of exporting surpluses to world markets.

In other words, the diversion of 10% of smallholder output to the modern channel results in two main counterveiling effects. First, smallholder farmers benefit directly from higher farmgate prices due to two effects. As a direct effect, they receive higher prices for the 10% portion of output marketed to the modern channel. In addition, they indirectly benefit from higher smallholder farm-gate prices as traditional retailers bid for newly tightened supplies.

The second effect of higher traditional retail food prices suppresses the ability of households to generate savings and accumulate capital. Reduced capital accumulation produces further negative effects throughout the economy, namely in labor productivity.

The total effect of this diversion is summed up in GDP. As seen in Table 10.4 above, compared to the baseline case, annual GDP is projected to register losses after 1990 in the amount of about 0.0025, on average, through 2055.

10.3.1 Smallholder Access Policy Discussion

The analysis of smallholder participation in the modern marketing channel shows that smallholders may capture a greater value-added share for themselves. While the specific nature of the change in production and marketing is not identified, the results should lead smallholders, commercial farmers, processors, and retailers to investigate the best means to achieve this potential benefit. The research literature on Zambian food and agriculture has many micro-level studies considering the economic effects of various changes to transportation infrastructure, production technologies, human capital and mangerial skill of farmers, input prices, agronomy, produce storage, credit and financing, the roles of middlemen, and market information. The next step, then, is to investigate how much these ideas contribute towards the ability of smallholders to meet the needs of downstream modern channel firms for produce with desirable attributes. Any micro-level adjustment that can profitably move smallholders closer to full participation in the modern marketing channel would be worth implementing.

11 Conclusion

This study examines the effect of structural change as it relates to the supermarket revolution in developing nations. Transformation of food marketing channels accompanies economic growth in many nations through rising incomes, which change consumer demand for food. As a result, modern food marketing channels begin to displace traditional channels, which in turn affects factor markets, especially in the agricultural sector. A dynamic general equilibrium (DGE) model is used to examine the effect of this structural transformation story on smallholder farmers in Zambia. Policy experiments are carried out against the baseline case to examine two general sets of alternative conditions affecting the growth of Zambia's economy and in particular the economic position of smallholder farmers.

To better understand the development and growth of Zambian food channels in recent years, a brief comparison with American agriculture and marketing channels is undertaken. Changes to agricultural marketing that covered the span of many generations in the United States were acheived in the Zambian economy in just a few decades. The fast rate of change along the whole Zambian food marketing channel, from the farm to the retail supermarket, has created greater demands for services from institutions such as land titling.

A baseline model is constructed using a social accounting matrix of Zambia for 1995. This model is composed of four final goods sectors–industry, services, modern food retail, and traditional food retail–and two intermediate sectors–commercial farming and smallholder farming. Analysis of the modern food retail and traditional food retail sectors required additional disaggregation of the original services sector. The breakout of these two sectors was accomplished with the addition of surveys of Zambia's retail food markets and demographics. A similar challenge was faced with the analysis of Zambia's intermediate agricultural sector since the smallholder farming sector operates largely in the informal economy. The disaggregation of the agricultural sector was accomplished with the addition of production and cost accounting studies of Zambian farming.

Sector growth accounting is conducted to gain an understanding of the effects of changes in Zambia's factor prices and endowments on output across all sectors. Resulting elasticities indicate the sign of direct and indirect effects, but also in some cases estimates of the magnitude. Although the commercial farming sector is a fraction of the size of the smallholder farming sector, its capital intensive nature of production greatly enhances output. The larger smallholder farming sector behaves more like the labor-intensive services sector.

In the first policy experiment, the bifurcation of Zambia's agricultural land markets prevents smallholder farmers from participating in modern food marketing channels. High transaction costs in terms of time and financial resources make conversion of customary land into commercial land title prohibitively expensive for smallholder farmers. The simulated conversion of land title, without changing ownership, causes a reallocation of capital and labor resources in the modeled economy that benefits smallholders in their roles as producers and household owners of factors of production. With the increase in commercial land area, labor becomes scarce and farm production becomes more capital intensive, thus increasing labor productivity and smallholder household income. This analysis highlights the importance of integrating land markets and giving smallholders an effective increase in the range of their resource allocation decisions.

In the second policy experiment, constraints to smallholder participation in modern food marketing channels are relaxed in order to understand the effects on not only smallholder farmers, but also on Zambia's factor and output markets. Participation in modern marketing channels allows smallholders to supply not only greater downstream value-added processors, but also the world wholesale market. The results show that policies to open modern channels to smallholders benefit smallholders as households and producers, although GDP falls slightly. Further investigation of the effectiveness of changes to specific policies and market channel structures and stages would be suitable under this framework. Such improvements in transportation infrastructure, storage, futures markets, market prices, availability of credit, extension services, and processing could be explored.

The systematic design of this dynamic general equilibrium model would make it applicable to other emerging economies experiencing similar food marketing channel transitions. Although the specifics are different for each economy, the general conceptual framework may be of use.

In summary, these results show that the policy environment of Zambia can affect the structure of its economy and the livelihood of smallholder farmers. It is the responsibility of the Zambian people to design and institute the legal and market infrastructure necessary to foster economic growth and increase the range of economic choices for themselves, and especially their smallholder farmers.

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A Appendices

A.1 Appendix A

A.1.1 Derivation of the expenditure function with Stone Geary framework

We start with a Stone Geary utility function

$$H = \frac{q^{1-\theta} - 1}{1-\theta} e^{(n-\rho)t} + \xi \left(w + k\left(r - n\right) + \pi_c + \pi_h - \nu\left(\bar{p}\right) q - \gamma \cdot p\right) \tag{31}$$

Taking the partial derrivative of utility with respect to q yields

$$q^{-\theta} e^{(n-\rho)t} - \xi \nu\left(\bar{p}\right) = 0 \tag{32}$$

and

$$\dot{\xi} = -\frac{\partial H}{\partial k} = -\xi\left(r - n\right) \tag{33}$$

Taking the log and differentiating with respect to t yields

$$-\theta\frac{\dot{q}}{q} + (n-\rho) - \frac{\dot{\xi}}{\xi} - \sum_j \frac{\nu_j\left(\bar{p}\right) p_j}{\nu\left(\bar{p}\right)} \frac{\dot{p}_j}{p_j} = 0 \Rightarrow \tag{34}$$

Substituting $\lambda_j = \frac{\nu_j(\bar{p})p_j}{\nu(\bar{p})}$in (39), we have

$$-\theta\frac{\dot{q}}{q} + (n-\rho) - \frac{\dot{\xi}}{\xi} - \sum_j \lambda_j \frac{\dot{p}_j}{p_j} \tag{35}$$

Thus, equal to (6), Euler is

$$\theta\frac{\dot{q}}{q} = r - \rho - \sum_j \lambda_j \frac{\dot{p}_j}{p_j} \tag{36a}$$

Home good market clearing implies

$$\frac{\partial}{\partial p_s}\left(\nu\left(\bar{p}\right) q - \gamma \cdot p\right) = Y^s\left(\cdot\right) \Rightarrow let \gamma_s = 0$$

Let $\gamma_s = 0$ and service output simplifies to

$$\frac{\partial}{\partial p_s}\nu\left(\bar{p}\right)q = Y^s\left(\cdot\right) \tag{37a}$$

which implies

$$\frac{\lambda_s \nu\left(\bar{p}\right)q}{p_s} = Y^s\left(\cdot\right) \tag{38}$$

Solving for q gives

$$q = \frac{p_s Y^s\left(\cdot\right)}{\lambda_s \nu\left(\bar{p}\right)} \tag{39}$$

Thus, differentiating (39) we have

$$\sum_j \nu_{p_j}\left(\bar{p}\right)q\dot{p}_j + \nu\left(\bar{p}\right)\dot{q} = \frac{\dot{p}_s Y^s\left(\cdot\right)}{\lambda_s} + \frac{p_s Y^s_{p_s}\left(\cdot\right)\dot{p}_s}{\lambda_s} + \frac{p_h Y^s_{p_s}\left(\cdot\right)\dot{p}_h}{\lambda_s} + \frac{p_s Y^s_k\left(\cdot\right)\dot{k}}{\lambda_s} \tag{40}$$

Re-write (40) by substituting $\nu_{p_j}\left(\bar{p}\right) = \lambda_j \nu\left(\bar{p}\right)/p_j$.

$$\sum_j \lambda_j \nu\left(\bar{p}\right)q\frac{\dot{p}_j}{p_j} + \nu\left(\bar{p}\right)q\frac{\dot{q}}{q} = \frac{\dot{p}_s Y^s\left(\cdot\right)}{\lambda_s} + \frac{p_s Y^s_{p_s}\left(\cdot\right)\dot{p}_s}{\lambda_s} + \frac{p_h Y^s_{p_s}\left(\cdot\right)\dot{p}_h}{\lambda_s} + \frac{p_s Y^s_k\left(\cdot\right)\dot{k}}{\lambda_s} \tag{41}$$

Now, substitute the Euler equation (36a)for $\dot{q}/q$

$$\sum_j \lambda_j \nu\left(\bar{p}\right)q\frac{\dot{p}_j}{p_j} + \nu\left(\bar{p}\right)q\left[\frac{r-\rho}{\theta} - \frac{1}{\theta}\sum_j \lambda_j\frac{\dot{p}_j}{p_j}\right] = \tag{42}$$
$$\frac{\dot{p}_s Y^s\left(\cdot\right)}{\lambda_s} + \frac{p_s Y^s_{p_s}\left(\cdot\right)\dot{p}_s}{\lambda_s} + \frac{p_h Y^s_{p_s}\left(\cdot\right)\dot{p}_h}{\lambda_s} + \frac{p_s Y^s_k\left(\cdot\right)\dot{k}}{\lambda_s}$$

Factor $\nu\left(\bar{p}\right)q$ and simplify

$$\nu\left(\bar{p}\right)q\left[\sum_j \lambda_j\frac{\dot{p}_j}{p_j} + \frac{r-\rho}{\theta} - \frac{1}{\theta}\sum_j \lambda_j\frac{\dot{p}_j}{p_j}\right] = \tag{43}$$
$$\frac{\dot{p}_s Y^s\left(\cdot\right)}{\lambda_s} + \frac{p_s Y^s_{p_s}\left(\cdot\right)\dot{p}_s}{\lambda_s} + \frac{p_h Y^s_{p_s}\left(\cdot\right)\dot{p}_h}{\lambda_s} + \frac{p_s Y^s_k\left(\cdot\right)\dot{k}}{\lambda_s}$$

Factor $1/\theta$ on the left hand side of (43)

$$\frac{\nu(\bar{p})\,q}{\theta}\left[r-\rho+\sum_j \lambda_j \frac{\dot{p}_j}{p_j}(\theta-1)\right]= \tag{44}$$
$$\frac{\dot{p}_s Y^s(\cdot)}{\lambda_s}+\frac{p_s Y^s_{p_s}(\cdot)\,\dot{p}_s}{\lambda_s}+\frac{p_h Y^s_{p_s}(\cdot)\,\dot{p}_h}{\lambda_s}+\frac{p_s Y^s_k(\cdot)\,\dot{k}}{\lambda_s}$$

In the Stone Geary utility function (31), expenditure is defined as

$$E=\nu(\bar{p})\,q+\gamma_r p_r+\gamma_d p_d \tag{45}$$

Time differentiate (45)

$$\dot{E}=\nu(\bar{p})\,\dot{q}+\sum_{j=s,r,d}\nu_{p_j}(\bar{p})\,q\dot{p}_j+\gamma_r\dot{p}_r+\gamma_d\dot{p}_d \tag{46}$$

Multiply each term on the RHS by $\frac{q}{q},\frac{p_j}{p_j},\frac{p_r}{p_r},\frac{p_d}{p_d}$, respectively and simplify.

$$\begin{aligned}
\dot{E} &= \nu(\bar{p})\,q\frac{\dot{q}}{q}+\sum_{j=s,r,d}\lambda_j\frac{\nu(\bar{p})\,q}{p_j}p_j\frac{\dot{p}_j}{p_j}+\gamma_r p_r\frac{\dot{p}_r}{p_r}+\gamma_d p_d\frac{\dot{p}_d}{p_d} \\
\dot{E} &= \nu(\bar{p})\,q\frac{\dot{q}}{q}+\sum_{j=s,r,d}\lambda_j\nu(\bar{p})\,q\frac{\dot{p}_j}{p_j}+\gamma_r p_r\frac{\dot{p}_r}{p_r}+\gamma_d p_d\frac{\dot{p}_d}{p_d} \\
\dot{E} &= \nu(\bar{p})\,q\left(\frac{\dot{q}}{q}+\sum_{j=s,r,d}\lambda_j\frac{\dot{p}_j}{p_j}\right)+\gamma_r p_r\frac{\dot{p}_r}{p_r}+\gamma_d p_d\frac{\dot{p}_d}{p_d}
\end{aligned} \tag{47}$$

A.2 Appendix B

A.2.1 Reducing the dimensionality of the system

We first express the four zero profit conditions (12) in the six unknowns $\{\widehat{w},r^k,p_r,p_d,p_s,p_h\}$ as functions of p_s and p_h:

$$\left\{\hat{w}=W(p_s,p_h)\,,\ r^k=R(p_s,p_h)\,,\ p_r=P^r(p_s,p_h)\,,\ p_d=P^d(p_s,p_h)\right\} \tag{48}$$

We then substitute zero profit reduced forms into the factor market clearing equations(13 and 14) for the labor market

$$\widetilde{c}_w^m(p_s,p_h)\widehat{y}_m + \widetilde{c}_w^r(p_s,p_h)\widehat{y}_r + \widetilde{c}_w^d(p_s,p_h)\widehat{y}_d + \widetilde{c}_w^s(p_s,p_h)\widehat{y}_s \tag{49}$$

$$= 1 + \widetilde{\pi}_w^c(p_s,p_h)\widehat{H}_c + \widetilde{\pi}_w^h(p_s,p_h)\widehat{H}_h$$

capital market

$$\widetilde{c}_r^m(p_s,p_h)\widehat{y}_m + \widetilde{c}_r^r(p_s,p_h)\widehat{y}_r + \widetilde{c}_r^d(p_s,p_h)\widehat{y}_d + \widetilde{c}_r^s(p_s,p_h)\widehat{y}_s \tag{50}$$

$$= \widehat{k} + \widetilde{\pi}_r^c(p_s,p_h)\widehat{H}_c + \widetilde{\pi}_r^h(p_s,p_h)\widehat{H}_h$$

where, to simplify notation and highlight the endogenous variables, p_s and p_h, we define

$$\begin{aligned} \widetilde{c}_r^d(p_s,p_h) &\equiv c^d(W(p_s,p_h),R(p_s,p_h),P^d(p_s,p_h)), \text{ and} \\ \widetilde{c}^j\,(p_s,p_h) &\equiv c^j(W(p_s,p_h),R(p_s,p_h)),\ j=m,r,s \end{aligned}$$

and, for $i = \hat{w}, r^k$, we have:

$$\begin{aligned} \widetilde{\pi}_i^c(p_s,p_h) &\equiv \pi_i^c(pv^c\,(p_c,p_m,p_s)\,,W(p_s,p_h),R(p_s,p_h)), \quad \text{and} \\ \widetilde{\pi}_i^h(p_s,p_h) &\equiv \pi_i^h(pv^h\,(p_h,p_m,p_s)\,,W(p_s,p_h),R(p_s,p_h)) \end{aligned}$$

Next, through expenditure, $\widehat{E}$, use the relationship between final demand for modern retail food (16) and traditional retail food(17)

$$\frac{p_r\,(\widehat{y}_r-\gamma_r)}{\lambda_r} = \varepsilon\,(p_m,p_r,p_d,p_s)\,\hat{q} = \frac{p_d\,(\widehat{y}_d-\gamma_d)}{\lambda_d} \tag{51}$$

and solve for modern retail output, $\widehat{y}_r$

$$\hat{y}_r = \frac{\lambda_r}{\lambda_d}\frac{p_d}{p_r}\,(\widehat{y}_d-\gamma_d)+\gamma_r \tag{52}$$

With this result, we substitute for $\widehat{y}_r$ into new factor market clearing equations (49 and 50) and rearrange terms to obtain, using (48),

labor market

$$\widetilde{c}_w^m(p_s,p_h)\widehat{y}_m + \left[\widetilde{c}_w^r(p_s,p_h)\frac{\lambda_r}{\lambda_d}\frac{P^d\,(p_s,p_h)}{P^r\,(p_s,p_h)}\,(\widehat{y}_d-\gamma_d)+\gamma_r+\widetilde{c}_w^d(p_s,p_h)\widehat{y}_d\right] + \widetilde{c}_w^s(p_s,p_h)\widehat{y}_s = \tag{53}$$

$$1 + \widetilde{\pi}_w^c(p_s, p_h)\widehat{H}_c + \widetilde{\pi}_w^h(p_s, p_h)\widehat{H}_h$$

capital market

$$\widetilde{c}_r^m(p_s, p_h)\widehat{y}_m + \left[\widetilde{c}_w^r(p_s, p_h)\frac{\lambda_r}{\lambda_d}\frac{P^d(p_s, p_h)}{P^r(p_s, p_h)}(\widehat{y}_d - \gamma_d) + \gamma_r + \widetilde{c}_w^d(p_s, p_h)\widehat{y}_d\right] + \widetilde{c}_r^s(p_s, p_h)\widehat{y}_s = \tag{54}$$

$$\widehat{k} + \widetilde{\pi}_r^c(p_s, p_h)\widehat{H}_c + \widetilde{\pi}_r^h(p_s, p_h)\widehat{H}_h$$

traditional farm level market

$$\tilde{\pi}_{p_h}^h(p_s, p_h))\widehat{H}_h - \tilde{c}_{p_h}^d(p_s, p_h)\widehat{y}_d = 0 \tag{55}$$

This gives us three equations, (53), (54),and (55), that are linear in $\hat{y}_m, \hat{y}_d$, and $\hat{y}_s$. Solve and express the result as a function of endogenous variables only:

$$\begin{aligned} \hat{y}_m &= \tilde{y}^m\left(p_s, p_h, \hat{k}\right) \\ \hat{y}_s &= \tilde{y}^s\left(p_s, p_h, \hat{k}\right) \\ \hat{y}_d &= \tilde{y}^d\left(p_s, p_h, \hat{k}\right) \end{aligned} \tag{56}$$

and thus

$$\hat{y}_r = \tilde{y}^r\left(p_s, p_h, \hat{k}\right) = \frac{\lambda_r}{\lambda_d}\frac{P^d(p_s, p_h)}{P^r(p_s, p_h)}\left(\tilde{y}^d\left(p_s, p_h, \hat{k}\right) - \gamma_d\right) + \gamma_r \tag{57}$$

From the home good market clearing condition (18), we have

$$\tilde{\varepsilon}(p_m, p_h, p_s)\, q = \frac{p_s}{\lambda_s}\bar{Y}^s\left(p_s, p_h\hat{k}\right) \tag{58}$$

where

$$\bar{Y}^s\left(p_s, p_h\hat{k}\right) \equiv \left((1 - \sigma_{ss})\,\tilde{y}^s\left(p_s, p_h, \hat{k}\right) - \sigma_{sm}\tilde{y}^m\left(p_s, p_h, \hat{k}\right) - \sigma_{sc}\tilde{y}^c(p_s, p_h) - \sigma_{sh}\tilde{y}^h(p_s, p_h)\right)$$

and

$$\tilde{\varepsilon}(p_m, p_h, p_s) = \varepsilon\left(p_m, P^r(p_s, p_h), P^d(p_s, p_h), p_s\right)$$

A.3 Appendix C

A.3.1 Mathematica Code

Dynamic Computable General Equilibrium Model of Zambia Food Channels
Combined Land and SH-Modern Channel Simulations

```
Off[ General::spell, General::spell1 ]

(* This file solves a Stone-Geary system. *)

(* Procedure:
        1.Open the Excel SAM file
          "SAM GA Zambia ca1980 ZKW1994.xlsx".
           2. This model is preset to the
          baseline with land and smallholder-
         modern channel scenarios set to zero.
           3. To run the land scenario go to section
          1.1 and change the h2d & h3d & y22d &
  y33d parameters by removing the negative
  number that makes them
  zero.  Then run the program.
   4. To run the smallholder-
 modern channel scerio go to section 1.1 and
  change the tau τ parameter by removing the negative
  number that makes it zero.  Then run the program.
   5. To return the model to the basecase reset all the above
  parameters to zero by subtracting the value from itself.
   6. See the SAM chapter on how to change
  parameter values for a new baseline. *)
```

1.0 Notation

```
(* TT is the length of time over which model is to be solved,
j = 1 = Ind, 22 = Mod Ag., 2 = Mod Ret.,
33 = Trad. Ag., 3 = Trad Ret, 4 =Service(s),
mn = number used to scale data,
H  = land normalized to unity,
LL = number of workers given by data in t = 0,
p1,p22,p2 = border price Ind 1 ,
Modern Ag p22, and Mod. retail p2, resp,
p3,p33 = traditional retail price
  and smallholder farm level price, resp.,
p4 = price of service good,
p2p = price of commercial land,
aπ22,aπ33 = total rent to sector specific resource
  for Modern and Smallholder agr respectively,
KK = stock of capital from growth accounting,
k0 is initial capital stock typically set equal to KK,
C(j)= consumption in t(0), j=1(ind),
2(modern retail),3(traditional retail),4(services),
L(j)= labor in t(0) ,
K(j)= capital in t(0),
Y(j)= output in t(0) j=1(ind),22(mod ag),
2(mod ret),33(smallholder ag),3(trad ret),4(services),
YI22,YI33 = Intermediate Modern ag and smallholder
  ag in modern and traditional retail, respectively,
ρ, θ, x, n, δd = rate of time discount,
intertemporal preference, Harrod rate of tech. change,
rate of growth of the work force, depreciation, respectively,
rk = r +
  δd because no composite capital (see page 128 Roe et al.) *)

(* j=1(industry),j=2(modern food retail),
j=3 (traditional food retail),j=4 (other services),
jj=22 (commercial agriculture) & jj=
  33 (Smallholder agriculture) *)

(* FLAG FOR PREFERENCES: if this is Stone-Geary preferences,
set SG=1, and x = 0 *)

SG = 1;(* S-G flag *)
```

1.1 Data from SAM and Given Parameters

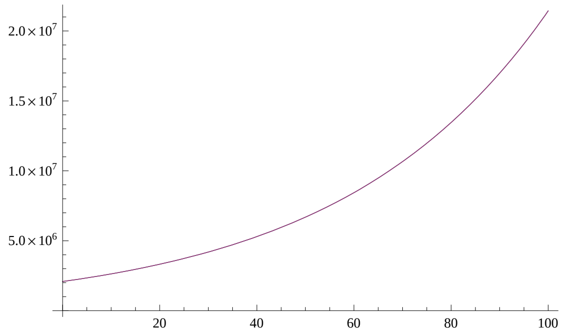
```
(* KK = sKK/mn * 1.5 adjustment *)
```

```
{θ = 1.2, ρ = 0.04, x = 0, n = 0.0233, δd = 0.04, mn = 1 000 000 000,
  LL = 2 086 079, TT = 100 }; (* x = 0.03361 for no SG *)
(* GTAP data is in billions of Zambian Kwacha *)

τ = 0.1 - 0.1 (* 0 = turned off *)
  (* τ is the % of smallholder output marketed
   in the modern food retail channel. *)
0.

(* "c:\documents and settings\lars1102\desktop\Zambia
  SAM AL\SAM GA Zambia ca1980 ZKW1994.xlsx" *)

sam =
 Take[Import["c:\users\lars1102\desktop\SAM GA Zambia ca1980
      ZKW1994.xlsx", {"Data", 65}], 22] //
  TableForm (*Do this to import the first 22 rows of
   data on the 65th tab of the SAM file. *)
```

C1	6.60732×10^{11}	Amounts converted to 1994 ZMK to agree w
C2	6.80846×10^{10}	
C3	5.54416×10^{11}	
C4	1.17121×10^{12}	
SAV	1.72924×10^{11}	
L1	2.10422×10^{11}	
L2	1.50193×10^{10}	
L3	8.06785×10^{10}	
L4	7.14397×10^{11}	
L22	3.34758×10^{10}	
L33	2.90124×10^{11}	
Api22	1.12686×10^{10}	
Api33	6.96299×10^{10}	
KK	8.89832×10^{12}	KK figure is already in 1994 ZMK from wo
K1	5.51735×10^{11}	
K2	1.2396×10^{10}	
K3	4.65648×10^{10}	
K4	4.56821×10^{11}	
K22	6.74191×10^{10}	
K33	6.74191×10^{10}	
YI22	4.06692×10^{10}	
YI33	4.27173×10^{11}	

```
{sC1 = sam[[1, 1]], sC2 = sam[[1, 2]],
  sC3 = sam[[1, 3]], sC4 = sam[[1, 4]], ssav = sam[[1, 5]],
  sL1 = sam[[1, 6]], sL2 = sam[[1, 7]], sL3 = sam[[1, 8]],
  sL4 = sam[[1, 9]], sL22 = sam[[1, 10]], sL33 = sam[[1, 11]],
  sApi22 = sam[[1, 12]], sApi33 = sam[[1, 13]],
  sKK = sam[[1, 14]], sK1 = sam[[1, 15]], sK2 = sam[[1, 16]],
  sK3 = sam[[1, 17]], sK4 = sam[[1, 18]], sK22 = sam[[1, 19]],
  sK33 = sam[[1, 20]], sYI22 = sam[[1, 21]], sYI33 = sam[[1, 22]]};

{C1 = Part[sC1, 2] / mn, C2 = Part[sC2, 2] / mn,
  C3 = Part[sC3, 2] / mn, C4 = Part[sC4, 2] / mn,
  sav = Part[ssav, 2] / mn, L1 = Part[sL1, 2] / mn,
  L2 = Part[sL2, 2] / mn, L3 = Part[sL3, 2] / mn,
  L4 = Part[sL4, 2] / mn, L22 = Part[sL22, 2] / mn,
  L33 = Part[sL33, 2] / mn, aπ22 = Part[sApi22, 2] / mn,
  aπ33 = Part[sApi33, 2] / mn, KK = Part[sKK, 2] / mn * 1.5,
  K1 = Part[sK1, 2] / mn, K2 = Part[sK2, 2] / mn,
  K3 = Part[sK3, 2] / mn, K4 = Part[sK4, 2] / mn,
  K22 = Part[sK22, 2] / mn, K33 = Part[sK33, 2] / mn,
  YI22 = Part[sYI22, 2] / mn, YI33 = Part[sYI33, 2] / mn};

KK (* increased by factor of 1.5. *)

13347.5

{yrstart = 1980, yrcal = 1980, aa[t_] = Exp[(x + n) t]};
(* Use this for output. Yrcal is
 the year calibration starts and is used to
 construct tables. 1995 is the GTAP SAM year. *)

{C1, C2, C3, C4, sav} // N (* Consumption from GTAP SAM *)

{660.732, 68.0846, 554.416, 1171.21, 172.924}

{wkr[t_] = LL Exp[n t]};
(* Total number of workers at growth rate n*t. *)
```

```
Plot[{wkr[t], LL Exp[n t]}, {t, 0, TT}]
```




```
{L1, L2, L3, L4, L22, L33, aπ22, aπ33, KK} //
 N (* Labor expenditures from GTAP SAM. *)
```

```
{210.422, 15.0193, 80.6785, 714.397,
 33.4758, 290.124, 11.2686, 69.6299, 13 347.5}
```

```
{K1, K2, K3, K4, K22, K33} // N
 (* Cost of Capital from GTAP SAM *)
```

```
{551.735, 12.396, 46.5648, 456.821, 67.4191, 67.4191}
```

```
{H2 = 269 005, H3 = 3 041 995}
(* Baseline Land endowment for commercial &
 smallholder agriculture respectively. These
 do not change. See production function scale
 parameters for the change in land area. *)
```

```
{269 005, 3 041 995}
```

```
{h2d = (1 + 2.827080 - 2.827080), h3d = 1 - .25 + .25}
(* 1 = turned off *)(* Change in land area
 for simulation from land data spreadsheet. *)
```

```
{1., 1.}
```

```
{y22d = 1.2840368 - .2840368, y33d = 1 - .04075 + .04075}
(* 1= turned off *)(* Change in output
 for simulation from land data spreadsheet. *)
```

```
{1., 1.}
```

```
{YI22, YI33} // N
 (* Intermediate Inputs from GTAP SAM in CD function *)
```

```
{40.6692, 427.173}
```

```
{K = K1 + K2 + K3 + K4 + K22 + K33, L = L1 + L2 + L3 + L4 + L22 + L33} // N
```

```
{1202.36, 1344.12}
```

```
{R = (K ) / (KK), θ x + ρ + δd} // N
 (* Implied initial r(0) and estimate of rk_ss  *)
```

```
{0.0900811, 0.08}
```

```
KK
```

```
13 347.5
```

```
xx =
 Take[Import["c:\users\lars1102\desktop\SAM GA Zambia ca1980
      ZKW1994.xlsx", {"Data", 66}], 9] //
  TableForm (*Do this to see the first seven rows
   of data on the 9th tab,
  the first row is blank and labels are on the right *)
```

1980.	1981.	1982.	1983.	1984
2106.98	2236.93	2174.01	2131.26	2124
8898.32	9050.25	9134.27	9125.73	9066
2.08608×10^6	2.15591×10^6	2.23964×10^6	2.32405×10^6	2.41
752.211	789.558	784.79	760.058	738.
247.463	267.657	236.388	256.176	270.
973.585	1044.82	970.981	877.538	881.
1949.	1727.	1538.	1464.	1318
378.	270.5	244.75	337.25	269.

```
{gpo = xx[[1, 2]], ko1 = xx[[1, 3]],
  lpo = xx[[1, 4]], gind = xx[[1, 5]], ago = xx[[1, 6]],
  gser = xx[[1, 7]], pcop = xx[[1, 8]], pcor = xx[[1, 9]]};
```

```
{gpo2 = Interpolation[gpo], ko12 = Interpolation[ko1],
  lpo2 = Interpolation[lpo], gind2 = Interpolation[gind],
  ago2 = Interpolation[ago], gser2 = Interpolation[gser],
  pcop2 = Interpolation[pcop], pcor2 = Interpolation[pcor]};
```

```
{ko12[5], lpo2[2], ago2[2]} // N (* test sample to
  verify that above gpo equations pull the right data *)
```

$\{9066.09, 2.15591 \times 10^6, 267.657\}$

```
(* Sector Gross Value of
 Output: verify that these values match GTAP SAM *)

{Y1 = L1 + K1, Y2 = L2 + K2 + YI22, Y3 = L3 + K3 + YI33,
  Y4 = L4 + K4, Y22 = L22 + K22 + aπ22, Y33 = L33 + K33 + aπ33} // N

{762.157, 68.0846, 554.416, 1171.22, 112.164, 427.173}

(* Total payments to capital & labor, from GTAP SAM *)

{K = KK, k0 = KK};
(* Initial capital stock. NOTE: use growth accounting
    to determine stock and adjust R accordingly *)

(* 2. Calibrate utility and production
 function and initial capital stock from Data *)

{CC = C1 + C2 + C3 + C4, λ1 = C1 / CC, λ2 = (C2 / CC),
  λ3 = (C3 / CC), λ4 = 1 - λ1 - λ2 - λ3, γd2 = 0, γd3 = 0 } //
 N(* Expenditure shares (verify w/ GTAP SAM),
 and utility function parameters.  γd2,
 γd3 = subsistence parameters in alternate approach *)

{2454.45, 0.269198, 0.0277393, 0.225882, 0.47718, 0., 0.}

(* &&&&&&&&&&&&&&& Calibrate STONE-
   GEARY demand system &&&&&&&&&&&&&&&& *)

(* US food expenditure,
representing "rich" country, share is 0.0973 *)
```

```
If[SG - 1 == 0, {λfdM = 0.0973 * .11, λfdT = 0.0973 * .89,
  (* Share spent on food if rich.  γmod =
   modern food consumption; γtrad = traditional food
    consumption.  Consumption Shares are from GTAP SAM *)
sg = FindRoot[{λfdM (CC - γmod - γtrad) + γmod - C2 == 0,
     λfdT (CC - γmod - γtrad) + γtrad - C3 == 0},
    {γmod, 124}, {γtrad, 1008}],
{λfdM (CC - γmod - γtrad) + γmod - C2,
    λfdT (CC - γmod - γtrad) + γtrad - C3} /. sg,
{λ11 = C1 / (CC - (γmod /. sg) - (γtrad /. sg)),
  λ44 = C4 / (CC - (γmod /. sg) - (γtrad /. sg))},
{λ1 = λ11, λ2 = λfdM, λ3 = λfdT, λ4 = λ44} // N,
{γd2 = (γmod /. sg), γd3 = (γtrad /. sg)},
(λ11 + λ44 + λfdM + λfdT)}]
 (* Check homogeneity of Epsilon--should =1 *)
```

```
{0.010703, 0.086597, {γmod → 46.3638, γtrad → 378.676},
 {-3.55271 × 10^-15, 0.}, {0.325579, 0.577121},
 {0.325579, 0.010703, 0.086597, 0.577121},
 {46.3638, 378.676}, 1.}
```

```
(* Another approach is to set subsistence
 parameters based on physical need *)

(* {γd2=0,γd3=5040*LL //N *)
(* ZMK needed to meet min cons. of 2$/day But number of
 workers are only 1/2 of population is this is 1$/day *)
(*These are currently set to zero above *)

(* &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&& *)
```

2.0 Factor Elasticities

$$\left\{\alpha = \frac{L1}{(Y1)},\ \beta_1 = \frac{L2}{(Y2)}\right.$$

```
  (* note no -YI22 (intermediate not subtracted) *),
```

$$\left.\beta_2 = \frac{K2}{(Y2)},\ \beta_3 = 1 - \beta_1 - \beta_2\right\} \text{ // N}$$

```
 (* Industry and Modern Food Retail *)
 (* see (2.2)cost functions *)
```

```
{0.276088, 0.220598, 0.182068, 0.597334}
```

```
{0.2760876519205419`, 0.2205977382875606`,
 0.1820678513731826`, 0.5973344103392568`}
{0.276088, 0.220598, 0.182068, 0.597334}
```

$\left\{\gamma_1 = \frac{L3}{(Y3)}\right.$ (* note no -YI33*), $\gamma_2 = \frac{K3}{(Y3)}$, $\gamma_3 = 1 - \gamma_1 - \gamma_2$,
$\left.\delta = \frac{L4}{(Y4)}\right\}$ // N (* Traditional Food Retail and Services *)

```
{0.14552, 0.0839889, 0.770491, 0.609961}
```

$\left\{\epsilon_1 = \frac{L22}{(Y22)}, \epsilon_2 = \frac{K22}{(Y22)}, \epsilon_3 = 1 - \epsilon_1 - \epsilon_2\right\}$ //
N (* Commercial Agriculture *)

```
{0.298456, 0.601079, 0.100466}
```

$\left\{\phi_1 = \frac{L33}{(Y33)}, \phi_2 = \frac{K33}{(Y33)}, \phi_3 = 1 - \phi_1 - \phi_2\right\}$ //
N (* Smallholder Agriculture *)

```
{0.679172, 0.157826, 0.163002}
```

$\{\alpha / (1 - \alpha), \beta_1 / (1 - \beta_1), \gamma_1 / (1 - \gamma_1), \epsilon_1 / (1 - \epsilon_1), \phi_1 / (1 - \phi_1), \delta / (1 - \delta)\}$

```
(* sector factor intensities: high = L intensive;
low = K or H intensive *) (* note that land is much
 bigger factor for smallholder agriculture sector *)
{0.381383, 0.283035, 0.170302, 0.425426, 2.11693, 1.56384}

(* Calculate production function scale parameters *)
(* chg Y4,Y22 =% chg in output based on factor elasticity,
ln 16 of land data.xls. chg in H2,
H3 from ln 15 of land data.xls.  Current
  setting: corporate farm size = 8000 hectares*)
```

$\{A1 = Y1 \big/ \left((L1 / L)^{\alpha} (K1 / R)^{(1-\alpha)}\right)$,
$A2 = Y2 \big/ \left((L2 / L)^{\beta_1} (K2 / R)^{\beta_2}\, YI22^{\beta_3}\right)$,
$A3 = Y3 \big/ \left((L3 / L)^{\gamma_1} (K3 / R)^{(\gamma_2)} (YI33)^{\gamma_3}\right)$,
$A4 = Y4 \big/ \left((L4 / L)^{\delta} (K4 / R)^{(1-\delta)}\right)$,
$A22 = (Y22\, y22d) \big/ \left((L22 / L)^{\epsilon_1} (K22 / R)^{(\epsilon_2)} (H2\, h2d)^{\epsilon_3}\right)$,
$A33 = (Y33\, y33d) \big/ \left((L33 / L)^{\phi_1} (K33 / R)^{(\phi_2)} (H3\, h3d)^{\phi_3}\right)\}$ // N

```
{2.30603, 8.18388, 4.64365, 61.7918, 1.80049, 37.3637}
```

```
(* Calculate net scale parameters *)
```

$$\left\{a_1 = \frac{A1}{\alpha^{-\alpha}\ (1-\alpha)^{(\alpha-1)}},\ a_2 = \frac{A2}{\beta_1{}^{-\beta_1}\ \beta_2{}^{-\beta_2}\ \beta_3{}^{-\beta_3}},\right.$$
$$a_3 = \frac{A3}{\gamma_1{}^{-\gamma_1}\ \gamma_2{}^{-\gamma_2}\ \gamma_3{}^{-\gamma_3}},\ a_4 = \frac{A4}{\delta^{-\delta}\ (1-\delta)^{(\delta-1)}},$$
$$\left. a_{22} = A22\ (\epsilon_1{}^{\epsilon_1})\ (\epsilon_2{}^{\epsilon_2})\ (\epsilon_3{}^{\epsilon_3}),\ a_{33} = A33\ \left(\phi_1{}^{\phi_1}\right)\ \left(\phi_2{}^{\phi_2}\right)\ \left(\phi_3{}^{\phi_3}\right)\right\}\ //\ N$$

```
{1.27929, 3.16081, 2.33051, 31.6585, 0.733709, 15.9725}
```

2.1 Profit Functions

```
(* Commercial Agriculture profit, supply & factor demand *)
```

$$pfm[p22\_,\ w\_,\ rk\_] = (a_{22})^{\frac{1}{\epsilon_3}}\ (p22)^{\frac{1}{\epsilon_3}}\ w^{\frac{-\epsilon_1}{\epsilon_3}}\ rk^{\frac{-\epsilon_2}{\epsilon_3}}\ H2;$$

```
(* Commercial agriculture value added*)
```

$yam[p22\_, w\_, rk\_] = \partial_{p22}\ pfm[p22, w, rk];$ `(* Hotelling's Lemma; value of total commercial farm output*)`
$lam[p22\_, w\_, rk\_] = -\partial_{w}\ pfm[p22, w, rk];$
`(* conditional factor demand--labor *)`
$kam[p22\_, w\_, rk\_] = -\partial_{rk}\ pfm[p22, w, rk];$
`(* conditional factor demand--capital *)`

```
{lam[1, L, R], L22 / L}
{0.0249054, 0.0249054}
```

```
{pfm[1, L, R] - aπ22, lam[1, L, R] - (L22 / L),
 kam[1, L, R] - (K22 / R)}(* check *)
```

$\left\{1.42109\times10^{-14},\ 6.245\times10^{-17},\ 1.93268\times10^{-12}\right\}$

```
{pfm[1, L, R], yam[1, L, R], lam[1, L, R], kam[1, L, R]} //
 N (* check with GTAP SAM for pfm and yam *)
{11.2686, 112.164, 0.0249054, 748.427}
```

```
(*  Smallholder Agriculture profit, supply & factor demand *)
```

$$pft[p33\_,\ w\_,\ rk\_] = (a_{33})^{\frac{1}{\phi_3}}\ (p33)^{\frac{1}{\phi_3}}\ w^{\frac{-\phi_1}{\phi_3}}\ rk^{\frac{-\phi_2}{\phi_3}}\ H3;$$

```
(* Smallholder Agriculture value added*)
```

```
yat[p33_, w_, rk_] = ∂p33 pft[p33, w, rk];
(* Hotelling's Lemma; value of total output *)
lat[p33_, w_, rk_] = -∂w pft[p33, w, rk];
(* conditional factor demand--labor *)
kat[p33_, w_, rk_] = -∂rk pft[p33, w, rk];
(* conditional factor demand--capital *)
```

```
{pft[1, L, R] - aπ33, yat[1, L, R] - Y33,
 lat[1, L, R] - (L33 / L), kat[1, L, R] - (K33 / R)}(* check *)
```

$\{2.27374\times10^{-13}, 1.53477\times10^{-12}, 7.21645\times10^{-16}, 2.50111\times10^{-12}\}$

```
{pft[1, L, R], yat[1, L, R], lat[1, L, R], kat[1, L, R]} //
 N (* check with GTAP SAM for pft and yat *)
```

{69.6299, 427.173, 0.215847, 748.427}

```
{p1 = 1, p22 = 1};(* Model's two exogenous prices,
industry and commercial agriculture. *)
```

2.2 Cost Functions

$$\text{c1[w\_, rk\_]} = \frac{(w^{\alpha}\, rk^{1-\alpha})}{a_1};\text{(* Industry.*)}$$

$$\text{logc1[w\_, rk\_]} = \alpha\,\text{Log[w]} + (1-\alpha)\,\text{Log[rk]} - \text{Log}[a_1];$$

$$\text{c2[w\_, rk\_]} = \frac{(w^{\beta_1}\, rk^{\beta_2}\, p22^{\beta_3})}{a_2};\text{(* Modern food retail *)}$$

$$\text{logc2[w\_, rk\_]} = \beta_1\,\text{Log[w]} + \beta_2\,\text{Log[rk]} + \beta_3\,\text{Log[p22]} - \text{Log}[a_2];$$

$$\text{c3[w\_, rk\_, p33\_]} = \frac{(w^{\gamma_1}\, rk^{\gamma_2}\, p33^{\gamma_3})}{a_3};$$

(* Traditional food retail *)

$$\text{logc3[w\_, rk\_, p33\_]} = \gamma_1\,\text{Log[w]} + \gamma_2\,\text{Log[rk]} + \gamma_3\,\text{Log[p33]} - \text{Log}[a_3];$$

$$\text{c4[w\_, rk\_]} = \frac{(w^{\delta}\, rk^{1-\delta})}{a_4};\text{(* Services *)}$$

$$\text{logc4[w\_, rk\_]} = \delta\,\text{Log[w]} + (1-\delta)\,\text{Log[rk]} - \text{Log}[a_4];$$

3.0 From the Zero Profit Conditions

```
(* CAUTION this may not work for value added prices with I-
  O > 0 because not log-linear in pv *)

zerop =
 Solve[{logc1[w, rk] - Log[p1] == 0, logc2[w, rk] - Log[p2] == 0,
    logc3[w, rk, p33] - Log[p3] == 0, logc4[w, rk] - Log[p4] == 0},
   {w, rk, p2, p3, Reals}] // N
(* Four zero profit condition equations;
four variables. Prosp. Eq. 12*)
```

$$\left\{\left\{w \to 1344.12\, p4^{2.16823},\ rk \to \frac{0.0900811}{p4^{0.826924}},\ p2 \to 1.\, p4^{0.32775},\ p3 \to 1.\, p33^{0.770491}\, p4^{0.246068}\right\}\right\}$$

```
(* redefine prices in terms of p4 and p33 *)
ww[p4_] = (w /. zerop)[[1]];  (* cost of labor *)
rrk[p4_] = (rk /. zerop)[[1]];
(* interest cost on capital (return on capital) *)
pp2[p4_] = (p2 /. zerop)[[1]];(* price modern food retail *)
pp3[p33_, p4_] = (p3 /. zerop)[[1]];
(* price traditional food retail *)

{ww[1] - L, rrk[1] - R, pp2[1] - 1, pp3[1, 1] - 1}(* check *)
```

$$\left\{-2.72848\times 10^{-12},\ 1.249\times 10^{-16},\ -5.55112\times 10^{-16},\ -6.66134\times 10^{-16}\right\}$$

3.1 Intra-temporal Equations

```
(* Redefine the 2 agricultural
 sectors in terms of value added prices *)

pπm[p4_] = pfm[p22, ww[p4], rrk[p4]];
(* commercial agriculture; p22 = 1; p4 endogenous *)

ym[p4_] = yam[p22, ww[p4], rrk[p4]];
(* commercial farm output *)
lm[p4_] = lam[p22, ww[p4], rrk[p4]];
km[p4_] = kam[p22, ww[p4], rrk[p4]];
```

```
{pπm[1] - aπ22, lm[1] - (L22 / L),
  km[1] - (K22 / R), ym[1] - (Y22)} // N(* check *)
```

$\{-1.24345\times10^{-14},\ 5.89806\times10^{-17},\ -7.95808\times10^{-13},\ 0.\}$

```
pπt[p33_, p4_] = pft[p33, ww[p4], rrk[p4]];
(* smallholder agriculture; p33, p4 endogenous *)

yt[p33_, p4_] = yat[p33, ww[p4], rrk[p4]];
(* smallholder farm output *)
lt[p33_, p4_] = lat[p33, ww[p4], rrk[p4]];
kt[p33_, p4_] = kat[p33, ww[p4], rrk[p4]];

{pπt[1, 1] - aπ33, lt[1, 1] - (L33 / L), kt[1, 1] - (K33 / R)}
(* check *)
```

$\{7.10543\times10^{-13},\ 2.72005\times10^{-15},\ 6.9349\times10^{-12}\}$

4.1 Define the elements and the supply equations using the factor market clearing equations

```
A1l[w_, rk_] = ∂w c1[w, rk];(* Industry labor demand *)
(* 1= the number one; l= the letter l *)
a1l[p4_] = A1l[ww[p4], rrk[p4]];
(* labor demand in terms of p4 *)
A1k[w_, rk_] = ∂rk c1[w, rk]; (* capital demand  *)
a1k[p4_] = A1k[ww[p4], rrk[p4]];
(* capital demand in terms of p4 *)

A2l[w_, rk_] = ∂w c2[w, rk];
(* Modern food retail labor demand *)
a2l[p4_] = A2l[ww[p4], rrk[p4]];
(* labor demand in terms of p4 *)
A2k[w_, rk_] = ∂rk c2[w, rk]; (* capital demand *)
a2k[p4_] = A2k[ww[p4], rrk[p4]];
(* capital demand in terms of p4 *)

A3l[w_, rk_, p33_] = ∂w c3[w, rk, p33];
(* Traditional food retail labor demand *)
a3l[p33_, p4_] = A3l[ww[p4], rrk[p4], p33];
(* labor demand in terms of p4 *)
A3k[w_, rk_, p33_] = ∂rk c3[w, rk, p33]; (* capital demand *)
a3k[p33_, p4_] = A3k[ww[p4], rrk[p4], p33];
(* capital demand in terms of p4 *)

A4l[w_, rk_] = ∂w c4[w, rk];(* Service labor demand *)
a4l[p4_] = A4l[ww[p4], rrk[p4]];
(* labor demand in terms of p4 *)
A4k[w_, rk_] = ∂rk c4[w, rk];(* capital demand *)
a4k[p4_] = A4k[ww[p4], rrk[p4]];
(* capital demand in terms of p4 *)


(* The link between modern retail
 supply and traditional retail supply via the
 expenditure ratio. This is Prosp. Eq. 16 *)
```

$$\text{yY2[p33\_, p4\_, y3\_]} = \left(\frac{\lambda_2}{\lambda_3}\right)\left(\frac{\text{pp3[p33, p4]}}{\text{pp2[p4]}}\right)(\text{y3} - \gamma\text{d3}) + \gamma\text{d2};$$

```
(* Modern food retail output depends on
 consumption shares and y3 output. Prosp. Eq. 16 *)
```

```
{yY2[1, 1, Y3], Y2, yY2[1, 1, Y3] - Y2} (* check *)
```

{68.0846, 68.0846, 4.26326 × 10^-14}

4.2 Form the factor market clearing conditions (Prosp. Eq. 13 and 14)

```
lmkt[p33_, p4_, y1_, y3_, y4_] =
  a1l[p4] y1 + a2l[p4] yY2[p33, p4, y3] +
   a3l[p33, p4] y3 + a4l[p4] y4 + lm[p4] + lt[p33, p4] - 1;

kmkt[p33_, p4_, y1_, y3_, y4_, k_] =
  a1k[p4] y1 + a2k[p4] yY2[p33, p4, y3] +
   a3k[p33, p4] y3 + a4k[p4] y4 + km[p4] + kt[p33, p4] - k;

(* Now market clearing for traditional supply channel *)

dmy33[w_, rk_, p33_, y3_] = ∂p33 c3[w, rk, p33] y3 (1 - τ);
(* Derived demand for smallholder
 agriculture output y33. Prosp. Eq. 18b. *)

dmxy32[w_, rk_, p33_, y3_] = ∂p33 c3[w, rk, p33] y3 τ;
(* Derived modern channel (modern food retail or export)
 demand for smallholder agriculture output. *)

πTt[p33_, p4_, y3_] = yt[p33, p4] - dmy33[ww[p4], rrk[p4], p33, y3]
 (*-dmxy32[ww[p4],rrk[p4],p33,y3]*);
(* clearing of traditional market
 channel: smallholder agriculture  supply -
   derived traditional retail
    demand (*- derived modern (ret or export) demand = 0)*).
     Smallholder agriculture production transferred to
    modern channel is excluded in this market clearing.
     NOTE we are subtracting for intermediate
    use ai3333 if other intermeidate uses
    need to subtract here. Prosp. Eq. 15 *)

(* Testing: do markets clear? *)

{yt[1, 1], dmy33[ww[1], rrk[1], 1, Y3],
 dmxy32[ww[1], rrk[1], 1, Y3], yt[1, 1] -
  dmy33[ww[1], rrk[1], 1, Y3] - dmxy32[ww[1], rrk[1], 1, Y3]}
(* verify with GTAP SAM. Smallholder
 agriculture output should not fall.  *)
```

{427.173, 427.173, 0., 4.718 × 10^-12}

```
{lmkt[1, 1, Y1, Y3, Y4], kmkt[1, 1, Y1, Y3, Y4, K], πTt[1, 1, Y3]}
(* check *)
```

```
{3.9968 × 10^-15, -1.36424 × 10^-11, 4.66116 × 10^-12}
```

4.3 Derive Supply Equations

```
soly = Solve[
   {lmkt[p33, p4, y1, y3, y4] == 0, kmkt[p33, p4, y1, y3, y4, k] == 0,
    πTt[p33, p4, y3] == 0}, {y1, y3, y4}];
 (* L, K, and intermediate agricultural supply
 for traditional channel;
solving for Industry, traditional food retail,
and services output *)
```

```
yy1[p33_, p4_, k_] = (y1 /. soly)[[1]];(* Industry *)
(* p33, p4, k are endogenous variables *)
yy3[p33_, p4_] = (y3 /. soly)[[1]];
(* Traditional food retail *)
yy4[p33_, p4_, k_] = (y4 /. soly)[[1]];(* Services *)
yy2[p33_, p4_] = yY2[p33, p4, yy3[p33, p4]];
(* Modern Retail supply. Depends on y2 consumption
 in yY2. This is updated for new SH supply in the
 Commercial Agriculture Sector section below. *)
```

```
{yy3[1, 1], yy2[1, 1]}
```

```
{554.416, 68.0846}
```

```
{yy1[1, 1, K] - Y1, yy3[1, 1] - Y3, yy4[1, 1, K] - Y4,
 yy2[1, 1] - Y2, yt[1, 1] - Y33}(* check *)
```

```
{8.29914 × 10^-12, 6.0254 × 10^-12,
 -1.40972 × 10^-11, 7.81597 × 10^-13, 4.49063 × 10^-12}
```

```
{yy1[1, 1, K], Y1, yy3[1, 1], Y3, yy4[1, 1, K], Y4, yy2[1, 1],
 Y2, yt[1, 1], Y33} (* Sector outputs *) (* check *)
```

```
{762.157, 762.157, 554.416, 554.416, 1171.22,
 1171.22, 68.0846, 68.0846, 427.173, 427.173}
```

```
(* Commercial Agriculture sector
 Derived Demand by Modern Retail *)
```

```
Y222[w_, rk_, p2p_] = (∂p2p (w^β1 rk^β2 p2p^β3)/a2);
(* Modern retail derived demand for commercial agriculture
  per retail unit. p2p = price commercial land;
β3= commercial land factor elasticity *)

y222[p33_, p4_] = Y222[ww[p4], rrk[p4], p22] yy2[p33, p4];
(* Modern food retail derived demand for
 commercial agriculture.  Substitute cost of
 capital with endogenous p4. Prosp. Eq. 18a. *)

{Y222[1, 1, 1], yy2[1, 1]}(* check *)

{0.188981, 68.0846}

{y222[1, 1] - YI22, y222[1, 1], yy2[1, 1], YI22}(* check *)

{4.47642 × 10^-13, 40.6692, 68.0846, 40.6692}

yy3[1, 1]

554.416


(* Smallholder agriculture sector
 Derived Demand by traditional food retail *)

Y333[w_, rk_, p33_] = (∂p33 c3[w, rk, p33]);
(* Traditional retail derived demand for
 smallholder agriculture per retail unit *)

yy32[p33_, p4_] = τ yt[p33, p4] / (Y333[ww[p4], rrk[p4], p33]);
(* modern channel final demand for
 food using smallholder agriculture supply *)

y332[p33_, p4_] = Y333[ww[p4], rrk[p4], p33] yy32[p33, p4];
(* Modern Channel derived demand
 for smallholder agriculture input *)
(*sub rrk[p4] for rk. Prosp. Eq. 18b.  This is a
  plug to make the tradebalance TB=0. *)

yy3[p33_, p4_] = (1 - τ) (y3 /. soly)[[1]] - yy32[p33, p4];
(* Update yy3 traditional retail output for smallholder
 agriculture production sold to modern channel. *)

{τ yt[1, 1], y332[1, 1]}

{0., 0.}
```

```
{yy2[1, 1], yy32[1, 1], yy2[1, 1] + yy32[1, 1]}
(* should equal modern food retail output on GTAP SAM *)
{68.0846, 0., 68.0846}

y333[p33_, p4_] = Y333[ww[p4], rrk[p4], p33] yy3[p33, p4];
(* Traditional food retail derived
 demand for smallholder agriculture input *)
(*sub rrk[p4] for rk. Prosp. Eq. 18b. *)

{yy3[1, 1], yy32[1, 1], y333[1, 1], y332[1, 1]}
{554.416, 0., 427.173, 0.}

{yy3[1, 1], y333[1, 1]}
{554.416, 427.173}

{yy32[1, 1], y332[1, 1]}
{0., 0.}

{y333[1, 1] + y332[1, 1] - YI33, y333[1, 1], y332[1, 1], YI33}
(* check *)
{4.37694 × 10^-12, 427.173, 0., 427.173}

y33f[p33_, p4_] = yt[p33, p4] - y333[p33, p4] - y332[p33, p4];
(* smallholder agriculture output -
 traditional food retail derived demand -
 modern food retail derived transfer demand *)

{y33f[1, 1], yt[1, 1], y333[1, 1], y332[1, 1]}
(* supply = derived demand traditional food retail +
  derived demand modern food retail;
p33=p4=1 for test; should = SAM.  check *)
{5.68434 × 10^-14, 427.173, 427.173, 0.}


(* Update Commercial farm sector Derived
 Demand by Modern food retail for changes in yy2
 for changes in yy3 equation in SM section above*)

yy2[p33_, p4_] = yY2[p33, p4, yy3[p33, p4]];
```

```
Y222[w_, rk_, p2p_] = (∂p2p (w^β1 rk^β2 p2p^β3) / a2);
(* Modern food retail derived demand for commercial
  agriculture per retail unit. p2p = price commercial land;
β3= commercial land factor elasticity *)
```

$$\mathtt{Y222[w\_, rk\_, p2p\_]} = \left(\partial_{p2p} \frac{\left(w^{\beta_1}\, rk^{\beta_2}\, p2p^{\beta_3}\right)}{a_2}\right);$$

```
y222[p33_, p4_] = Y222[ww[p4], rrk[p4], p22] yy2[p33, p4];
(* Modern food retail derived demand for
 commercial agriculture output.  Substitute cost
 of capital with endogenous p4. Prosp. Eq. 18a. *)

{Y222[1, 1, 1], yy2[1, 1]}(* check *)
{0.188981, 68.0846}

{y222[1, 1] - YI22, y222[1, 1], yy2[1, 1], YI22}(* check *)
{4.47642 × 10^-13, 40.6692, 68.0846, 40.6692}

{yy3[1, 1], yy2[1, 1]}
{554.416, 68.0846}
```

5.0 Solve for the Steady State

```
(* Construct Prosp. Eq. 24 *)
```

$$\mathtt{epslionQ[p33\_, p4\_, k\_]} = \frac{p4}{\lambda_4}\,\mathtt{yy4[p33, p4, k]};$$

```
(* Expenditure *)

exps[p33_, p4_, k_] =
  epslionQ[p33, p4, k] + γd2 pp2[p4] + γd3 pp3[p33, p4];

{γd2, γd3}
{46.3638, 378.676}

{CC - exps[1, 1, K], CC, exps[1, 1, K]}
(* check (should agree with GTAP SAM) *)
{-0.00709184, 2454.45, 2454.45}
```

```
dmdy33[w_, rk_, p33_, p3_, p4_, k_] =
  (1 - τ) (∂p33 c3[w, rk, p33]) ((λ3/λ4) (p4/p3) yy4[p33, p4, k] + γd3);
 (* Traditional food retail derived demand
 for smallholder output *)

dmdy32[w_, rk_, p33_, p3_, p4_, k_] =
  τ (∂p33 c3[w, rk, p33]) ((λ3/λ4) (p4/p3) yy4[p33, p4, k] + γd3);
 (* Modern channel derived demand for smallholder output. *)

dmdY33[p33_, p4_, k_] =
  dmdy33[ww[p4], rrk[p4], p33, pp3[p33, p4], p4, k];
 (* derived traditional food retail demand for
 smallholder agriculture supply y3 *)

dmdY32[p33_, p4_, k_] =
  dmdy32[ww[p4], rrk[p4], p33, pp3[p33, p4], p4, k];
 (* derived modern channel demand for
 smallholder agriculture supply y3 *)

exdmd33[p33_, p4_, k_] =
  {yt[p33, p4] - dmdY33[p33, p4, k] - dmdY32[p33, p4, k]};
 (* traditional channel agriculture supply
   equals derived traditional retail demand &
 derived modern channel demand. *)

{exdmd33[1, 1, K], yt[1, 1], dmdY33[1, 1, K], dmdY32[1, 1, K]}
(* check *)

{{-0.000473183}, 427.173, 427.173, 0.}

{dmdY33[1, 1, K] + dmdY32[1, 1, K]}

{427.173}

(* The budget constraint Prosp. Eq 24*)

bud[p33_, p4_, k_] = ww[p4] + k (rrk[p4] - x - δd - n) +
   pπm[p4] + pπt[p33, p4] - exps[p33, p4, k];
(* -x-δd-n not in SAM. These make up the difference
  in the bud check below because the SAM is static. *)

{x - δd - n, x, δd, n}

{-0.0633, 0, 0.04, 0.0233}
```

```
{bud[1, 1, K] - sav, bud[1, 1, K], sav} // N (* check *)
{-844.902, -671.979, 172.924}

{ww[1], K (rrk[1]), K (rrk[1] - x - δd - n), pπm[1],
 pπt[1, 1], exps[1, 1, K]} (* check with GTAP SAM *)
{1344.12, 1202.36, 357.46, 11.2686, 69.6299, 2454.45}

(* Euler equation for steady state *)

sr = FindRoot[rrk[p4] - ρ - δd - θ x == 0, {p4, 1}] (* Prosp. Eq. 26*)
{p4 → 1.15434}

s1 = FindRoot[{bud[p33, (p4 /. sr), k] == 0,
   exdmd33[p33, (p4 /. sr), k] == 0}, {p33, 1}, {k, K}]
{p33 → 1.23759, k → 30637.2}

lmkt[p33, (p4 /. sr), yy1[p33, (p4 /. sr), k],
  yy3[p33, (p4 /. sr)], yy4[p33, (p4 /. sr), k]] /.
 s1 (* Labor market clearing check *)
1.11022 × 10^-15

kmkt[p33, (p4 /. sr), yy1[p33, (p4 /. sr), k],
  yy3[p33, (p4 /. sr)], yy4[p33, (p4 /. sr), k], k] /.
 s1 (* K capital market clearing check *)
1.81899 × 10^-11

{exps[p33 /. s1, (p4 /. sr), k /. s1], CC // N
 (* expt[p33,(p4/.sr)]/.s1,expm[p33,(p4/.sr)]/.s1*)}
(* Steady State and t=0 levels of expenditure  *)
{2434.51, 2454.45}

{yy1[p33 /. s1, (p4 /. sr), k /. s1]
 (* Ind *),  (* Steady state levels of output *)
 yy3[p33 /. s1, (p4 /. sr)], (* Traditional food retail *)
 yy4[p33 /. s1, (p4 /. sr), k /. s1], (* Services *)
 yy2[p33 /. s1, (p4 /. sr)](* Modern food retail *)}
{2516.42, 515.118, 961.723, 66.006}

(* Steady state levels of consumption of final goods *)
```

```
cc1[p33_, p4_, k_] = λ1 (1/p1) epslionQ[p33, p4, k]; (* Industry *)
cc2[p33_, p4_, k_] = λ2 epslionQ[p33, p4, k] / pp2[p4] + γd2;
(* Modern food retail *)
cc3[p33_, p4_, k_] = λ3 epslionQ[p33, p4, k] / pp3[p33, p4] + γd3;
(* Traditional food retail *)
cc4[p33_, p4_, k_] = λ4 (1/p4) epslionQ[p33, p4, k]; (* Services *)

{(cc1[p33, (p4 /. sr), k] /. s1) - (yy1[p33, (p4 /. sr), k] /. s1),
 (* cc1=Ind SS cons; yy1 Ind SS output; (-)→ export  ??? *)
 ym[(p4 /. sr)] + (y332[p33, (p4 /. sr)] /. s1) -
  (y222[p33, (p4 /. sr)] /. s1), (* ym=comm ag output;
 y222=modern retail demand. So, (-)→ imports *)
 (cc2[p33, (p4 /. sr), k] /. s1) - (yy2[p33, (p4 /. sr)] /. s1),
 (cc3[p33, (p4 /. sr), k] /. s1) - (yy3[p33, (p4 /. sr)] /. s1),
 (cc4[p33, (p4 /. sr), k] /. s1) - (yy4[p33, (p4 /. sr), k] /. s1)}
```

$\{-1890.14,\ 49.1928,\ -5.68434\times10^{-14},\ -3.41061\times10^{-13},\ 0.\}$

6.0 Differential Equations

```
(* Euler qdot/q =
 (1/θ)(rk-ρ-δd-θx -[λ4(p4dot/p4)+λ3(p3dot/p3)+λ2(p2dot/p2)])*)

p2dot[p4_, dp4_] = ∂p4 pp2[p4] dp4;(* p2 dot eqtn *)
p3dot[p33_, dp33_, dp4_] = (∂p33 pp3[p33, p4]) dp33 +
   (∂p4 pp3[p33, p4]) dp4;(* p3 dot eqtn *)

(* Make substitution to obtain (Prosp. Eq. 29): *)

euler[p33_, p4_, dp33_, dp4_] = (1/θ) (rrk[p4] - ρ - δd - θ x +
     (θ - 1) (λ4 (dp4/p4) + λ3 (p3dot[p33, dp33, dp4] / pp3[p33, p4]) +
        λ2 (p2dot[p4, dp4] / pp2[p4])));

(* The LHS of the home-good market equation *)
```

```
eDpt[p33_, p4_, k_, dp33_, dp4_] =
  epslionQ[p33, p4, k] euler[p33, p4, dp33, dp4];

(* Obtain the RHS of the home good equation by
 differentiating service good p4/λ4 yy4[p33,p4,k] *)
edSt[p33_, p4_, k_, dp33_, dp4_, dk_] =
  (∂p33 exps[p33, p4, k]) dp33 +
   (∂p4 exps[p33, p4, k]) dp4 + (∂k exps[p33, p4, k] dk);

(* Set the two equal *)
edteql[p33_, p4_, k_, dp33_, dp4_, dk_] =
  eDpt[p33, p4, k, dp33, dp4] - edSt[p33, p4, k, dp33, dp4, dk];

(* Market clearing traditional channel *)

exp[p33_, p4_, k_, dp33_, dp4_, dk_] =
  (∂p33 exdmd33[p33, p4, k]) dp33 +
   (∂p4 exdmd33[p33, p4, k]) dp4 + (∂k exdmd33[p33, p4, k]) dk;

(*Check Solve diff to verify if it
 provides same sol as steady state above *)
FindRoot[{exp[p33, p4, k, 0, 0, 0] == 0,
  edteql[p33, p4, k, 0, 0, 0] == 0, bud[p33, p4, k] == 0},
 {p33, (p33 /. s1)}, {p4, (p4 /. sr)}, {k, (k /. s1)}]
{p33 → 1.23759, p4 → 1.15434, k → 30 637.2}


(* The three dot (change) equations: p33, p4, k *)

sdot = Solve[{edteql[p33, p4, k, dp33, dp4, dk] == 0,
    exp[p33, p4, k, dp33, dp4, dk] == 0}, {dp33, dp4}];

doT33[p33_, p4_, k_, dk_] = (dp33 /. sdot)[[1]];
doT4[p33_, p4_, k_, dk_] = (dp4 /. sdot)[[1]];
doTk[p33_, p4_, k_, dk_] = (dk /. sdot)[[1]];

pdot33[p33_, p4_, k_] = doT33[p33, p4, k, bud[p33, p4, k]];
(* smallholder p33 *)

pdot4[p33_, p4_, k_] = doT4[p33, p4, k, bud[p33, p4, k]];
(* services p4 *)

kdot[p33_, p4_, k_] = doTk[p33, p4, k, bud[p33, p4, k]];
(* capital k *)
```

```
{pdot33[p33 /. s1, p4 /. sr, k /. s1],
 pdot4[p33 /. s1, p4 /. sr, k /. s1],
 kdot[p33 /. s1, p4 /. sr, k /. s1]}
(* growth rates from the ln[182] p33 p4 k
  dot equations should = zero at ss. check *)
```

$\{5.65173 \times 10^{-17}, 2.92385 \times 10^{-17}, 4.54747 \times 10^{-13}\}$

7.0 Transition Analysis

```
{kss = k /. s1, p33ss = p33 /. s1, p4ss = p4 /. sr}
```

{30 637.2, 1.23759, 1.15434}

```
a11 =
  D[bud[p33, p4, k], k] /. {(k → kss), (p33 → p33ss), (p4 → p4ss)};
a12 = D[bud[p33, p4, k], p33] /.
   {(k → kss), (p33 → p33ss), (p4 → p4ss)};
a13 = D[bud[p33, p4, k], p4] /.
   {(k → kss), (p33 → p33ss), (p4 → p4ss)};

a21 = D[pdot33[p33, p4, k], k] /.
   {(k → kss), (p33 → p33ss), (p4 → p4ss)};
a22 = D[pdot33[p33, p4, k], p33] /.
   {(k → kss), (p33 → p33ss), (p4 → p4ss)};
a23 = D[pdot33[p33, p4, k], p4] /.
   {(k → kss), (p33 → p33ss), (p4 → p4ss)};

a31 = D[pdot4[p33, p4, k], k] /.
   {(k → kss), (p33 → p33ss), (p4 → p4ss)};
a32 = D[pdot4[p33, p4, k], p33] /.
   {(k → kss), (p33 → p33ss), (p4 → p4ss)};
a33 = D[pdot4[p33, p4, k], p4] /.
   {(k → kss), (p33 → p33ss), (p4 → p4ss)};

m = {{a11, a12, a13}, {a21, a22, a23}, {a31, a32, a33}}
```

$\{\{0.131327, 7217.35, -24754.8\},$
$\{1.64754 \times 10^{-6}, 0.0905435, -0.325487\},$
$\{1.02431 \times 10^{-6}, 0.056293, -0.200629\}\}$

```
MatrixForm[m]
```

$$\begin{pmatrix} 0.131327 & 7217.35 & -24754.8 \\ 1.64754\times 10^{-6} & 0.0905435 & -0.325487 \\ 1.02431\times 10^{-6} & 0.056293 & -0.200629 \end{pmatrix}$$

```
(* Eigenvalues and Eigenvectiors of Jacobian *)

{ev1, ev2, ev3} = Eigenvalues[m]
```

$\{0.0413986, -0.0201568, -6.28709\times 10^{-17}\}$

```
{{v1, v2, v3}, {wv1, wv2, wv3}, {vv1, vv2, vv3}} = Eigenvectors[m]
```

$\{\{1., 0.0000101661, 6.59673\times 10^{-6}\},$
$\{-1., -0.0000217823, -0.0000124701\},$
$\{1., -0.0000181961, -2.08498\times 10^{-19}\}\}$

```
If[ev1 < -0.0001, {slope1, slope2} = {v2 / v1, v3 / v1}]
If[ev2 < -0.0001, {slope1, slope2} = {wv2 / wv1, wv3 / wv1}]
If[ev3 < -0.0001, {slope1, slope2} = {vv2 / vv1, vv3 / vv1}]
```

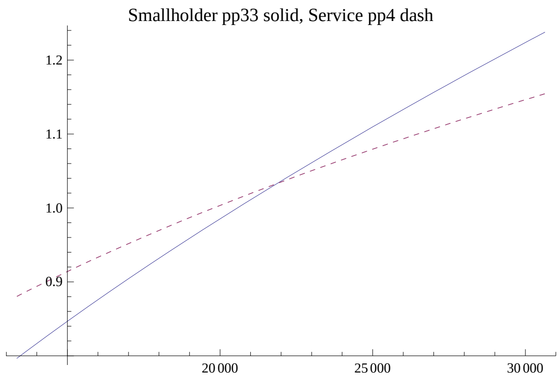
{0.0000217823, 0.0000124701}

```
s2 = NDSolve[{p33'[k] == If[k == kss, slope1,
      (pdot33[p33[k], p4[k], k] / bud[p33[k], p4[k], k])],
    p4'[k] == If[k == kss, slope2,
      (pdot4[p33[k], p4[k], k] / bud[p33[k], p4[k], k])],
    p33[kss] == (p33ss), p4[kss] == (p4ss)}, {p33, p4},
   {k, k0, kss}, Method -> {"DiscontinuityProcessing" -> False}]
  (* the 3 differential equations *)
```

```
{{p33 -> InterpolatingFunction[{{13 347.5, 30 637.2}}, <>],
  p4 -> InterpolatingFunction[{{13 347.5, 30 637.2}}, <>]}}
```

```
pp33[k_] = p33[k] /. s2[[1, 1]];
(* Smallholder agriculture price *)
pp4[k_] = p4[k] /. s2[[1, 2]]; (* Services price *)
```

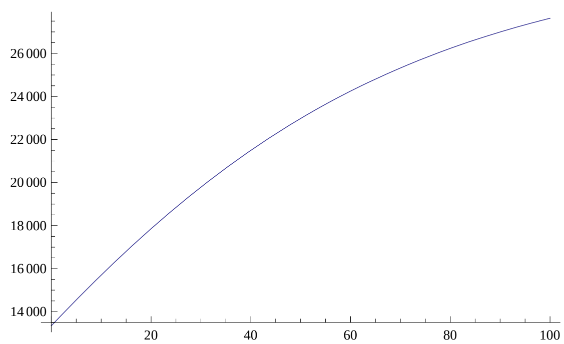
```
Plot[{pp33[k](*solid*), pp4[k]}(*dash*), {k, k0, kss},
 PlotLabel → "Smallholder pp33 solid, Service pp4 dash",
 PlotStyle → {Thin, Dashing[{0.01}]}]
```



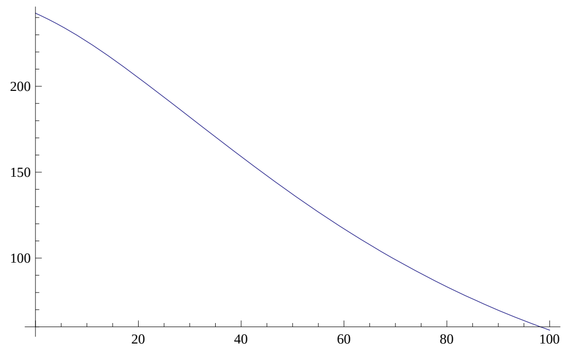
7.1 Integrate Forward kdot using Policy Function

```
st2 = NDSolve[{k'[t] == bud[(p33[k[t]] /. s2[[1, 1]]),
      (p4[k[t]] /. s2[[1, 2]]), k[t]], k[0] == (k0)},
  k, {t, 0, TT}] (* may have to change time
  frame to better fit model *)
{{k → InterpolatingFunction[{{0., 100.}}, <>]}}
```

```
Plot[Evaluate[{k[t]} /. st2], {t, 0, TT}]
```



```
Plot[Evaluate[{k'[t]} /. st2], {t, 0, TT}]
```



8.0 The Model is Now Solved. Now, calculate remaining variables.

8.1 Express the 3 endogenous variables as functions of time but note many are in per worker “hat” form

```
kk[t_] = (k[t] /. st2)[[1]];(* capital stock *)

p33t[t_] = pp33[kk[t]];
(* Price paid to smallholder farmers for output *)

p33t[5]

0.833132

p4t[t_] = pp4[kk[t]];(* Price of services *)

{kk[0], KK, p33t[0], p4t[0]} (* check *)

{13 347.5, 13 347.5, 0.796743, 0.88034}

(* %%%%%%%%%%%% *)

wt[t_] = ww[p4t[t]];
rkt[t_] = rrk[p4t[t]];
p2t[t_] = pp2[p4t[t]];(* price modern food retail *)
p3t[t_] = pp3[p33t[t], p4t[t]];
(* price traditional food retail *)


(* Commercial Agriculture *)
```

```
πmt[t_] = pπm[p4t[t]];
ymt[t_] = ym[p4t[t]];
lmt[t_] = lm[p4t[t]];
kmt[t_] = km[p4t[t]];
{H2 h2d, h2d}
(* hectares of commercial agriculture land area;
change in commercial agriculture land area *)
πmh[t_] = πmt[t] / (H2 h2d);
```

{269 005., 1.}

```
(* Smallholder Agriculture *)

πtt[t_] = pπt[p33t[t], p4t[t]];
ytt[t_] = yt[p33t[t], p4t[t]];
ltt[t_] = lt[p33t[t], p4t[t]];
ktt[t_] = kt[p33t[t], p4t[t]];
ytxt[t_] = ((τ yt[p33t[t], p4t[t]]) / p33t[t]) p22;
(* Smallholder agriculture output tranferred to Modern
 Food Retail and adjusted for price differential
 between p33t and p22 since this smallholder
 production is sold for price p22 and not p33t.  *)
{H3 h3d, h3d} (* hectares of smallholder agriculture land
 area; change in smallholder agriculture land area *)
πth[t_] = πtt[t] / (H3 h3d);
```

$\{3.042 \times 10^6, 1.\}$

```
{τ yt[1, 1] - y332[1, 1], τ yt[1, 1], y332[1, 1]} (* check *)
```

{0., 0., 0.}

```
(* Final good supplies *)

yy1t[t_] = yy1[p33t[t], p4t[t], kk[t]];(* Industry *)
yy3t[t_] = yy3[p33t[t], p4t[t]];(* Traditional food retail *)
yy4t[t_] = yy4[p33t[t], p4t[t], kk[t]];(* Services *)
yy2t[t_] = yy2[p33t[t], p4t[t]]; (* Modern food retail *)


(* Derived demands *)

y222t[t_] = y222[p33t[t], p4t[t]];(* Modern food
 retail derived demand for modern channel produce *)
```

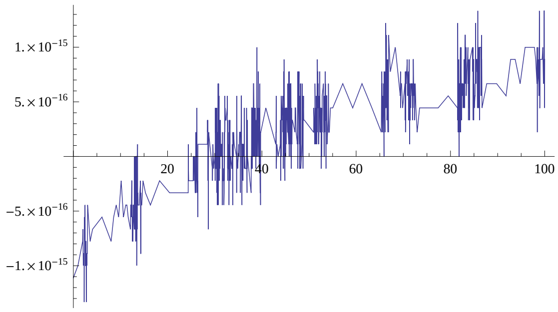
```
y333t[t_] = y333[p33t[t], p4t[t]];
(* Traditional food retail derived
 demand for smallholder agriculture produce *)

y332t[t_] = y332[p33t[t], p4t[t]];
(* Modern food retail derived demand
 for smallholder agriculture produce. *)

(* Labor demands in final good sectors *)

l1t[t_] = a1l[p4t[t]] yy1t[t];
l2t[t_] = a2l[p4t[t]] yy2t[t];
l3t[t_] = a3l[p33t[t], p4t[t]] yy3t[t];
l4t[t_] = a4l[p4t[t]] yy4t[t];

{yy3t[0], yy2t[0], a2l[1]}

{482.848, 57.2844, 0.000164121}

(* Capital demands in final good sectors *)

k1t[t_] = a1k[p4t[t]] yy1t[t];
k2t[t_] = a2k[p4t[t]] yy2t[t];
k3t[t_] = a3k[p33t[t], p4t[t]] yy3t[t];
k4t[t_] = a4k[p4t[t]] yy4t[t];

(* Household expendeiture, price index,
and utility index p33t[t_]*)

hhexp[t_] = exps[p3t[t], p4t[t], kk[t]];(* HH expenditure *)

pindex[t_] = p1^λ1 (p2t[t])^λ2 (p3t[t])^λ3 (p4t[t])^λ4;
(* Price index *)

c1[t_] = cc1[p33t[t], p4t[t], kk[t]];
c2[t_] = cc2[p33t[t], p4t[t], kk[t]];
c3[t_] = cc3[p33t[t], p4t[t], kk[t]];
c4[t_] = cc4[p33t[t], p4t[t], kk[t]];
hq[t_] = epslionQ[p33t[t], p4t[t], kk[t]] / pindex[t];
(* Felicity *)
```

```
shrc2[t_] = (p2t[t] c2[t]) / (hhexp[t]);(* Share spent on modern food*)

shrc3[t_] = (p3t[t] c3[t]) / (hhexp[t]);
(* Share spent on traditional food *)


gdpt[t_] = wt[t] + (rkt[t]) kk[t] + πmt[t] + πtt[t];
(* GDP at time t *)
savt[t_] = bud[p33t[t], p4t[t], kk[t]] + kk[t] (x + δd + n);
(* savings at time t *)
exy1[t_] = yy1t[t] - savt[t] - c1[t];
(* excess demand for industrial goods. + = export,
- = import *)
exym[t_] = ymt[t] + ytxt[t] - y222t[t] - y332t[t];
(* excess demand for commercial agriculture =
 Commercial agriculture output + smallholder agriculture
   tranferred output - domestic intermediate demand *)
TB[t_] = exy1[t] + exym[t]; (* trade balance *)

{TB[0], exym[0], exy1[0], ytxt[1]}
(* corresponding years should = each other *)
{-0.0010924, 102.867, -102.868, 0.}

{ymt[0], ytxt[0], y222t[0], y332t[0]}
{135.685, 0., 32.818, 0.}

{yy1t[0], Y1}
{1303.19, 762.157}

{slr[t_] = wt[t] / gdpt[t], skr[t_] = rkt[t] kk[t] / gdpt[t],
  s22r[t_] = πmt[t] / gdpt[t], s33r[t_] = πtt[t] / gdpt[t]};

{slr[0] + skr[0] + s22r[0] + s33r[0]} (* check *)
{1.}

{wt[0], rkt[0] kk[0], πmt[0], πtt[0]}
{1019.59, 1335.99, 13.6317, 49.3307}
```

```
{lmt[0] + ltt[0] + l1t[0] + l2t[0] + l3t[0] + l4t[0]}
(* check should = 1 *)
```

```
{1.}
```

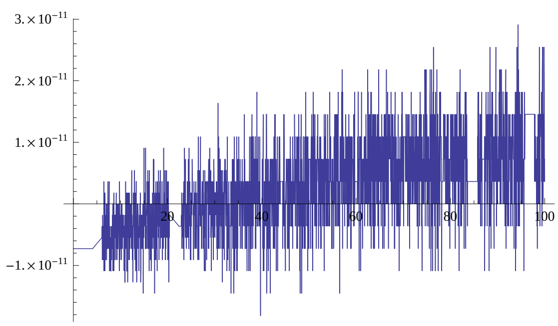
```
Plot[{lmt[t] + ltt[t] + l1t[t] + l2t[t] + l3t[t] + l4t[t] - 1},
 {t, 0, TT}] (* check should = 0 *)
```




```
{kmt[1] + ktt[1] + k1t[1] + k2t[1] + k3t[1] + k4t[1] - kk[1]}
(* check should = 0 *)
```

$\{-5.45697\times 10^{-12}\}$

```
Plot[{kmt[t] + ktt[t] + k1t[t] + k2t[t] + k3t[t] + k4t[t] - kk[t]},
 {t, 0, TT}]
(* level of K stock at time t.  check should = 0 *)
```



10.0 Data Tables

```
Print[" MACROECONOMIC DATA
   ALL VARIABLES ARE IN PER WORKER TERMS "]
```

```
TableForm[macro = Table[{yrcal + t, t,
     gdpt[t] mn aa[t] / wkr[t],
     (* gdp by Income Method per worker at time t *)
     savt[t] mn aa[t] / wkr[t], (* savings per worker *)
     savt[t]
     ───────, (*ratio of savings to gdp *)
     gdpt[t]
     kk[t] mn aa[t] / wkr[t], (* capital stock per worker *)
     kk[t]
     ───────, (* ratio of capital stock to gdp *)
     gdpt[t]
     exy1[t] mn aa[t] / wkr[t],
     (* excess demand for industrial goods *)
     exym[t] mn aa[t] / wkr[t]}, (* excess demand
     for commercial agriculture goods *)
    {t, yrstart - yrcal, TT, 5}],
  TableHeadings → {Automatic,
    {Year, "t", gdpt, savt, savt/gdpt, kk, kk/gdpt, exy1, exym}}]
Print["PRICES OF INPUTS, INTERMEDIATE GOODS, AND FINAL GOODS"]
TableForm[prices = Table[{yrcal + t, t,
     wt[t] mn aa[t] / wkr[t], (* cost of labor per worker *)
     rkt[t], (* rate of return on capital *)
     p2t[t], (* price of modern retail food *)
     p3t[t], (* price of traditional retail food *)
     p33t[t],
     (* price of smallholder agricultural products *)
     p4t[t]}, (* price of services *)
    {t, yrstart - yrcal, TT, 5}], TableHeadings →
   {Automatic, {Year, "t", wt, rkt, p2t, p3t, p33t, p4t}}]
Print["COMMERCIAL AND SMALLHOLDER
   FARM SECTOR DATA PER WORKER"]
TableForm[farms = Table[{yrcal + t, t,
     πmt[t] mn aa[t] / wkr[t],
     (* commercial farm profit per worker *)
     ymt[t] mn aa[t] / wkr[t], (* commercial
      farm output per worker *)
     πmh[t] mn aa[t], (* commercial farm profit per hectare *)
     lmt[t] wkr[t],
     (* # of workers employed on commercial farms *)
     kmt[t] mn aa[t] / wkr[t], (* quantity of capital
      deployed on commercial farms per worker *)
```

```
     πtt[t] mn aa[t] / wkr[t], (* smallholder
      farm profit per worker *)
     ytt[t] mn aa[t] / wkr[t], (* smallholder
      farm output per worker*)
     πth[t] mn aa[t], (* smallholder farm profit per hectar*)
     ltt[t] wkr[t],
     (* # of workers employed on smallholder farms *)
     ktt[t] mn aa[t] / wkr[t]}, (* capital deployed
     on smallholder farms per worker*)
    {t, yrstart - yrcal, TT, 5}], TableHeadings → {Automatic,
    {Year, "t", πmt, ymt, πmh, lmt, kmt, πtt, ytt, πth, ltt, ktt}}]
Print["SUPPLY OF INTERMEDIATE AND FINAL GOODS PER WORKER"]
TableForm[supply = Table[{yrcal + t, t,
     yy1t[t] mn aa[t] / wkr[t],
     (* industry sector supply per worker *)
     yy2t[t] mn aa[t] / wkr[t],
     (* modern retail supply per worker *)
     y222t[t] mn aa[t] / wkr[t],
     (* commercial farm supply per worker *)
     yy3t[t] mn aa[t] / wkr[t],
     (* traditional retail supply per worker *)
     y333t[t] mn aa[t] / wkr[t] + y332t[t] mn aa[t] / wkr[t],
     (* smallholder farm supply per worker *)
     yy4t[t] mn aa[t] / wkr[t]},
    (* supply of services per worker *)
    {t, yrstart - yrcal, TT, 5}], TableHeadings → {Automatic,
    {Year, "t", yy1t, yy2t, y222t, yy3t, y333t + y332t, yy4t}}]
Print["LABOR AND CAPITAL INPUTS TO FINAL GOODS"]
TableForm[fnlgdInputs = Table[{yrcal + t, t,
     l1t[t], (* labor input to industry *)
     l2t[t], (* labor input to modern retail *)
     l3t[t], (* labor input to traditional retail *)
     l4t[t], (* labor input to services *)
     k1t[t] mn aa[t] / wkr[t],
     (* capital input to industry per worker *)
     k2t[t] mn aa[t] / wkr[t], (* capital input
      to modern retail per worker *)
     k3t[t] mn aa[t] / wkr[t], (* capital input
      to traditional retail per worker *)
     k4t[t] mn aa[t] / wkr[t]}, (* capital input
     to services per worker *)
    {t, yrstart - yrcal, TT, 5}], TableHeadings → {Automatic,
    {Year, "t", l1t, l2t, l3t, l4t, k1t , k2t, k3t , k4t}}]
```

```
Print["HOUSEHOLD EXPENDITURE AND CONSUMPTION"]
TableForm[hhold = Table[{yrcal + t, t,
    hhexp[t] mn aa[t] / wkr[t],
    (* household expenditures per worker *)
    pindex[t], (* aggregated price index *)
    (hq[t] mn aa[t] / wkr[t]), (* felicity per worker *)
    c1[t] mn aa[t] / wkr[t],
    (* consumption of industrial goods *)
    c2[t] mn aa[t] / wkr[t], (* consumption
     of modern retail food *)
    c3[t] mn aa[t] / wkr[t], (* consumption
     of traditional retail food *)
    c4[t] mn aa[t] / wkr[t]}, (* consumption of services *)
   {t, yrstart - yrcal, TT, 5}], TableHeadings →
  {Automatic, {Year, "t", hhexp, pindex, hq, c1, c2, c3, c4}}]
```

MACROECONOMIC DATA   ALL VARIABLES ARE IN PER WORKER TERMS

	Year	t	gdpt	savt	$\frac{\text{savt}}{\text{gdpt}}$	kk
1	1980	0	1.15937×10^6	521 293.	0.449634	6.39835
2	1985	5	1.23194×10^6	553 954.	0.449659	6.9711
3	1990	10	1.30049×10^6	584 632.	0.449548	7.52398
4	1995	15	1.36492×10^6	613 317.	0.449344	8.05385
5	2000	20	1.42522×10^6	640 035.	0.449079	8.55845
6	2005	25	1.48144×10^6	664 838.	0.448777	9.03633
7	2010	30	1.5337×10^6	687 794.	0.448454	9.48667
8	2015	35	1.58212×10^6	708 987.	0.448124	9.90921
9	2020	40	1.62688×10^6	728 508.	0.447794	1.03041
10	2025	45	1.66816×10^6	746 452.	0.447471	1.0672
11	2030	50	1.70614×10^6	762 919.	0.44716	1.10136
12	2035	55	1.74103×10^6	778 005.	0.446863	1.13299
13	2040	60	1.77304×10^6	791 807.	0.446582	1.16222
14	2045	65	1.80235×10^6	804 420.	0.446319	1.18910
15	2050	70	1.82915×10^6	815 933.	0.446072	1.21395
16	2055	75	1.85364×10^6	826 432.	0.445842	1.23671
17	2060	80	1.87599×10^6	835 998.	0.44563	1.25758
18	2065	85	1.89637×10^6	844 707.	0.445433	1.2767
19	2070	90	1.91494×10^6	852 630.	0.445252	1.29418
20	2075	95	1.93184×10^6	859 833.	0.445086	1.31015
21	2080	100	1.94721×10^6	866 379.	0.444933	1.32473

PRICES OF INPUTS, INTERMEDIATE GOODS, AND FINAL GOODS

	Year	t	wt	rkt	p2t	p3t
1	1980	0	488 760.	0.100093	0.95909	0.81348
2	1985	5	518 832.	0.0978394	0.967785	0.847684
3	1990	10	547 266.	0.0958687	0.975622	0.879474
4	1995	15	574 017.	0.0941395	0.982686	0.908929
5	2000	20	599 077.	0.0926178	0.989054	0.936147
6	2005	25	622 464.	0.0912749	0.994796	0.961238
7	2010	30	644 216.	0.090087	0.999974	0.98432
8	2015	35	664 387.	0.0890339	1.00465	1.00552
9	2020	40	683 043.	0.0880985	1.00886	1.02495
10	2025	45	700 258.	0.0872662	1.01266	1.04273
11	2030	50	716 108.	0.0865244	1.01609	1.05899
12	2035	55	730 676.	0.0858624	1.01919	1.07385
13	2040	60	744 043.	0.0852708	1.02199	1.08739
14	2045	65	756 290.	0.0847415	1.02451	1.09974
15	2050	70	767 495.	0.0842675	1.02679	1.11099
16	2055	75	777 736.	0.0838426	1.02885	1.12122
17	2060	80	787 085.	0.0834614	1.03071	1.13053
18	2065	85	795 611.	0.0831192	1.03239	1.13899
19	2070	90	803 381.	0.0828117	1.03391	1.14667
20	2075	95	810 455.	0.0825352	1.03528	1.15365
21	2080	100	816 893.	0.0822866	1.03652	1.15999

COMMERCIAL AND SMALLHOLDER FARM SECTOR DATA PER WORKER

	Year	t	πmt	ymt	πmh	lmt	k
1	1980	0	6534.6	65 043.	50 674.5	82 854.3	3
2	1985	5	6271.25	62 421.7	54 641.1	84 161.7	3
3	1990	10	6044.92	60 168.9	59 176.8	86 412.2	3
4	1995	15	5849.4	58 222.8	64 338.	89 570.3	3
5	2000	20	5679.7	56 533.7	70 190.3	93 630.2	3
6	2005	25	5531.81	55 061.7	76 809.4	98 610.2	3
7	2010	30	5402.45	53 774.	84 281.6	104 550.	3
8	2015	35	5288.91	52 643.9	92 705.1	111 507.	3
9	2020	40	5188.96	51 649.	102 191.	119 560.	3
10	2025	45	5100.74	50 770.9	112 866.	128 803.	3
11	2030	50	5022.69	49 994.	124 870.	139 349.	3
12	2035	55	4953.48	49 305.1	138 366.	151 330.	3
13	2040	60	4892.	48 693.2	153 533.	164 901.	3
14	2045	65	4837.28	48 148.6	170 573.	180 237.	3
15	2050	70	4788.52	47 663.2	189 717.	197 538.	3
16	2055	75	4744.99	47 229.9	211 220.	217 033.	3
17	2060	80	4706.09	46 842.7	235 372.	238 977.	3
18	2065	85	4671.29	46 496.3	262 499.	263 662.	3
19	2070	90	4640.11	46 186.	292 964.	291 417.	3
20	2075	95	4612.17	45 907.9	327 180.	322 611.	3
21	2080	100	4587.1	45 658.3	365 607.	357 661.	3

SUPPLY OF INTERMEDIATE AND FINAL GOODS PER WORKER

	Year	t	yy1t	yy2t	y222t	yy3t
1	1980	0	624 709.	27 460.3	15 731.9	231 462.
2	1985	5	671 231.	27 783.8	16 061.6	232 870.
3	1990	10	714 863.	28 089.4	16 369.7	234 157.
4	1995	15	755 626.	28 376.6	16 656.8	235 333.
5	2000	20	793 579.	28 645.4	16 923.6	236 405.
6	2005	25	828 808.	28 896.	17 170.8	237 381.
7	2010	30	861 418.	29 129.	17 399.3	238 270.
8	2015	35	891 532.	29 344.9	17 610.2	239 079.
9	2020	40	919 279.	29 544.5	17 804.3	239 814.
10	2025	45	944 797.	29 728.6	17 982.8	240 482.
11	2030	50	968 224.	29 898.	18 146.5	241 089.
12	2035	55	989 698.	30 053.7	18 296.6	241 640.
13	2040	60	1.00935×10^6	30 196.4	18 434.	242 139.
14	2045	65	1.02733×10^6	30 327.2	18 559.6	242 592.
15	2050	70	1.04374×10^6	30 446.8	18 674.2	243 003.
16	2055	75	1.05871×10^6	30 556.1	18 778.8	243 376.
17	2060	80	1.07236×10^6	30 655.8	18 874.2	243 713.
18	2065	85	1.08479×10^6	30 746.8	18 961.1	244 019.
19	2070	90	1.0961×10^6	30 829.7	19 040.1	244 296.
20	2075	95	1.10639×10^6	30 905.1	19 112.	244 547.
21	2080	100	1.11574×10^6	30 973.7	19 177.4	244 774.

LABOR AND CAPITAL INPUTS TO FINAL GOODS

	Year	t	l1t	l2t	l3t	l4t
1	1980	0	0.352882	0.0118869	0.05606	0.3378
2	1985	5	0.357184	0.0114326	0.055366	0.3410
3	1990	10	0.360638	0.0110466	0.054759	0.3438
4	1995	15	0.363437	0.0107164	0.0542263	0.3463
5	2000	20	0.365725	0.0104326	0.0537576	0.3486
6	2005	25	0.367609	0.0101873	0.053344	0.3506
7	2010	30	0.369173	0.00997433	0.0529782	0.3524
8	2015	35	0.370478	0.00978871	0.052654	0.3540
9	2020	40	0.371575	0.00962632	0.0523661	0.3555
10	2025	45	0.372501	0.00948379	0.05211	0.3568
11	2030	50	0.373288	0.00935834	0.0518818	0.3580
12	2035	55	0.37396	0.00924761	0.0516782	0.3591
13	2040	60	0.374535	0.00914965	0.0514963	0.3601
14	2045	65	0.375031	0.00906281	0.0513336	0.3609
15	2050	70	0.375459	0.00898567	0.0511879	0.3617
16	2055	75	0.37583	0.00891703	0.0510574	0.3624
17	2060	80	0.376153	0.00885586	0.0509403	0.3631
18	2065	85	0.376435	0.00880127	0.0508351	0.3636
19	2070	90	0.376682	0.00875249	0.0507407	0.3642
20	2075	95	0.376899	0.00870886	0.0506558	0.3646
21	2080	100	0.377089	0.00866978	0.0505795	0.3650

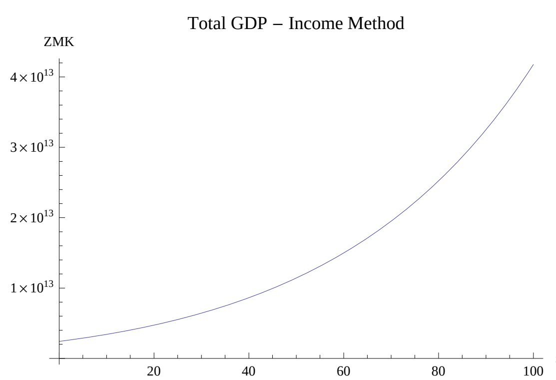
HOUSEHOLD EXPENDITURE AND CONSUMPTION

	Year	t	hhexp	pindex	hq	c1
1	1980	0	582 020.	0.912218	514 237.	152 728
2	1985	5	629 575.	0.930233	540 299.	163 637
3	1990	10	674 820.	0.946632	564 661.	174 031
4	1995	15	717 625.	0.961548	587 350.	183 876
5	2000	20	757 921.	0.975102	608 413.	193 155
6	2005	25	795 690.	0.987412	627 911.	201 861
7	2010	30	830 956.	0.998586	645 915.	209 999
8	2015	35	863 773.	1.00872	662 502.	217 578
9	2020	40	894 218.	1.01792	677 754.	224 616
10	2025	45	922 388.	1.02625	691 754.	231 133
11	2030	50	948 392.	1.03381	704 585.	237 153
12	2035	55	972 344.	1.04065	716 328.	242 702
13	2040	60	994 366.	1.04685	727 062.	247 807
14	2045	65	1.01458×10^6	1.05247	736 863.	252 494
15	2050	70	1.0331×10^6	1.05755	745 803.	256 793
16	2055	75	1.05006×10^6	1.06216	753 951.	260 728
17	2060	80	1.06555×10^6	1.06632	761 370.	264 327
18	2065	85	1.0797×10^6	1.0701	768 122.	267 614
19	2070	90	1.09261×10^6	1.07351	774 262.	270 614
20	2075	95	1.10438×10^6	1.0766	779 843.	273 349
21	2080	100	1.11509×10^6	1.07939	784 912.	275 840

11.0 Charts

11.1 Macroeconomic Data: GDP, Trade, Capital, Savings

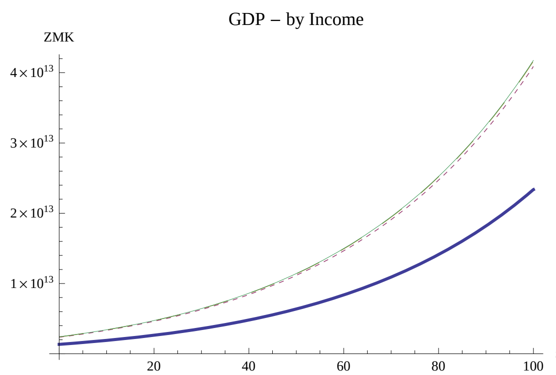
```
Plot[{mn gdpt[t] aa[t]}, {t, 0, TT},
 PlotLabel → "Total GDP - Income Method",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin}]
```



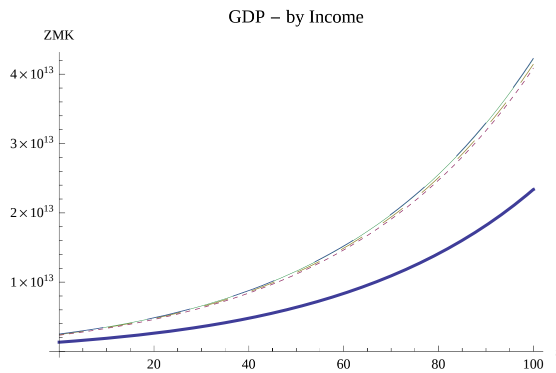
```
mn gdpt[0] aa[0] (* 2.41854*10^12 = GDP:I =/= GDP:Expend =
    GDP:VA= 2.48484*10^12. 2.41854-2.48484=
      -0.0663. Why?  don't know. Maybe saving or trade. *)
```

2.41854×10^{12}

```
Plot[{rkt[t] mn kk[t] aa[t],
  rkt[t] mn kk[t] aa[t] + mn wt[t] aa[t],
  rkt[t] mn kk[t] aa[t] + mn wt[t] aa[t] + mn πtt[t] aa[t],
  rkt[t] mn kk[t] aa[t] + mn wt[t] aa[t] +
   mn πtt[t] aa[t] + mn πmt[t] aa[t]}, {t, 0, TT},
 PlotLabel → "GDP - by Income", AxesLabel → {t, ZMK},
 PlotStyle → {Thick, Dashing[{.01}], Dashing[{.05}], Thin}]
```



```
Plot[{rkt[t] mn kk[t] aa[t],
  rkt[t] mn kk[t] aa[t] + mn wt[t] aa[t],
  rkt[t] mn kk[t] aa[t] + mn wt[t] aa[t] + mn exym[t] aa[t],
  (* excess demand for commercial agriculture. + = export,
  - = import *)
  rkt[t] mn kk[t] aa[t] + mn wt[t] aa[t] +
   mn exym[t] aa[t] + mn πtt[t] aa[t],
  rkt[t] mn kk[t] aa[t] + mn wt[t] aa[t] + mn exym[t] aa[t] +
   mn πtt[t] aa[t] + mn πmt[t] aa[t]}, {t, 0, TT},
 PlotLabel → "GDP - by Income", AxesLabel → {t, ZMK},
 PlotStyle → {Thick, Dashing[{.01}],
   Dashing[{.05}], Thin, Dashing[{.09}], Thin}]
```



```
Print["GDP by Income"]
TableForm[
 GDPincome = Table[{yrcal + t, t, rkt[t] mn kk[t] aa[t],
    mn wt[t] aa[t], mn πtt[t] aa[t], mn πmt[t] aa[t]},
   {t, yrstart - yrcal, 75, 5}],
 TableHeadings → {Automatic, {Year, "t", rkt, wt, πtt, πmt}}]
```

GDP by Income

	Year	t	rkt	wt	πtt
1	1980	0	1.33599×10^{12}	1.01959×10^{12}	4.93307×10^{10}
2	1985	5	1.59861×10^{12}	1.21605×10^{12}	5.81078×10^{10}
3	1990	10	1.89953×10^{12}	1.44118×10^{12}	6.81103×10^{10}
4	1995	15	2.24332×10^{12}	1.69841×10^{12}	7.94858×10^{10}
5	2000	20	2.63513×10^{12}	1.99157×10^{12}	9.24001×10^{10}
6	2005	25	3.08071×10^{12}	2.32499×10^{12}	1.0704×10^{11}
7	2010	30	3.58656×10^{12}	2.70355×10^{12}	1.23614×10^{11}
8	2015	35	4.15999×10^{12}	3.1327×10^{12}	1.4236×10^{11}
9	2020	40	4.80921×10^{12}	3.61861×10^{12}	1.63542×10^{11}
10	2025	45	5.54345×10^{12}	4.16818×10^{12}	1.87458×10^{11}
11	2030	50	6.37311×10^{12}	4.78919×10^{12}	2.14445×10^{11}
12	2035	55	7.30987×10^{12}	5.4904×10^{12}	2.44878×10^{11}
13	2040	60	8.36687×10^{12}	6.28163×10^{12}	2.79181×10^{11}
14	2045	65	9.55886×10^{12}	7.17395×10^{12}	3.17832×10^{11}
15	2050	70	1.09025×10^{13}	8.17977×10^{12}	3.61365×10^{11}
16	2055	75	1.24163×10^{13}	9.31306×10^{12}	4.10382×10^{11}

```
GDPincome = Export["c:\users\lars1102\desktop\Zambia
    Output Tables\gdpincometable.xls", GDPincome]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\gdpincometable.xls
```

```
{(rkt[0]) kk[0] + wt[0] + exym[0] + πtt[0] + πmt[0], exym[0]}
```

```
{2521.41, 102.867}
```

```
{(rkt[0]) kk[0] + wt[0] + πtt[0] + πmt[0]}
```

```
{2418.54}
```

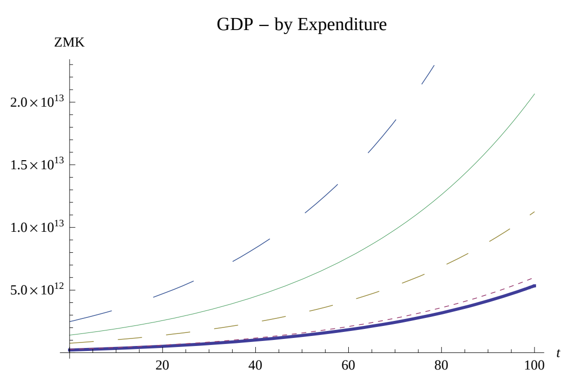
```
exy1[t_] = yy1t[t] - savt[t] - c1[t];
(* excess demand for industrial goods. + = export,
- = import *)
exym[t_] = ymt[t] + ytxt[t] - y222t[t] - y332t[t];
(* excess demand for commercial agriculture output +
 smallholder agriculture transferred output -
 domestic intermediate demand -
 intermediate demand for smallholder agriculture
  produce transferred to modern channel.*)
{exy1[0], exym[0]}
```

```
{-102.868, 102.867}
```

```
{ymt[0] - y222t[0], ytxt[0]}
```

```
{102.867, 0.}
```

```
Plot[{(c1[t] + exy1[t] ) mn aa[t],
   (* industrial & commercial agriculture final demand +
     intl trade: + = exports, - = imports*)
   (c1[t] + exy1[t] ) mn aa[t] + mn c2[t] aa[t],
   (c1[t] + exy1[t] ) mn aa[t] + mn c2[t] aa[t] + mn c3[t] aa[t],
   (c1[t] + exy1[t] ) mn aa[t] +
    mn c2[t] aa[t] + mn c3[t] aa[t] + mn c4[t] aa[t],
   (c1[t] + exy1[t] ) mn aa[t] + mn c2[t] aa[t] +
    mn c3[t] aa[t] + mn c4[t] aa[t] + mn savt[t] aa[t]},
 {t, 0, TT}, PlotLabel → "GDP - by Expenditure",
 AxesLabel → {t, ZMK}, PlotStyle →
  {Thick, Dashing[{.01}], Dashing[{.05}], Thin, Dashing[{.09}]}]
```



```
Print["GDP by Expenditure"]
TableForm[
 GDPexpenditure = Table[{yrcal + t, t, (c1[t] + exy1[t] ) mn aa[t],
    mn c2[t] aa[t], mn c3[t] aa[t],
    mn c4[t] aa[t], mn savt[t] aa[t]},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", c1, c2, c3, c4, saving}}]
```

GDP by Expenditure

	Year	t	c1	c2	c3
1	1980	0	2.15735×10^{11}	5.72842×10^{10}	4.82847×10^{11}
2	1985	5	2.74877×10^{11}	6.51204×10^{10}	5.45807×10^{11}
3	1990	10	3.42954×10^{11}	7.39712×10^{10}	6.16635×10^{11}
4	1995	15	4.21066×10^{11}	8.39607×10^{10}	6.96303×10^{11}
5	2000	20	5.1044×10^{11}	9.52282×10^{10}	7.859×10^{11}
6	2005	25	6.12451×10^{11}	1.07931×10^{11}	8.86651×10^{11}
7	2010	30	7.28638×10^{11}	1.22244×10^{11}	9.99935×10^{11}
8	2015	35	8.60729×10^{11}	1.38366×10^{11}	1.1273×10^{12}
9	2020	40	1.01066×10^{12}	1.5652×10^{11}	1.27048×10^{12}
10	2025	45	1.18062×10^{12}	1.76955×10^{11}	1.43143×10^{12}
11	2030	50	1.37305×10^{12}	1.99952×10^{11}	1.61236×10^{12}
12	2035	55	1.59069×10^{12}	2.25827×10^{11}	1.81571×10^{12}
13	2040	60	1.83666×10^{12}	2.54935×10^{11}	2.04428×10^{12}
14	2045	65	2.11441×10^{12}	2.87675×10^{11}	2.30116×10^{12}
15	2050	70	2.42787×10^{12}	3.24494×10^{11}	2.58986×10^{12}
16	2055	75	2.78142×10^{12}	3.65896×10^{11}	2.91432×10^{12}

```
GDPexpend = Export["c:\users\lars1102\desktop\Zambia Outpu
    Tables\gdpexpendituretable.xls", GDPexpenditure]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\gdpexpendituretable.xls

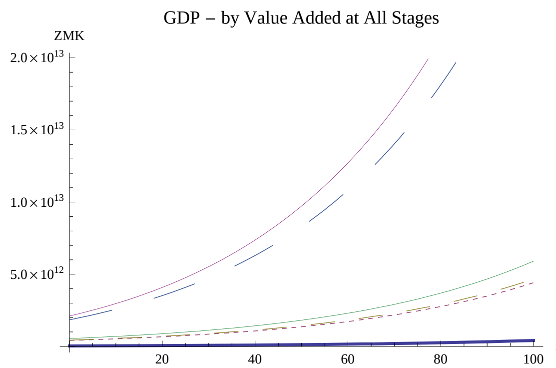
```
{(c4[0] + c1[0] + exy1[0] + c3[0] + c2[0] + savt[0]) mn aa[0],
 exy1[0]}
```

$\{2.48484 \times 10^{12}, -102.868\}$

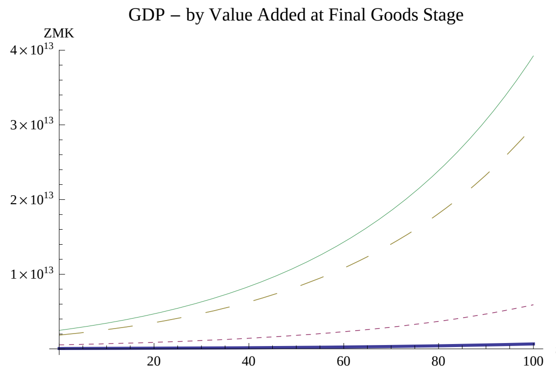
```
{(c4[0] + c1[0] + c3[0] + c2[0] + savt[0]) mn aa[0]}
```

$\{2.58771 \times 10^{12}\}$

```
Plot[{mn y222t[t] aa[t],
  mn y222t[t] aa[t] + mn y333t[t] aa[t],
  mn y222t[t] aa[t] +
   mn y333t[t] aa[t] + (yy2t[t] - y222t[t]) mn aa[t],
  mn y222t[t] aa[t] + mn y333t[t] aa[t] +
   (yy2t[t] - y222t[t]) mn aa[t] + (yy3t[t] - y333t[t]) mn aa[t],
  mn y222t[t] aa[t] + mn y333t[t] aa[t] + (yy2t[t] - y222t[t])
    mn aa[t] + (yy3t[t] - y333t[t]) mn aa[t] + mn yy1t[t] aa[t],
  mn y222t[t] aa[t] + y333t[t] + (yy2t[t] - y222t[t]) mn aa[t] +
   (yy3t[t] - y333t[t]) mn aa[t] +
   mn yy1t[t] aa[t] + mn yy4t[t] aa[t]}, {t, 0, TT},
 PlotLabel → "GDP - by Value Added at All Stages",
 AxesLabel → {t, ZMK}, PlotStyle → {Thick, Dashing[{.01}],
   Dashing[{.05}], Thin, Dashing[{.09}], Thin}]
```



```
Plot[{mn yy2t[t] aa[t],
  mn yy2t[t] aa[t] + mn yy3t[t] aa[t],
  mn yy2t[t] aa[t] + mn yy3t[t] aa[t] + mn yy1t[t] aa[t],
  mn yy2t[t] aa[t] + mn yy3t[t] aa[t] +
   mn yy1t[t] aa[t] + mn yy4t[t] aa[t]}, {t, 0, TT},
 PlotLabel → "GDP - by Value Added at Final Goods Stage",
 AxesLabel → {t, ZMK}, PlotStyle → {Thick, Dashing[{.01}],
   Dashing[{.05}], Thin, Dashing[{.09}], Thin}]
```



```
Print["GDP by Value Added"]
TableForm[GDPvalueadded = Table[{yrcal + t, t, mn yy2t[t] aa[t],
    mn yy3t[t] aa[t], mn yy1t[t] aa[t], mn yy4t[t] aa[t]},
   {t, yrstart - yrcal, 75, 5}],
 TableHeadings → {Automatic, {Year, "t", y2, y3, y1, y4}}]
```

GDP by Value Added

	Year	t	y2	y3	y1
1	1980	0	5.72844×10^{10}	4.82848×10^{11}	1.30319×10^{12}
2	1985	5	6.51206×10^{10}	5.45808×10^{11}	1.57325×10^{12}
3	1990	10	7.39714×10^{10}	6.16637×10^{11}	1.88254×10^{12}
4	1995	15	8.39608×10^{10}	6.96304×10^{11}	2.23575×10^{12}
5	2000	20	9.52284×10^{10}	7.85901×10^{11}	2.63817×10^{12}
6	2005	25	1.07931×10^{11}	8.86653×10^{11}	3.09572×10^{12}
7	2010	30	1.22244×10^{11}	9.99937×10^{11}	3.61507×10^{12}
8	2015	35	1.38366×10^{11}	1.1273×10^{12}	4.20373×10^{12}
9	2020	40	1.5652×10^{11}	1.27048×10^{12}	4.87013×10^{12}
10	2025	45	1.76955×10^{11}	1.43144×10^{12}	5.62377×10^{12}
11	2030	50	1.99952×10^{11}	1.61236×10^{12}	6.4753×10^{12}
12	2035	55	2.25827×10^{11}	1.81571×10^{12}	7.43673×10^{12}
13	2040	60	2.54935×10^{11}	2.04428×10^{12}	8.52154×10^{12}
14	2045	65	2.87675×10^{11}	2.30116×10^{12}	9.74491×10^{12}
15	2050	70	3.24494×10^{11}	2.58986×10^{12}	1.11239×10^{13}
16	2055	75	3.65896×10^{11}	2.91432×10^{12}	1.26776×10^{13}

```
GDPvalueadd = Export["c:\users\lars1102\desktop\Zambia Output
    Tables\gdpvalueaddedtable.xls", GDPvalueadded]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\gdpvalueaddedtable.xls

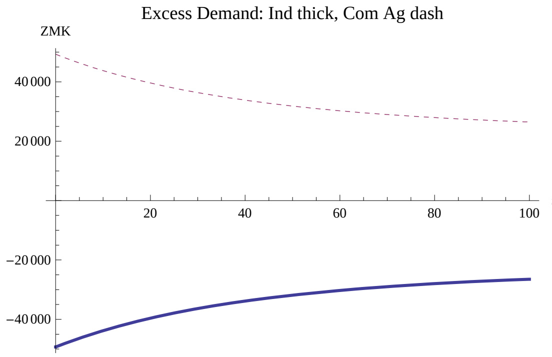
```
((yy4t[0] + yy1t[0] + y222t[0] + y333t[0] +
    (yy2t[0] - y222t[0]) + (yy3t[0] - y333t[0]))) mn aa[0]
```

2.48485×10^{12}

```
{yy1t[0], k1t[0], l1t[0]}
```

{1303.19, 9425.21, 0.352882}

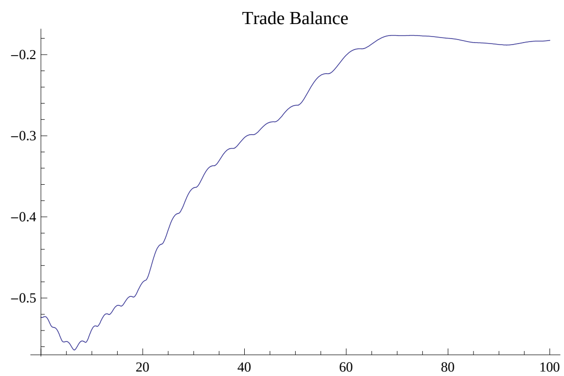
```
Plot[{mn exy1[t] aa[t] / wkr[t], mn exym[t] aa[t] / wkr[t]}, {t, 0,
  TT}, PlotLabel → "Excess Demand: Ind thick, Com Ag dash",
 AxesLabel → {t, ZMK}, PlotStyle → {Thick, Dashing[{.01}]}]
```



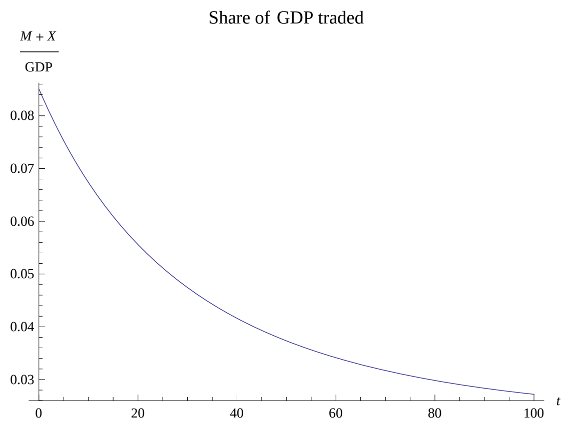

```
{exy1[0], exym[0]}
```

```
{-102.868, 102.867}
```

```
Plot[mn TB[t] aa[t] / wkr[t],
 {t, 0, TT}, PlotLabel → "Trade Balance"]
```



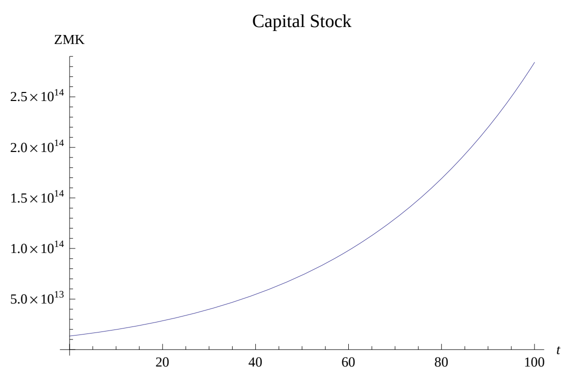
```
Plot[(Abs[exy1[t]] + Abs[exym[t]]) / gdpt[t],
 {t, 0, TT}, AxesLabel → {t, (X + M) / GDP},
 PlotLabel → "Share of GDP traded"]
```




```
(Abs[exy1[5]] + Abs[exym[5]]) / gdpt[5]
```

```
0.0752638
```

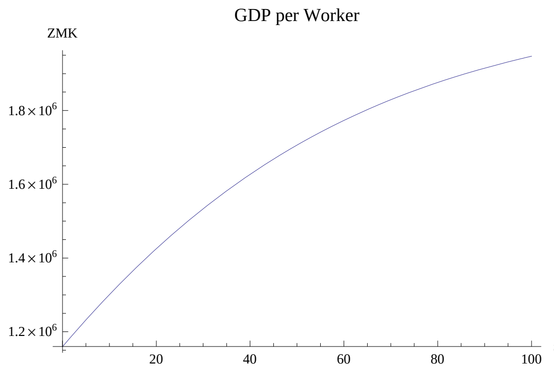
```
Plot[{mn kk[t] aa[t]}, {t, 0, TT}, PlotLabel → "Capital Stock",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin}]
```



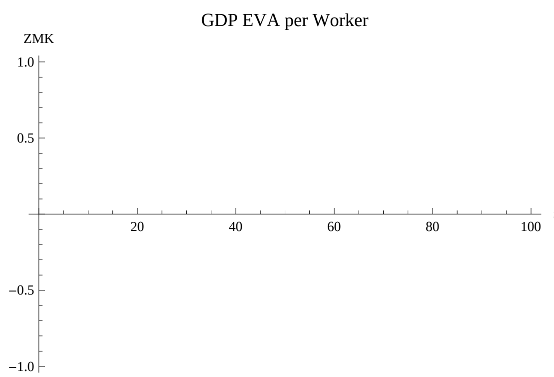

```
kk[0] aa[0]
```

```
13347.5
```

```
Plot[{mn gdpt[t] aa[t] / wkr[t]},
 {t, 0, TT}, PlotLabel → "GDP per Worker",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin}]
```

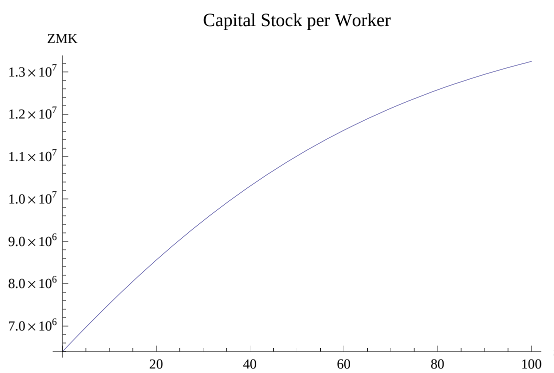



```
Plot[{mn evagdp[t] aa[t] / wkr[t]},
 {t, 0, TT}, PlotLabel → "GDP EVA per Worker",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin}]
```

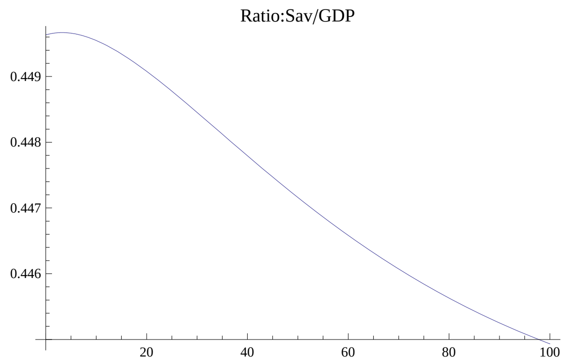


```
Plot[{mn savt[t] aa[t] / wkr[t]},
 {t, 0, TT}, PlotLabel → "SAV per Worker",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin}]
```

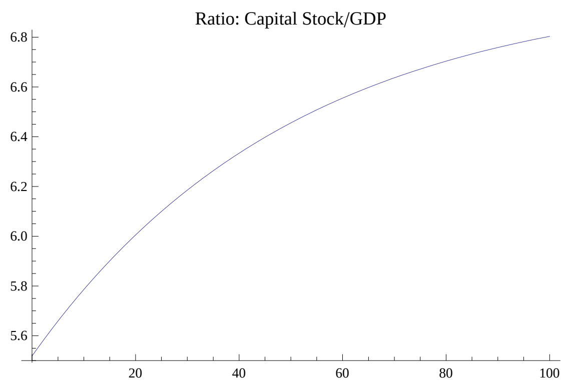

```
Plot[{mn kk[t] aa[t] / wkr[t]}, {t, 0, TT},
 PlotLabel → "Capital Stock per Worker",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin}]
```



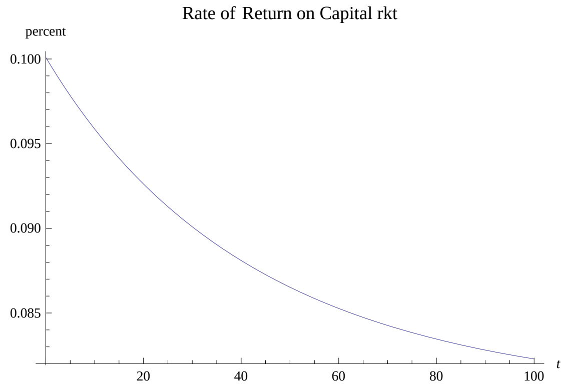
```
Plot[{savt[t]/gdpt[t]}, {t, 0, TT},
 PlotLabel → "Ratio:Sav/GDP", PlotStyle → {Thin}]
```




```
Plot[{kk[t]/gdpt[t]}, {t, 0, TT},
 PlotLabel → "Ratio: Capital Stock/GDP", PlotStyle → {Thin}]
```

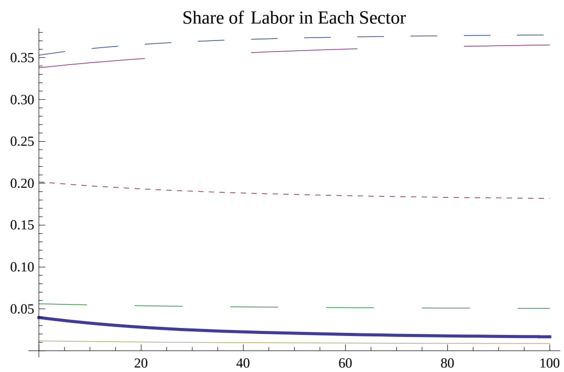


```
Plot[{rkt[t]}, {t, 0, TT},
 PlotLabel → "Rate of Return on Capital rkt",
 AxesLabel → {t, percent}, PlotStyle → {Thin}]
```



11.2 Labor Statistics

```
Plot[{lmt[t], ltt[t], l2t[t], l3t[t], l1t[t], l4t[t]},
 {t, 0, TT}, PlotLabel → "Share of Labor in Each Sector",
 PlotStyle → {Thick, Dashing[{0.01}], Thin,
   Dashing[{0.09}], Dashing[{0.05}], Dashing[{0.2}]}]
```

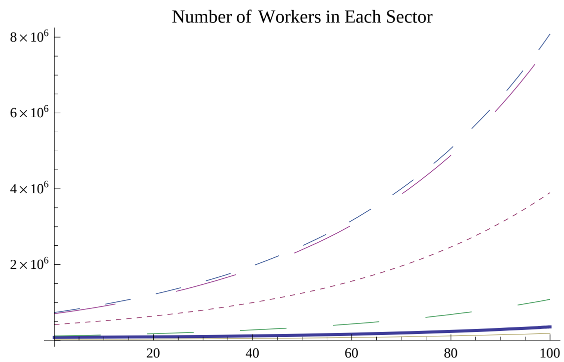



```
{lmt[0] + ltt[0] + l2t[0] + l3t[0] + l1t[0] + l4t[0]}
{1.}
```

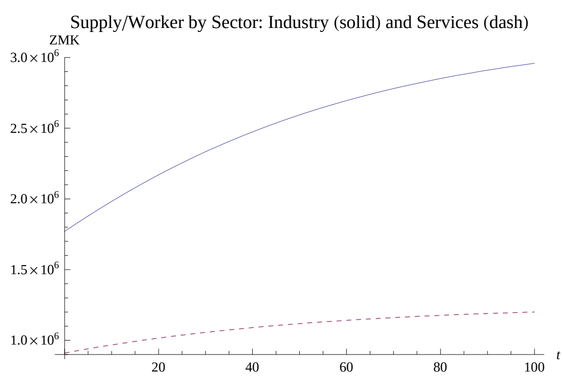
```
{lmt[0], ltt[0], l2t[0], l3t[0], l1t[0], l4t[0]}
```

```
{0.0397177, 0.201594, 0.0118869, 0.05606, 0.352882, 0.337859}
```

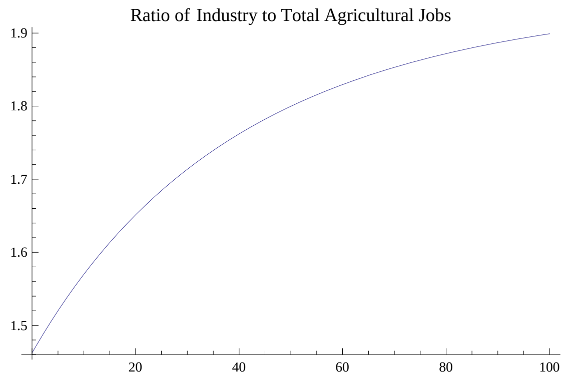
```
Plot[{lmt[t] wkr[t], ltt[t] wkr[t], l2t[t] wkr[t],
  l3t[t] wkr[t], l1t[t] wkr[t], l4t[t] wkr[t]}, {t, 0, TT},
 PlotLabel → "Number of Workers in Each Sector",
 PlotStyle → {Thick, Dashing[{0.01}], Thin,
   Dashing[{0.09}], Dashing[{0.05}], Dashing[{0.12}]}]
(* share X total # workers *)
```



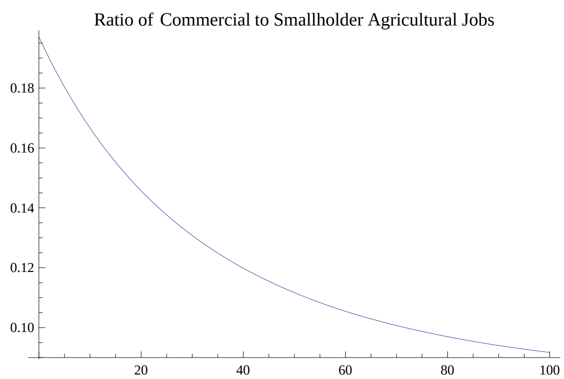

```
Plot[{(mn yy1t[t] aa[t]) / (l1t[t] wkr[t]),
  (mn yy4t[t] aa[t]) / (l4t[t] wkr[t])},
 {t, 0, TT}, PlotLabel → "Supply/Worker by Sector:
    Industry (solid) and Services (dash)",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{0.01}]}]
```



```
Plot[{l1t[t] / (lmt[t] + ltt[t])}, {t, 0, TT},
 PlotLabel → "Ratio of Industry to Total Agricultural Jobs",
 PlotStyle → {Thin}]
```




```
Plot[{lmt[t] / ltt[t]}, {t, 0, TT}, PlotLabel →
  "Ratio of Commercial to Smallholder Agricultural Jobs",
 PlotStyle → {Thin}]
```



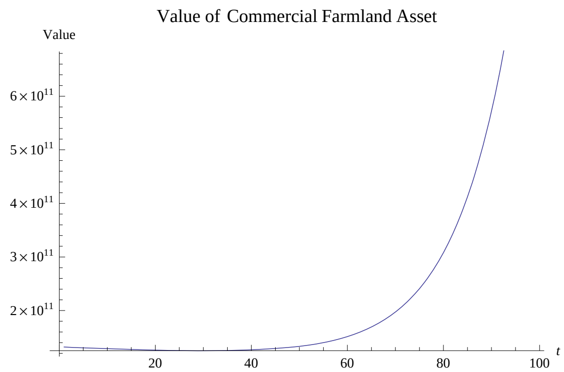

```
(* Land Market Analysis -- Commercial Farming *)

pp22[t_] = mn πmt[t] Exp[(x + n) t];
(* projected profits from commercial farmland *)
```

```
CAP22T = pp22[TT] / rkt[TT]
  (* capitalized value of land in terminal year TT *)
```

1.19522×10^{12}

```
Do[{pcdot = rkt[TT - t] CAP22T - mn πmt[TT - t], cap22t[TT - t] =
    CAP22T - pcdot, CAP22T = cap22t[TT - t]}, {t, 1, TT}];
```

```
ListPlot[Table[cap22t[t], {t, 1, TT - 1, 1}],
 Joined -> True, AxesLabel -> {t, Value},
 PlotLabel -> "Value of Commercial Farmland Asset"]
```




```
capv22cc[t_] = pp22[t] / rkt[t];
(* CapValue = income/cost of capital *)
```

```
capv22mktv[t_] = pp22[t] / cap22t[t];
(* cap value at time t basis: market value *)
```

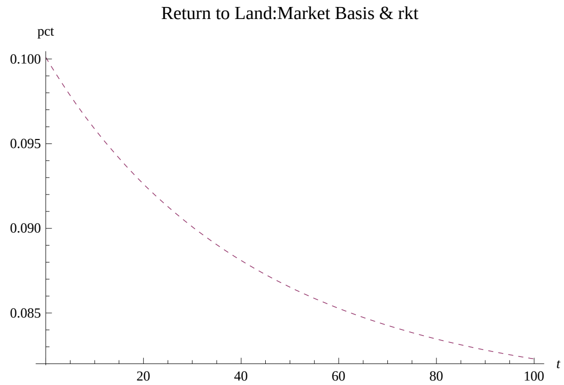
```
RtoCmLandCB[t_] = πmt[t] / (aπ22);
(* % return to land: Cost Basis *)
```

```
RtoCmLandMB[t_] = (mn πmt[t]) / cap22t[t];
(* % return to land: Market Value Basis *)
```

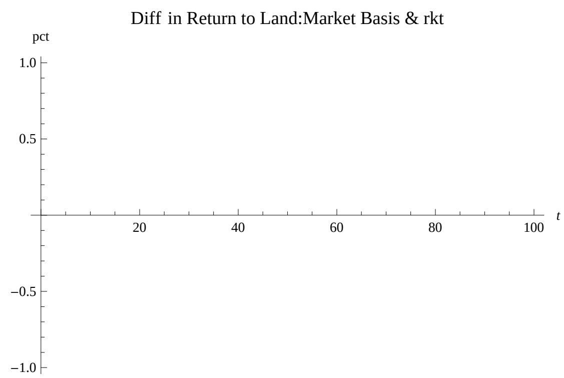
```
{RtoCmLandMB[1] - rkt[1]} (* hardly any difference *)
```

{0.00281347}

```
Plot[{RtoCmLandMB[t], rkt[t]}, {t, 0, TT},
 PlotLabel → "Return to Land:Market Basis & rkt",
 AxesLabel → {t, pct}, PlotStyle → {Thin, Dashing[{0.01}]}]
```




```
Plot[{RtoCmLandMB[t] - rkt[t]}, {t, 0, TT},
 PlotLabel → "Diff in Return to Land:Market Basis & rkt",
 AxesLabel → {t, pct}, PlotStyle → {Thin, Dashing[{0.01}]}]
```

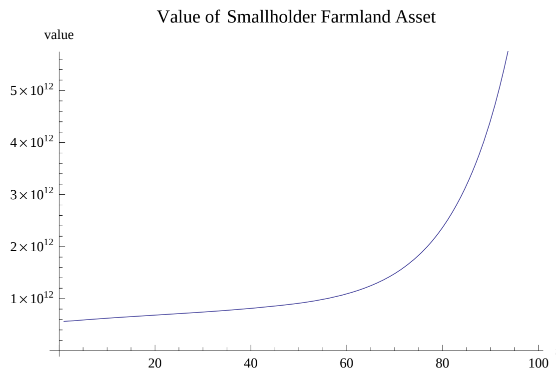



```
(* Land Market Analysis -- Smallholder Farming *)

pp33[t_] = mn πtt[t] Exp[(x + n) t];
(* projected profits from smallholder farmland *)

CAP33T = pp33[TT] / rkt[TT]
  (* capitalized value of land in terminal year TT *)
```

9.29149×10^{12}

```
Do[{ptdot = rkt[TT - t] CAP33T - mn πtt[TT - t], cap33t[TT - t] =
    CAP33T - ptdot, CAP33T = cap33t[TT - t]}, {t, 1, TT}];
```

```
ListPlot[Table[cap33t[t], {t, 1, TT - 1, 1}],
 Joined -> True, AxesLabel -> {t, value},
 PlotLabel -> "Value of Smallholder Farmland Asset"]
```




```
capv33cc[t_] = pp33[t] / rkt[t];
(* CapValue = income/cost of capital *)
```

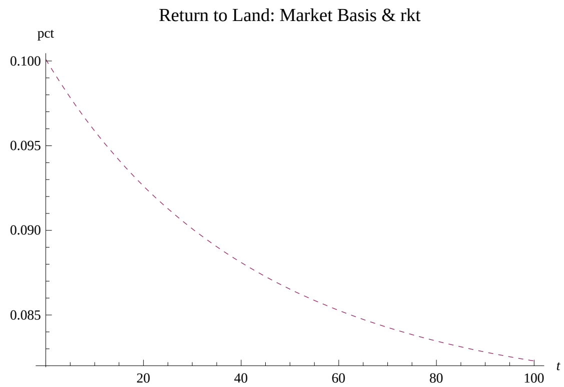
```
capv33mktv[t_] = pp33[t] / cap33t[t];
(* cap value at time t basis: market value *)
```

```
RtoSmLandCB[t_] = πtt[t] / (aπ33);
(* % return to land: Cost Basis *)
```

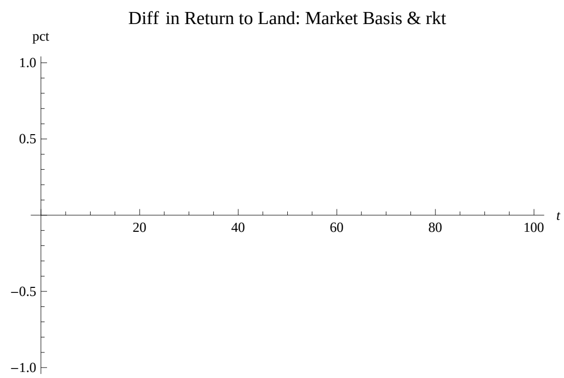
```
RtoSmLandMB[t_] = (mn πtt[t]) / cap33t[t];
(* % return to land: Market Value Basis *)
```

```
{RtoSmLandMB[1] - rkt[1]} (* hardly any difference *)
{-0.0111005}
```

```
Plot[{RtoSmLandMB[t], rkt[t]}, {t, 0, TT},
 PlotLabel → "Return to Land: Market Basis & rkt",
 AxesLabel → {t, pct}, PlotStyle → {Thin, Dashing[{0.01}]}]
```

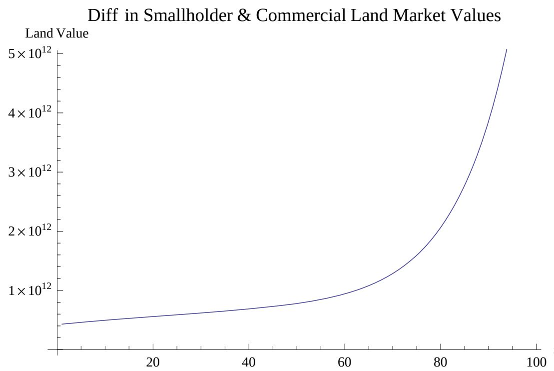



```
Plot[{RtoSmLandMB[t] - rkt[t]}, {t, 0, TT},
 PlotLabel → "Diff in Return to Land: Market Basis & rkt",
 AxesLabel → {t, pct}, PlotStyle → {Thin, Dashing[{0.01}]}]
```




```
DiffLcap[t_] = cap33t[t] - cap22t[t];
```

```
ListPlot[Table[DiffLcap[t], {t, 1, TT - 1, 1}],
 Joined -> True, AxesLabel -> {t, Land Value}, PlotLabel ->
  "Diff in Smallholder & Commercial Land Market Values"]
```

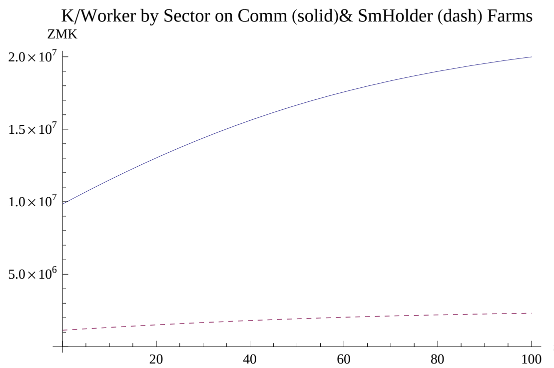



```
{cap33t[60], cap22t[60], DiffLcap[60]}
```

$\{1.09371 \times 10^{12}, 1.51426 \times 10^{11}, 9.42288 \times 10^{11}\}$

11.3 Agricultural Sector: Commercial and Smallholder Farming

```
Plot[{(mn kmt[t] aa[t]) / (lmt[t] wkr[t]),
   (mn ktt[t] aa[t]) / (ltt[t] wkr[t])}, {t, 0, TT}, PlotLabel →
   "K/Worker by Sector on Comm (solid)& SmHolder (dash) Farms",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{0.01}]}]
 (* per # of workers in the sector *)
```



```
Print["Capital/Worker by Agric. Sector"]
TableForm[KperAgrWorker =
  Table[{yrcal + t, t, (mn kmt[t] aa[t]) / (lmt[t] wkr[t]),
     (mn ktt[t] aa[t]) / (ltt[t] wkr[t])},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", Comm Farms, SmallH Farms}}]
```

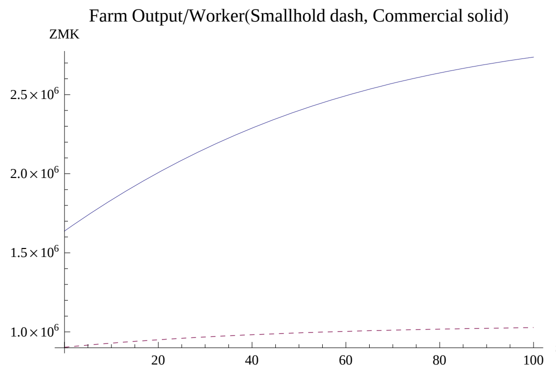
Capital/Worker by Agric. Sector

	Year	t	Comm Farms	Farms SmallH
1	1980	0	9.83431×10^6	1.13473×10^6
2	1985	5	1.06798×10^7	1.23229×10^6
3	1990	10	1.14967×10^7	1.32654×10^6
4	1995	15	1.22802×10^7	1.41694×10^6
5	2000	20	1.30269×10^7	1.5031×10^6
6	2005	25	1.37346×10^7	1.58476×10^6
7	2010	30	1.44019×10^7	1.66176×10^6
8	2015	35	1.50286×10^7	1.73407×10^6
9	2020	40	1.56146×10^7	1.80169×10^6
10	2025	45	1.61608×10^7	1.86471×10^6
11	2030	50	1.66683×10^7	1.92327×10^6
12	2035	55	1.71385×10^7	1.97752×10^6
13	2040	60	1.75731×10^7	2.02767×10^6
14	2045	65	1.7974×10^7	2.07392×10^6
15	2050	70	1.83429×10^7	2.11649×10^6
16	2055	75	1.86818×10^7	2.15559×10^6

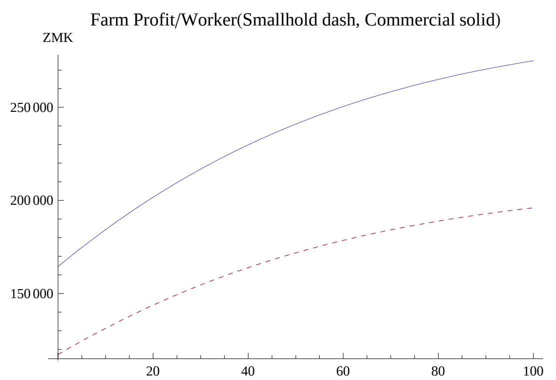
```
KperAgrWorker =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\KperAgrWorkertable.xls", KperAgrWorker]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\KperAgrWorkertable.xls

```
Plot[{(mn ymt[t] aa[t]) / (lmt[t] wkr[t]),
  (mn ytt[t] aa[t]) / (ltt[t] wkr[t])}, {t, 0, TT}, PlotLabel →
  "Farm Output/Worker(Smallhold dash, Commercial solid)",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{.01}]}]
(* per # of workers in the sector *)
```




```
Plot[{(mn πmt[t] aa[t]) / (lmt[t] wkr[t]),
  (mn πtt[t] aa[t]) / (ltt[t] wkr[t])}, {t, 0, TT}, PlotLabel →
  "Farm Profit/Worker(Smallhold dash, Commercial solid)",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{0.01}]}]
 (* per # of workers in the sector *)
```



```
Print["Output & Profit/Worker by Agric. Sector"]
TableForm[OutPProfperAgrWorker =
  Table[{yrcal + t, t, (mn ymt[t] aa[t]) / (lmt[t] wkr[t]),
    (mn ytt[t] aa[t]) / (ltt[t] wkr[t]), (mn πmt[t] aa[t]) /
     (lmt[t] wkr[t]), (mn πtt[t] aa[t]) / (ltt[t] wkr[t])},
   {t, yrstart - yrcal, 75, 5}], TableHeadings → {Automatic,
   {Year, "t", Comm Outp, SmH Output, Comm Prof, SmH Prof}}]
```

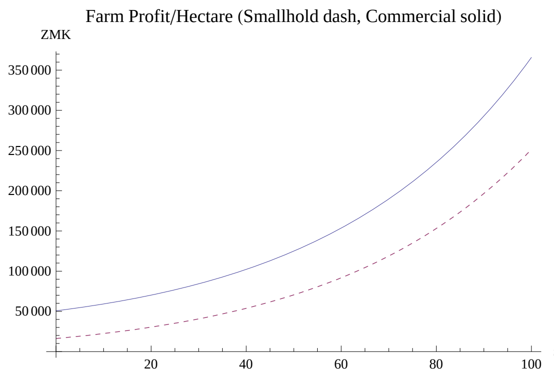
Output & Profit/Worker by Agric. Sector

	Year	t	Comm Outp	Output SmH	Comm Prof	Prc
1	1980	0	1.63763×10^6	903 229.	164 526.	117
2	1985	5	1.73839×10^6	916 924.	174 649.	124
3	1990	10	1.83366×10^6	929 320.	184 220.	131
4	1995	15	1.92329×10^6	940 538.	193 225.	137
5	2000	20	2.00726×10^6	950 685.	201 661.	143
6	2005	25	2.08562×10^6	959 864.	209 533.	149
7	2010	30	2.1585×10^6	968 164.	216 855.	154
8	2015	35	2.22609×10^6	975 669.	223 645.	159
9	2020	40	2.28859×10^6	982 455.	229 925.	163
10	2025	45	2.34627×10^6	988 591.	235 720.	168
11	2030	50	2.39938×10^6	994 138.	241 056.	171
12	2035	55	2.44819×10^6	999 153.	245 960.	175
13	2040	60	2.49298×10^6	1.00369×10^6	250 459.	178
14	2045	65	2.53401×10^6	1.00778×10^6	254 582.	181
15	2050	70	2.57156×10^6	1.01149×10^6	258 354.	184
16	2055	75	2.60587×10^6	1.01484×10^6	261 801.	186

```
AgrOutProf = Export["c:\users\lars1102\desktop\Zambia
    Output Tables\OutPProfperAgrWorkertable.xls",
  OutPProfperAgrWorker]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\OutPProfperAgrWorkertable.xls

```
Plot[{πmh[t] mn aa[t], πth[t] mn aa[t]}, {t, 0, TT}, PlotLabel →
  "Farm Profit/Hectare (Smallhold dash, Commercial solid)",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{0.01}]}]
 (* per # of workers in the sector *)
```




```
Print["Profit/Hectare by Agric. Sector"]
TableForm[Profperhectare =
  Table[{yrcal + t, t, πmh[t] mn aa[t], πth[t] mn aa[t]},
   {t, yrstart - yrcal, 75, 5}],
 TableHeadings → {Automatic, {Year, "t", Comm Pr Hec, SmH Pr Hec}}]
```

Profit/Hectare by Agric. Sector

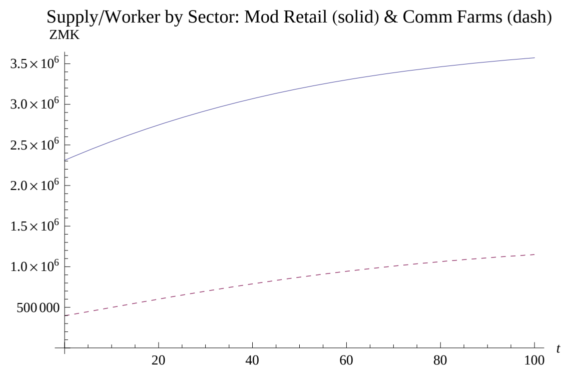
	Year	t	Comm Hec Pr	Hec Pr SmH
1	1980	0	50 674.5	16 216.6
2	1985	5	54 641.1	19 101.9
3	1990	10	59 176.8	22 390.
4	1995	15	64 338.	26 129.5
5	2000	20	70 190.3	30 374.8
6	2005	25	76 809.4	35 187.3
7	2010	30	84 281.6	40 636.
8	2015	35	92 705.1	46 798.3
9	2020	40	102 191.	53 761.4
10	2025	45	112 866.	61 623.5
11	2030	50	124 870.	70 494.7
12	2035	55	138 366.	80 499.
13	2040	60	153 533.	91 775.7
14	2045	65	170 573.	104 481.
15	2050	70	189 717.	118 792.
16	2055	75	211 220.	134 906.

```
AgrProfpHa = Export["c:\users\lars1102\desktop\Zambia Output
    Tables\Profperhectaretable.xls", Profperhectaretable]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\Profperhectaretable.xls
```

11.4 Modern Food Channel

```
Plot[{(mn yy2t[t] aa[t]) / (l2t[t] wkr[t]),
   (mn y222t[t] aa[t]) / (lmt[t] wkr[t])},
 {t, 0, TT}, PlotLabel → "Supply/Worker by Sector:
    Mod Retail (solid) & Comm Farms (dash)",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{0.01}]}]
 (* vertical difference is value added *)
```

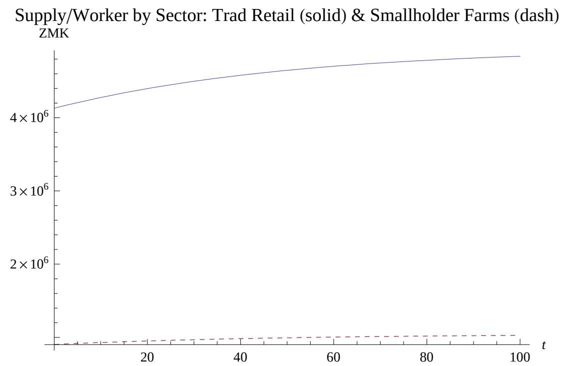


```
Plot[{(mn yy2t[t] aa[t] - mn y222t[t] aa[t]) /
    (l2t[t] wkr[t] + lmt[t] wkr[t])}, {t, 0, TT}, PlotLabel →
  "Value Added/Worker by Sector: Modern Food Channel",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin}]
 (* vertical difference is value added *)
```

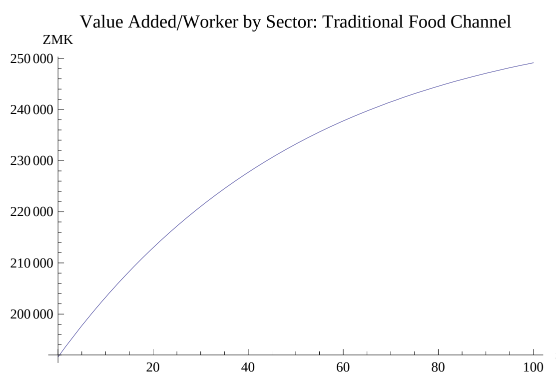
11.5 Traditional Food Channel

```
vamodch[t_] = (mn yy2t[t] aa[t] - mn y222t[t] aa[t]) /
    (l2t[t] wkr[t] + lmt[t] wkr[t]);
```

```
Plot[{(mn yy3t[t] aa[t]) / (l3t[t] wkr[t]),
  (mn y333t[t] aa[t]) / (ltt[t] wkr[t])}, {t, 0, TT},
 PlotLabel → "Supply/Worker by Sector: Trad
    Retail (solid) & Smallholder Farms (dash)",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{0.01}]}]
 (* vertical difference is value added *)
```




```
Plot[{(mn yy3t[t] aa[t] - mn y333t[t] aa[t]) /
   (l3t[t] wkr[t] + ltt[t] wkr[t])}, {t, 0, TT}, PlotLabel →
  "Value Added/Worker by Sector: Traditional Food Channel",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin}]
 (* vertical difference is value added *)
```



```
Print["Supply/Worker by Food Channel"]
TableForm[SupplyperWorkerbyChan =
  Table[{yrcal + t, t, (mn yy2t[t] aa[t]) / (l2t[t] wkr[t]),
     (mn y222t[t] aa[t]) / (lmt[t] wkr[t]), (mn yy3t[t] aa[t]) /
      (l3t[t] wkr[t]), (mn y333t[t] aa[t]) / (ltt[t] wkr[t])},
    {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", Comm Sup, Mod Sup, SmH Sup, Trad Sup}}]
```

Supply/Worker by Food Channel

	Year	t	Comm Sup	Mod Sup	SmH Sup
1	1980	0	2.31012×10^6	396 093.	4.12883×10^6
2	1985	5	2.43023×10^6	447 302.	4.20602×10^6
3	1990	10	2.54282×10^6	498 870.	4.27615×10^6
4	1995	15	2.64795×10^6	550 230.	4.33983×10^6
5	2000	20	2.74576×10^6	600 880.	4.39761×10^6
6	2005	25	2.83648×10^6	650 392.	4.45001×10^6
7	2010	30	2.9204×10^6	698 412.	4.49752×10^6
8	2015	35	2.99783×10^6	744 659.	4.54057×10^6
9	2020	40	3.06914×10^6	788 918.	4.57958×10^6
10	2025	45	3.13467×10^6	831 036.	4.6149×10^6
11	2030	50	3.1948×10^6	870 913.	4.64689×10^6
12	2035	55	3.24988×10^6	908 499.	4.67586×10^6
13	2040	60	3.30028×10^6	943 778.	4.70207×10^6
14	2045	65	3.34633×10^6	976 772.	4.7258×10^6
15	2050	70	3.38837×10^6	1.00753×10^6	4.74728×10^6
16	2055	75	3.42671×10^6	1.03611×10^6	4.76671×10^6

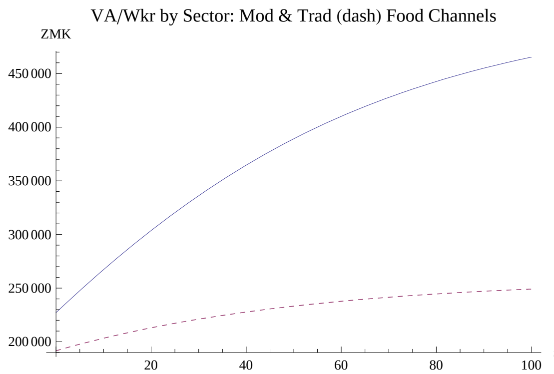
```
Supplybychannel =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\SupplyperWorkerbyChantable.xls",
  SupplyperWorkerbyChan]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\SupplyperWorkerbyChantable.xls
```

11.6 Comparison of Channel Value Added per Sectoral Worker

```
vatradch[t_] = (mn yy3t[t] aa[t] - mn y333t[t] aa[t]) /
   (l3t[t] wkr[t] + ltt[t] wkr[t]);
```

```
Plot[{vamodch[t], vatradch[t]}, {t, 0, TT}, PlotLabel →
  "VA/Wkr by Sector: Mod & Trad (dash) Food Channels",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{0.01}]}]
 (* vertical difference is value added. This
 shows VA per total workers in the channel *)
```




```
Print["VA per Worker by Food Channel"]
TableForm[
 VAbyChan = Table[{yrcal + t, t, vamodch[t], vatradch[t]},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", VA Mod Chan, VA Trad Chan}}]
```

VA per Worker by Food Channel

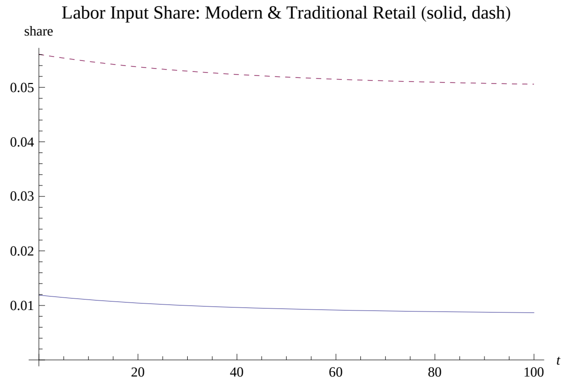
	Year	t	Chan Mod VA	Chan Trad VA
1	1980	0	227 273.	191 637.
2	1985	5	247 616.	197 717.
3	1990	10	267 205.	203 277.
4	1995	15	285 925.	208 355.
5	2000	20	303 696.	212 987.
6	2005	25	320 468.	217 208.
7	2010	30	336 220.	221 050.
8	2015	35	350 948.	224 545.
9	2020	40	364 667.	227 722.
10	2025	45	377 403.	230 608.
11	2030	50	389 192.	233 228.
12	2035	55	400 076.	235 606.
13	2040	60	410 101.	237 763.
14	2045	65	419 318.	239 720.
15	2050	70	427 776.	241 493.
16	2055	75	435 525.	243 101.

```
VAbychannel = Export["c:\users\lars1102\desktop\Zambia
    Output Tables\VAbyChantable.xls", VAbyChan]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\VAbyChantable.xls
```

11.7 Modern and Traditional Retail Comparisons

```
Plot[{l2t[t], l3t[t]}, {t, 0, TT},
 PlotLabel → "Labor Input Share:
    Modern & Traditional Retail (solid, dash)",
 AxesLabel → {t, share}, PlotStyle → {Thin, Dashing[{0.01}]}]
```



```
Plot[{(mn k2t[t] aa[t]) / (l2t[t] wkr[t]),
  (mn k3t[t] aa[t]) / (l3t[t] wkr[t])},
 {t, 0, TT}, PlotLabel → "Capital Stock/Worker by
    Sector: Mod & Trad Retail (solid, dash)",
 AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{0.01}]}]
```

```
Print["K/Worker by Food Channel"]
TableForm[KperworkerbyChan =
  Table[{yrcal + t, t, (mn k2t[t] aa[t]) / (l2t[t] wkr[t]),
    (mn k3t[t] aa[t]) / (l3t[t] wkr[t])},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", Cap / wkr Mod Ret, Cap / wkr Trad Ret}}]
```

K/Worker by Food Channel

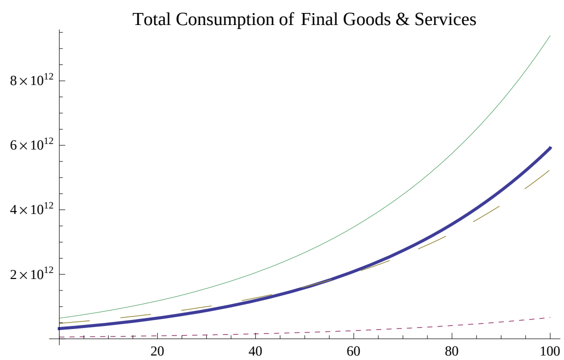
	Year	t	$\frac{\text{Cap Mod Ret}}{\text{wkr}}$	$\frac{\text{Cap Ret Trad}}{\text{wkr}}$
1	1980	0	4.03018×10^6	2.81833×10^6
2	1985	5	4.37668×10^6	3.06064×10^6
3	1990	10	4.71144×10^6	3.29474×10^6
4	1995	15	5.03251×10^6	3.51927×10^6
5	2000	20	5.33852×10^6	3.73326×10^6
6	2005	25	5.62853×10^6	3.93607×10^6
7	2010	30	5.90203×10^6	4.12733×10^6
8	2015	35	6.15883×10^6	4.3069×10^6
9	2020	40	6.39899×10^6	4.47486×10^6
10	2025	45	6.62283×10^6	4.63139×10^6
11	2030	50	6.83081×10^6	4.77682×10^6
12	2035	55	7.02351×10^6	4.91158×10^6
13	2040	60	7.20162×10^6	5.03613×10^6
14	2045	65	7.36587×10^6	5.151×10^6
15	2050	70	7.51706×10^6	5.25672×10^6
16	2055	75	7.65596×10^6	5.35386×10^6

```
KperworkerbyChan =
 Export["c:\users\lars1102\desktop\Zambia Output
   Tables\KperworkerbyChantable.xls", KperworkerbyChan]
```

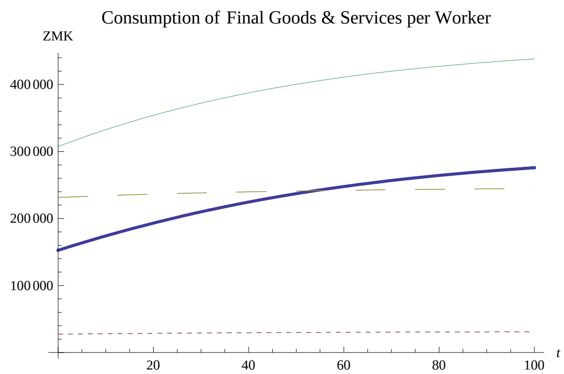
```
c:\users\lars1102\desktop\Zambia
  Output Tables\KperworkerbyChantable.xls
```

11.8 Consumption Expenditures and Felicity

```
Plot[{c1[t] mn aa[t], (* consumption of industrial goods *)
  c2[t] mn aa[t], (* consumption of modern retail food *)
  c3[t] mn aa[t],
  (* consumption of traditional retail food *)
  c4[t] mn aa[t]}, {t, 0, TT},
 PlotLabel → "Total Consumption of Final Goods & Services",
 PlotStyle → {Thick, Dashing[{0.01}], Dashing[{0.06}], Thin}]
```



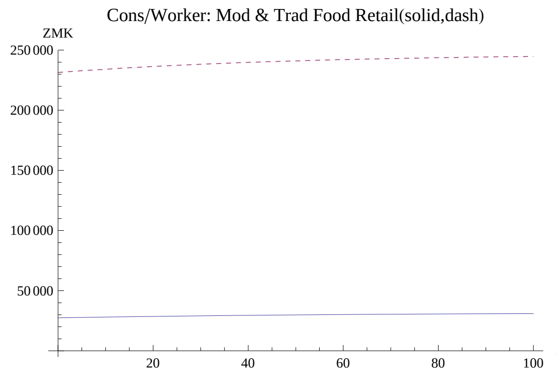
```
Plot[{c1[t] mn aa[t] / wkr[t],
   (* consumption of industrial goods per worker *)
  c2[t] mn aa[t] / wkr[t], (* consumption
   of modern retail food per worker *)
  c3[t] mn aa[t] / wkr[t], (* consumption of
   traditional retail food per worker *)
  c4[t] mn aa[t] / wkr[t]}, {t, 0, TT}, PlotLabel →
  "Consumption of Final Goods & Services per Worker",
 AxesLabel → {t, ZMK}, PlotStyle →
  {Thick, Dashing[{0.01}], Dashing[{0.06}], Thin}]
(* concave = growth rate is falling *)
```



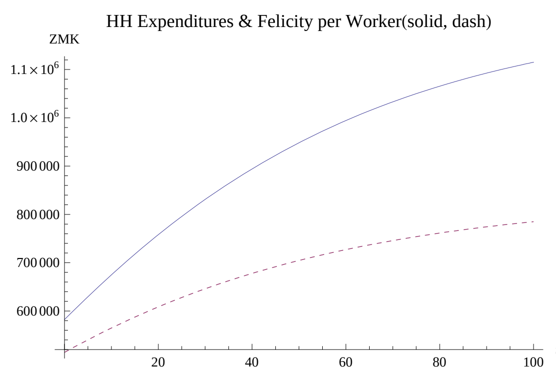

```
"Industry-thick, Modern Food-small
  dash, Traditional Food-big dash,Services-thin"
```

```
Industry-thick, Modern Food-small
  dash, Traditional Food-big dash,Services-thin
```

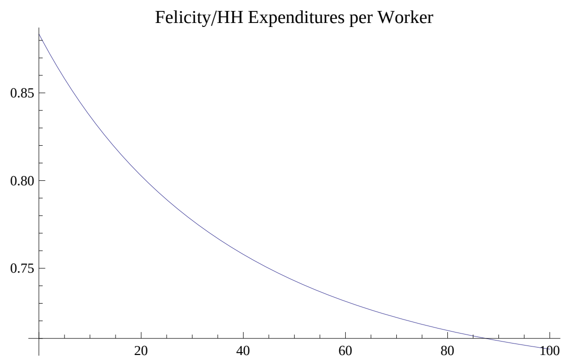
```
Plot[{mn c2[t] aa[t] / wkr[t],
   (* consumption of modern retail food *)
   mn c3[t] aa[t] / wkr[t](* consumption
    of traditional retail food *)
  }, {t, 0, TT}, PlotLabel →
   "Cons/Worker: Mod & Trad Food Retail(solid,dash)",
  AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{0.01}]}]
```



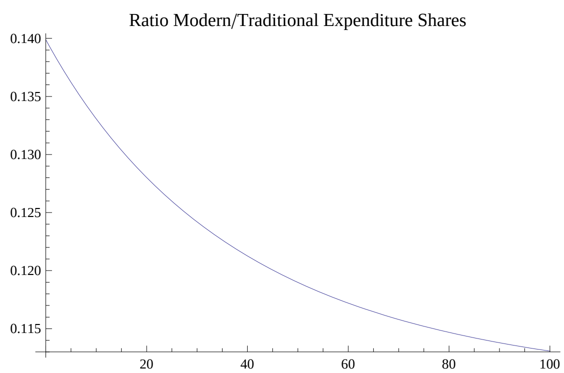

```
Plot[{mn hhexp[t] aa[t] / wkr[t], (mn hq[t] aa[t] / wkr[t])},
  {t, 0, TT}, PlotLabel →
   "HH Expenditures & Felicity per Worker(solid, dash)",
  AxesLabel → {t, ZMK}, PlotStyle → {Thin, Dashing[{0.01}]}]
  (* illustrates diminishing marginal utility *)
```



```
Plot[{hq[t] / hhexp[t]}, {t, 0, TT},
 PlotLabel → "Felicity/HH Expenditures per Worker",
 PlotStyle → {Thin}]
(* downward slope-->>diminishing marginal utilty *)
```




```
Plot[{shrc2[t] / shrc3[t]}, {t, 0, TT},
 PlotLabel → "Ratio Modern/Traditional Expenditure Shares",
 PlotStyle → {Thin}](* L shape agrees
 with more complex supermarket story *)
(* explanation: ↓shrc2[t]=↓↓[(p2 c2)/HHexp]
   and ↓shrc3[t]=↑↑[(p3 c3)/HHexp] c2=(λ2 HHexp)/p2 *)
```



```
Plot[{c2[t] / c3[t]}, {t, 0, TT}, PlotLabel →
  "Ratio Modern/Traditional Retail Food Expenditures",
 PlotStyle → {Thin}]
```


```
Print["Expenditure Ratios"]
TableForm[ExpendRatios =
  Table[{yrcal + t, t, shrc2[t] / shrc3[t], c2[t] / c3[t]},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", Mod to Tra Exp Sh, Mod to Tra Expend}}]
```

Expenditure Ratios

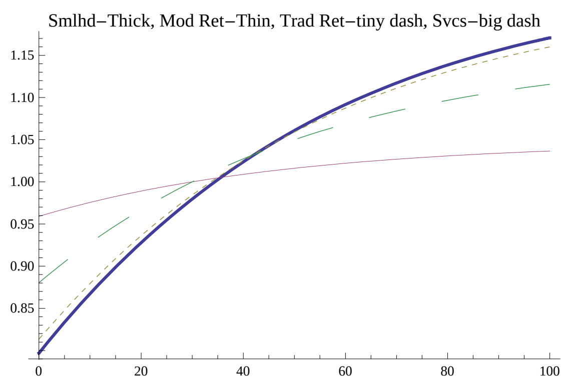
	Year	t	Exp Mod Sh to Tra	Expend Mod to Tra
1	1980	0	0.139874	0.118638
2	1985	5	0.136214	0.11931
3	1990	10	0.133074	0.119959
4	1995	15	0.130365	0.120581
5	2000	20	0.128019	0.121171
6	2005	25	0.125978	0.121728
7	2010	30	0.124196	0.122252
8	2015	35	0.122635	0.122741
9	2020	40	0.121264	0.123197
10	2025	45	0.120056	0.123621
11	2030	50	0.118988	0.124012
12	2035	55	0.118044	0.124374
13	2040	60	0.117206	0.124707
14	2045	65	0.116462	0.125013
15	2050	70	0.115799	0.125294
16	2055	75	0.115208	0.125551

```
ExpendRatios = Export["c:\users\lars1102\desktop\Zambia
    Output Tables\ExpendRatios.xls", ExpendRatios]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\ExpendRatios.xls
```

11.9 Prices

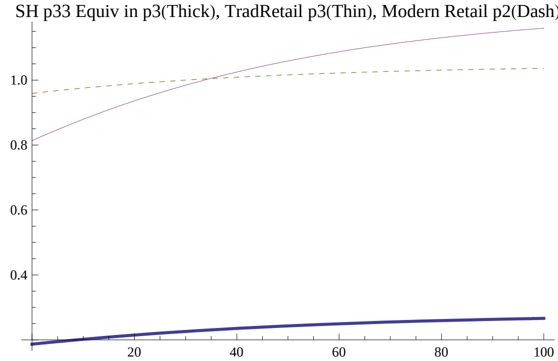
```
Plot[{p33t[t], p2t[t], p3t[t], p4t[t]},
 {t, 0, TT}, PlotLabel → "Smlhd-Thick, Mod
    Ret-Thin, Trad Ret-tiny dash, Svcs-big dash",
 PlotStyle → {Thick, Thin, Dashing[{0.01}], Dashing[{0.07}]}]
(* p33 p3 are not in equiv units -
 see next chart below for equiv units *)
```




```
p2equiv[t_] = p2t[t] - (y222t[t] / yy2t[t]) * p22;
(* price received by Commercial
 farms in Modern Retail food equivalents *)
p3equiv[t_] = p3t[t] - (y333t[t] / yy3t[t]) * p33t[t];
(* price received by Smallholder farms
 in Traditional Retail food equivalents *)
```

```
Plot[{p3equiv[t], p3t[t], p2t[t]}, {t, 0, TT},
 PlotLabel → "SH p33 Equiv in p3(Thick),
    TradRetail p3(Thin), Modern Retail p2(Dash)",
 PlotStyle → {Thick, Thin, Dashing[{0.01}]}]
(* p3equiv price received by Smallholder
 farms in Traditional food equivalents *)
```

SH p33 Equiv in p3(Thick), TradRetail p3(Thin), Modern Retail p2(Dash)



```
Print["Prices: p33 Equiv in p3, p3, p2, pindex"]
TableForm[AgrFoodPrices =
  Table[{yrcal + t, t, p3equiv[t], p3t[t], p2t[t], pindex[t]},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", p33 Equiv in p3, p3, p2, pindex}}]
```

Prices: p33 Equiv in p3, p3, p2, pindex

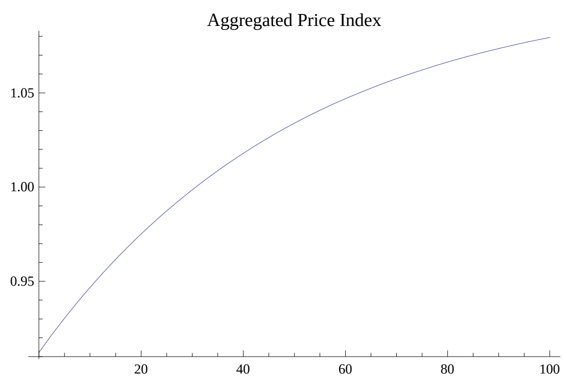
	Year	t	Equiv in p3 p33	p3	p2	pinde
1	1980	0	0.186701	0.81348	0.95909	0.912
2	1985	5	0.194551	0.847684	0.967785	0.930
3	1990	10	0.201847	0.879474	0.975622	0.946
4	1995	15	0.208607	0.908929	0.982686	0.961
5	2000	20	0.214854	0.936147	0.989054	0.975
6	2005	25	0.220613	0.961238	0.994796	0.987
7	2010	30	0.22591	0.98432	0.999974	0.998
8	2015	35	0.230775	1.00552	1.00465	1.008
9	2020	40	0.235234	1.02495	1.00886	1.017
10	2025	45	0.239316	1.04273	1.01266	1.026
11	2030	50	0.243048	1.05899	1.01609	1.033
12	2035	55	0.246457	1.07385	1.01919	1.040
13	2040	60	0.249566	1.08739	1.02199	1.046
14	2045	65	0.2524	1.09974	1.02451	1.052
15	2050	70	0.254981	1.11099	1.02679	1.057
16	2055	75	0.25733	1.12122	1.02885	1.062

```
AgrFoodPrices =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\AgrFoodPrices.xls", AgrFoodPrices]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\AgrFoodPrices.xls

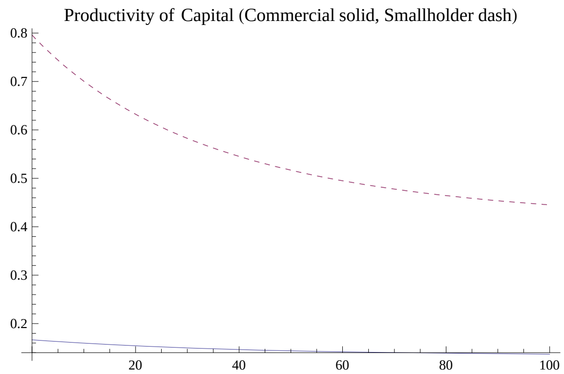
```
Plot[{p2equiv[t], p3equiv[t]}, {t, 0, TT},
 PlotLabel → "Price spread in equiv units b/t
    retail & farm (Trad dash; Modern solid) ",
 PlotStyle → {Thin, Dashing[{0.01}]}]
```


```
Plot[{pindex[t]}, {t, 0, TT},
 PlotLabel → "Aggregated Price Index", PlotStyle → {Thin}]
```

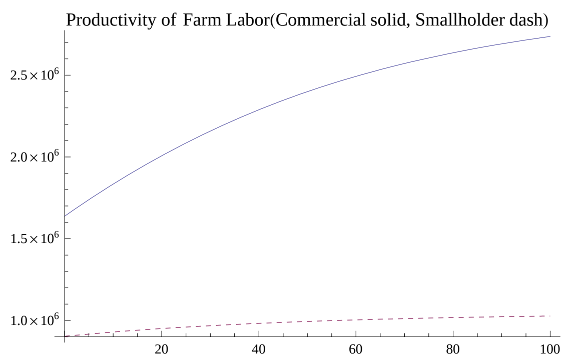


11.10 Productivity

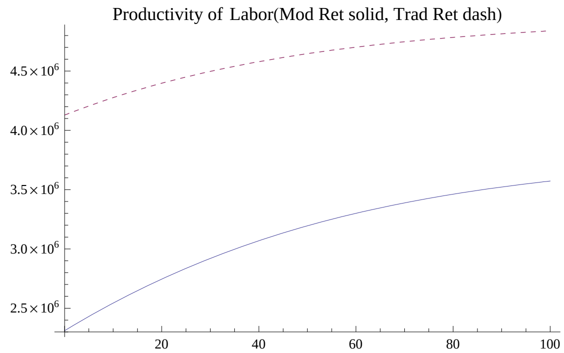
```
Plot[{ymt[t] / kmt[t], ytt[t] / ktt[t]},
 {t, 0, TT}, PlotLabel → "Productivity of
    Capital (Commercial solid, Smallholder dash)",
 PlotStyle → {Thin, Dashing[{0.01}]}]
```




```
Plot[{(ymt[t] mn aa[t]) / (lmt[t] wkr[t]),
  (ytt[t] mn aa[t]) / (ltt[t] wkr[t])}, {t, 0, TT},
 PlotLabel → "Productivity of Farm Labor(Commercial solid,
    Smallholder dash)", PlotStyle → {Thin, Dashing[{0.01}]}]
```



```
Plot[{(yy2t[t] mn aa[t]) / (l2t[t] wkr[t]),
   (yy3t[t] mn aa[t]) / (l3t[t] wkr[t])}, {t, 0, TT}, PlotLabel →
  "Productivity of Labor(Mod Ret solid, Trad Ret dash)",
 PlotStyle → {Thin, Dashing[{0.01}]}]
```




```
Export["c:\users\lars1102\desktop\Zambia
   Output Tables\macro_and.XLS", macro]
c:\users\lars1102\desktop\Zambia Output Tables\macro_and.XLS
```

12.0 Transition Statistics

12.1 Time to Double GDP

```
FindRoot[2 gdpt[0] aa[0] - (gdpt[t] aa[t]) == 0, {t, 50}]
{t → 20.659}
```

12.2 Time to Double GDP per Worker

```
FindRoot[
 (2 gdpt[0] aa[0] / wkr[0]) - (gdpt[t] aa[t] / wkr[t]) == 0, {t, 100}]
{t → 200.689}
```

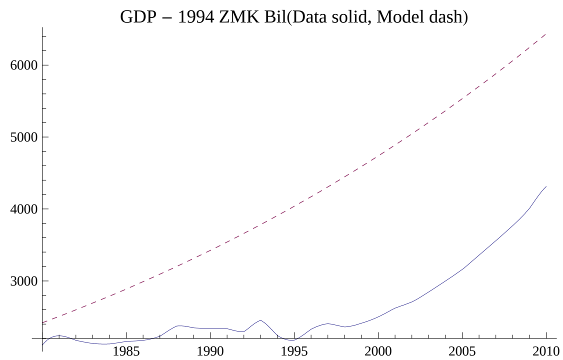
12.3 Half-life of Adjustment to Long-run Equilibrium

```
FindRoot[(gdpt[t] aa[t]) - (gdpt[0] aa[0] +
     1/2 (gdpt[TT] aa[TT] - gdpt[0] aa[0])) == 0, {t, 60}]
{t → 74.803}
```

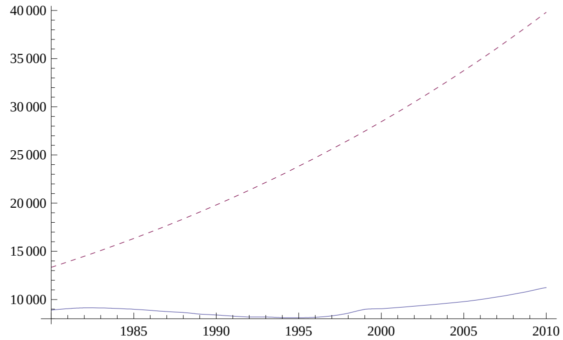
13.0 Validation

13.1 Validation Charts

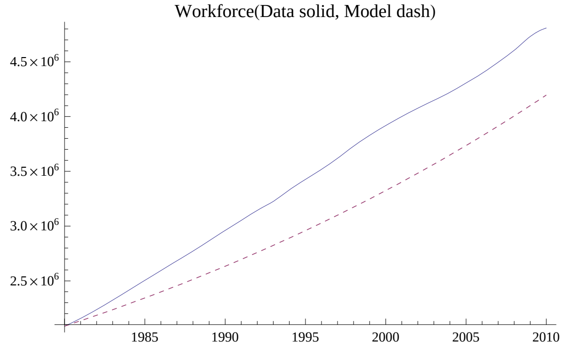
```
Plot[{gpo2[t - yrstart + 1], gdpt[t - yrstart] aa[t - yrstart]},
 {t, yrstart, yrstart + 30},
 PlotLabel → "GDP - 1994 ZMK Bil(Data solid, Model dash)",
 PlotStyle → {Thin, Dashing[{0.01}]}]
```



```
Plot[{ko12[t - yrstart + 1], kk[t - yrstart] aa[t - yrstart]},
 {t, yrstart, yrstart + 30}, PlotLabel → "Capital Stock -
1994 ZMK Bil(Data solid, Model dash)",
 PlotStyle → {Thin, Dashing[{0.01}]}]
```



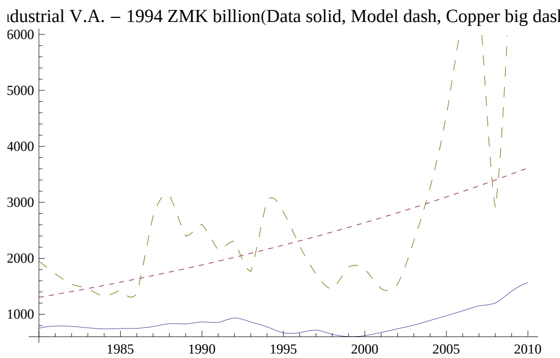

```
Plot[{lpo2[t - yrstart + 1], wkr[t - yrstart]},
 {t, yrstart, yrstart + 30},
 PlotLabel → "Workforce(Data solid, Model dash)",
 PlotStyle → {Thin, Dashing[{0.01}]}](* e^(nt)lzero = lt *)
```



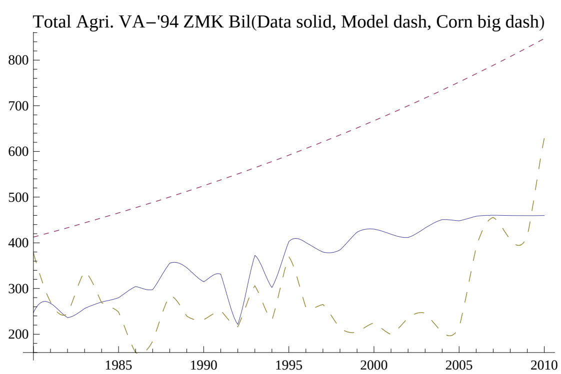

```
{wkr[0], lpo2[2]}
```

$\{2.08608 \times 10^6, 2.15591 \times 10^6\}$

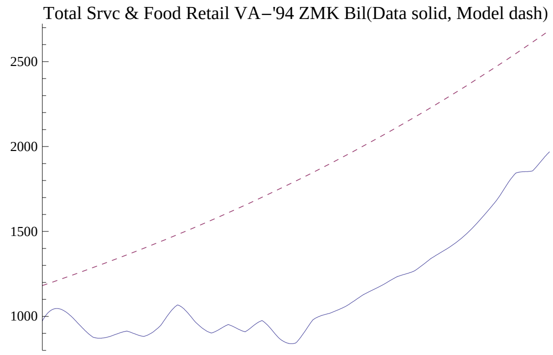
```
Plot[{gind2[t - yrstart + 1], yy1t[t - yrstart] aa[t - yrstart],
  pcop2[t - yrstart + 1]}, {t, yrstart, yrstart + 30},
 PlotLabel → "Industrial V.A. – 1994 ZMK billion(Data
    solid, Model dash, Copper big dash)",
 PlotStyle → {Thin, Dashing[{0.01}], Dashing[{0.02}]}]
```




```
Plot[{ago2[t - yrstart + 1],
  (y222t[t - yrstart] + y333t[t - yrstart]) aa[t - yrstart],
  pcor2[t - yrstart + 1]}, {t, yrstart, yrstart + 30},
 PlotLabel → "Total Agri. VA-'94 ZMK Bil(Data
    solid, Model dash, Corn big dash)",
 PlotStyle → {Thin, Dashing[{0.01}], Dashing[{0.02}]}]
```



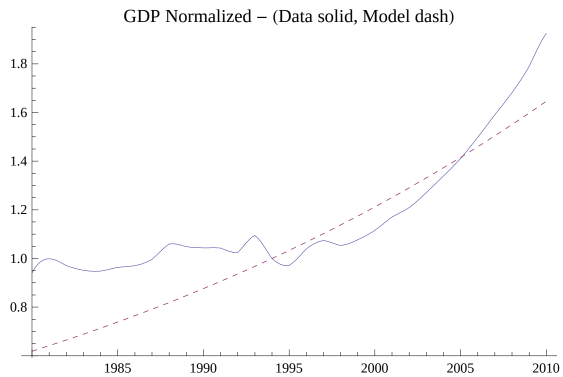
```
Plot[{gser2[t - yrstart + 1],
  (yy2t[t - yrstart] + yy3t[t - yrstart] + yy4t[t - yrstart])
   aa[t - yrstart]}, {t, yrstart, yrstart + 30},
 PlotLabel → "Total Srvc & Food Retail VA-'94 ZMK Bil(Data
    solid, Model dash)", PlotStyle → {Thin, Dashing[{0.01}]}]
```



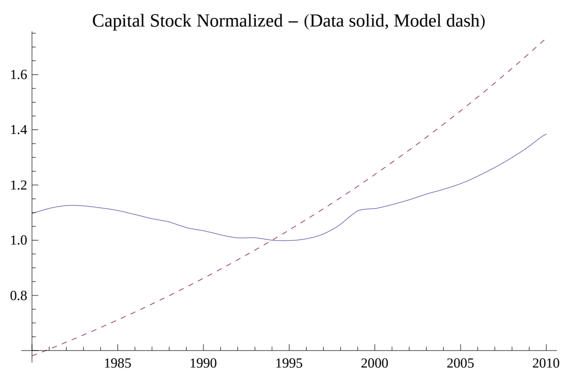
13.2 Validation Charts Normalized to 1994 (the 15th year)

```
(* Example: Plot[{wkr[t-1999]/wkr[0], lpo2[t-(1999-20)]/lpo2[20]},
  {t,1981,1999+7},PlotLabel→"Labor: Model Vs Data"] *)
```

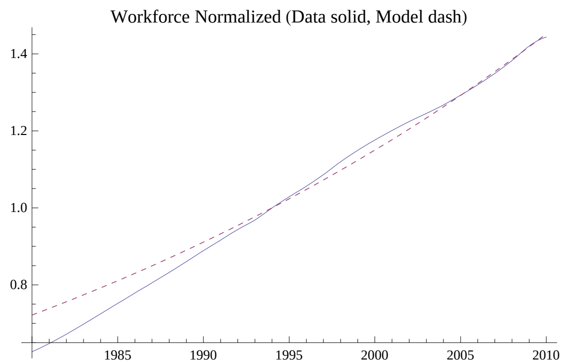
```
Plot[{(gpo2[t - yrstart + 1] / gpo2[15]),
   (gdpt[t - yrstart] aa[t - yrstart] ) / (gdpt[14] aa[14])},
 {t, yrstart, yrstart + 30},
 PlotLabel → "GDP Normalized - (Data solid, Model dash)",
 PlotStyle → {Thin, Dashing[{0.01}]}]
```



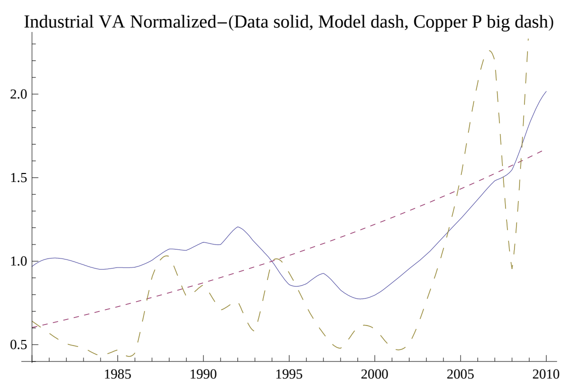

```
Plot[{(ko12[t - yrstart + 1] / ko12[15]),
   (kk[t - yrstart] aa[t - yrstart]) / (kk[14] aa[14])},
 {t, yrstart, yrstart + 30}, PlotLabel →
  "Capital Stock Normalized - (Data solid, Model dash)",
 PlotStyle → {Thin, Dashing[{0.01}]}]
```



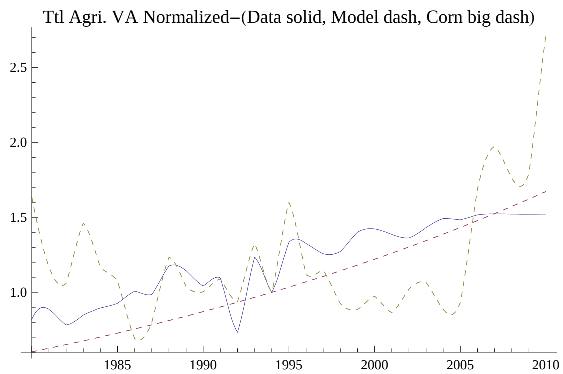
```
Plot[{(lpo2[t - yrstart + 1] / lpo2[15]), wkr[t - yrstart] / wkr[14]},
 {t, yrstart, yrstart + 30},
 PlotLabel → "Workforce Normalized (Data solid, Model dash)",
 PlotStyle → {Thin, Dashing[{0.01}]}]
```



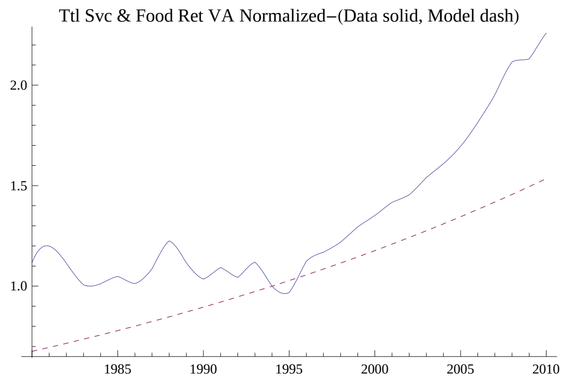

```
Plot[{gind2[t - yrstart + 1] / gind2[15],
  (yy1t[t - yrstart] aa[t - yrstart]) / (yy1t[14] aa[14]),
  pcop2[t - yrstart + 1] / pcop2[15]}, {t, yrstart, yrstart + 30},
 PlotLabel → "Industrial VA Normalized-(Data
    solid, Model dash, Copper P big dash)",
 PlotStyle → {Thin, Dashing[{0.01}], Dashing[{0.02}]}]
```



```
"Industrial Value Added Normalized
  – (Data thick, Model dash, Copper P Thin)"

Industrial Value Added Normalized
  – (Data thick, Model dash, Copper P Thin)

Plot[{ago2[t – yrstart + 1] / ago2[15],
  (yy1t[t – yrstart] aa[t – yrstart] ) / (yy1t[14] aa[14]),
  pcor2[t – yrstart + 1] / pcor2[15]},
 {t, yrstart, yrstart + 30}, PlotLabel → "Ttl Agri. VA
    Normalized–(Data solid, Model dash, Corn big dash)",
 PlotStyle → {Thin, Dashing[{0.01}], Dashing[{0.01}]}]
```



```
Plot[{(gser2[t - yrstart + 1] / gser2[15]),
  ((yy2t[t - yrstart] + yy3t[t - yrstart] + yy4t[t - yrstart])
     aa[t - yrstart]) / ((yy2t[14] + yy3t[14] + yy4t[14]) aa[14])},
 {t, yrstart, yrstart + 30}, PlotLabel →
  "Ttl Svc & Food Ret VA Normalized-(Data solid, Model dash)",
 PlotStyle → {Thin, Dashing[{0.01}]}]
```



14.0 Growth Accounting to Interprete Results

14.01 Growth Accounting Exercise

```
gyy1t[t_] = Log[yy1t[t] / yy1t[t - 1]];
(* Industry Growth Accounting Exercise *)
gl1t[t_] = α Log[l1t[t] / l1t[t - 1]];
gk1t[t_] = (1 - α) Log[k1t[t] / k1t[t - 1]];

tfpy1[t_] = gyy1t[t] - gl1t[t] - gk1t[t];
(* Total Factor Productivity (TFP) calculation *)

tfpy1[5]
```

-1.80411×10^{-16}

```
cgl1t[t_] = gl1t[t] / gyy1t[t];
(* percent contribution to growth *)
cgk1t[t_] = gk1t[t] / gyy1t[t];

ctoty1t[t_] = cgl1t[t] + cgk1t[t];
```

```
{ctoty1t[55], cgl1t[55], cgk1t[55], α}
{1., 0.0221768, 0.977823, 0.276088}

{gyy1t[1], gl1t[1], gk1t[1]}
(* gdp growth & direct contributions of L and K *)
{0.0151481, 0.000734269, 0.0144138}



gymt[t_] = Log[ymt[t] / ymt[t - 1]];
(* Commercial Farming Growth Accounting Exercise *)
glmt[t_] = ϵ1 Log[lmt[t] / lmt[t - 1]];
gkmt[t_] = ϵ2 Log[kmt[t] / kmt[t - 1]];

tfpymt[t_] = gymt[t] - glmt[t] - gkmt[t];(* TFP calculation *)

tfpymt[5]
1.16226 × 10^-16

cglmt[t_] = glmt[t] / gymt[t];
(* percent contribution to growth *)
cgkmt[t_] = gkmt[t] / gymt[t];

ctotymt[t_] = cglmt[t] + cgkmt[t];

{ctotymt[5], cglmt[5], cgkmt[5]}
{1., 0.731668, 0.268332}

{ϵ1, ϵ2, ϵ3}
{0.298456, 0.601079, 0.100466}

{gymt[5], glmt[5], gkmt[5]}
(* gdp growth & direct contributions of L and K *)
{-0.00785962, -0.00575063, -0.00210899}
```

```
gytt[t_] = Log[ytt[t] / ytt[t - 1]];
(* Smallholder Farming Growth Accounting Exercise *)
gltt[t_] = φ1 Log[ltt[t] / ltt[t - 1]];
gktt[t_] = φ2 Log[ktt[t] / ktt[t - 1]];

tfpytt[t_] = gytt[t] - gltt[t] - gktt[t];(* TFP calculation *)

tfpytt[5]
```

-8.45678×10^{-17}

```
cgltt[t_] = gltt[t] / gytt[t];
(* percent contribution to growth *)
cgktt[t_] = gktt[t] / gytt[t];

ctotytt[t_] = cgltt[t] + cgktt[t];

{ctotytt[5], cgltt[5], cgktt[5]}
{1., -3.19959, 4.19959}

{φ1, φ2, φ3}
{0.679172, 0.157826, 0.163002}

{gytt[5], gltt[5], gktt[5]}
(* gdp growth & direct contributions of L and K *)
{0.000503172, -0.00160994, 0.00211311}
```

```
gyy2t[t_] = Log[yy2t[t] / yy2t[t - 1]];
(* Modern Retail Growth Accounting Exercise *)
gl2t[t_] = β1 Log[l2t[t] / l2t[t - 1]];
gk2t[t_] = β2 Log[k2t[t] / k2t[t - 1]];
gy222t[t_] = β3 Log[y222t[t] / y222t[t - 1]];

tfpy2[t_] = gyy2t[t] - gl2t[t] - gk2t[t] - gy222t[t];
(* TFP calculation *)

tfpy2[5]
```

8.67362×10^{-18}

```
cgl2t[t_] = gl2t[t] / gyy2t[t];
(* percent contribution to growth *)
cgk2t[t_] = gk2t[t] / gyy2t[t];
cgy222t[t_] = gy222t[t] / gyy2t[t];

ctoty2t[t_] = cgl2t[t] + cgk2t[t] + cgy222t[t];

{ctoty2t[5], cgl2t[5], cgk2t[5], cgy222t[5]}

{1., -0.71616, 0.66712, 1.04904}

{β1, β2, β3}

{0.220598, 0.182068, 0.597334}

{gyy2t[5], gl2t[5], gk2t[5], gy222t[5]}
(* gdp growth & direct contributions of L and K *)

{0.00228046, -0.00163317, 0.00152134, 0.00239229}
```

```
gyy3t[t_] = Log[yy3t[t] / yy3t[t - 1]];
(* Traditional Retail Growth Accounting Exercise *)
gl3t[t_] = γ1 Log[l3t[t] / l3t[t - 1]];
gk3t[t_] = γ2 Log[k3t[t] / k3t[t - 1]];
gy333t[t_] = γ3 Log[y333t[t] / y333t[t - 1]];

tfpy3[t_] = gyy3t[t] - gl3t[t] - gk3t[t] - gy333t[t];
(* TFP calculation *)

tfpy3[5]

-9.54098 × 10^-18

cgl3t[t_] = gl3t[t] / gyy3t[t];
(* percent contribution to growth *)
cgk3t[t_] = gk3t[t] / gyy3t[t];
cgy333t[t_] = gy333t[t] / gyy3t[t];

ctoty3t[t_] = cgl3t[t] + cgk3t[t] + cgy333t[t];

{ctoty3t[5], cgl3t[5], cgk3t[5], cgy333t[5]}

{1., -0.29552, 0.963382, 0.332137}

{γ1, γ2, γ3}

{0.14552, 0.0839889, 0.770491}
```

```
{gyy3t[5], gl3t[5], gk3t[5], gy333t[5]}
(* gdp growth & direct contributions of L and K *)
{0.00116726, -0.000344947, 0.00112451, 0.000387689}
```

```
gyy4t[t_] = Log[yy4t[t] / yy4t[t - 1]];
(* Services Growth Accounting Exercise *)
gl4t[t_] = δ Log[l4t[t] / l4t[t - 1]];
gk4t[t_] = (1 - δ) Log[k4t[t] / k4t[t - 1]];

tfpy4[t_] = gyy4t[t] - gl4t[t] - gk4t[t];(* TFP calculation *)

tfpy4[5]
```

-9.71445×10^{-17}

```
cgl4t[t_] = gl4t[t] / gyy4t[t];
(* percent contribution to growth *)
cgk4t[t_] = gk4t[t] / gyy4t[t];

ctoty4t[t_] = cgl4t[t] + cgk4t[t];

{ctoty4t[5], cgl4t[5], cgk4t[5]}
{1., 0.136212, 0.863788}

δ
0.609961

{gyy4t[1], gl4t[1], gk4t[1]}
(* gdp growth & direct contributions of L and K *)
{0.00867832, 0.00118916, 0.00748916}
```

14.12 Calculate Elasticities (Improved Structure)

$$\epsilon\text{wwp4}[\text{p4\_}] = \frac{\left(\partial_{p4}\,\text{ww}[\text{p4}]\right)\,\text{p4}}{\text{ww}[\text{p4}]};\text{(* industry *)}$$

$$\text{(* }\epsilon\text{pp3p33}[\text{p33\_},\text{p4\_}] = \frac{\left(\partial_{p33}\,\text{pp3}[\text{p33},\text{p4}]\right)\text{p33}}{\text{pp3}[\text{p33},\text{p4}]};\text{(* industry *) *)}$$

$$\epsilon\text{pp3p4}[\text{p33\_}, \text{p4\_}] = \left(\left(\partial_{p4}\,\text{pp3}[\text{p33}, \text{p4}]\right)\,\text{p4}\right) \big/ \text{pp3}[\text{p33}, \text{p4}];$$

```
(* industry *)
```

```
ϵyy1p4[p33_, p4_, k_] =
  ((∂p4 yy1[p33, p4, k]) p4) / yy1[p33, p4, k] ;(* industry *)
```

14.1 Calculate Elasticities

```
ϵyy1p33[p33_, p4_, k_] =
  ((∂p33 yy1[p33, p4, k]) p33) / yy1[p33, p4, k] ;(* industry *)

ϵyy1p4[p33_, p4_, k_] =
  ((∂p4 yy1[p33, p4, k]) p4) / yy1[p33, p4, k] ;(* industry *)

ϵyy1k[p33_, p4_, k_] = ((∂k yy1[p33, p4, k]) k) / yy1[p33, p4, k] ;
(* industry *)

{ϵyy1p33[1, 1, K], ϵyy1p4[1, 1, K], ϵyy1k[1, 1, K]}

{1.77286, -9.06054, 2.8821}

ϵy222p33[p33_, p4_] = ((∂p33 y222[p33, p4]) p33) / y222[p33, p4] ;
(* commercial agriculture *)

ϵy222p4[p33_, p4_] = ((∂p4 y222[p33, p4]) p4) / y222[p33, p4] ;
(* commercial agriculture *)

ϵy222H = 1; (* elasticity of commercial farmland *)

{ϵy222p33[1, 1], ϵy222p4[1, 1]}

{5.64479, -8.2326}



ϵyy2p33[p33_, p4_] = ((∂p33 yy2[p33, p4]) p33) / yy2[p33, p4] ;
(* modern food retail *)

ϵyy2p4[p33_, p4_] = ((∂p4 yy2[p33, p4]) p4) / yy2[p33, p4] ;
(* modern food retail *)

{ϵyy2p33[1, 1], ϵyy2p4[1, 1]}

{5.64479, -8.56035}



ϵy333p33[p33_, p4_] = ((∂p33 y333[p33, p4]) p33) / y333[p33, p4] ;
(* smallholder agriculture *)
```

```
ϵy333p4[p33_, p4_] = ((∂p4 y333[p33, p4]) p4) / y333[p33, p4];
(* smallholder agriculture *)
ϵy333H = 1; (* elasticity of smallholder farmland *)
{ϵy333p33[1, 1], ϵy333p4[1, 1]}
{5.1349, -8.23358}
```

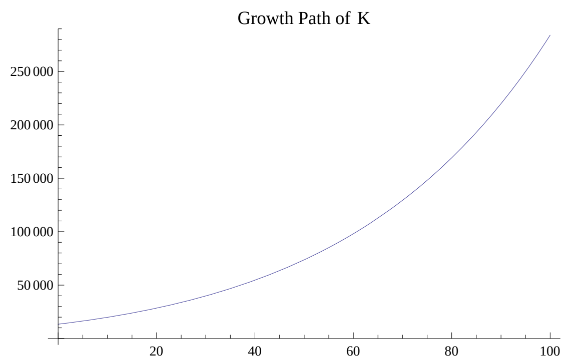
```
ϵyy3p33[p33_, p4_] = ((∂p33 yy3[p33, p4]) p33) / yy3[p33, p4];
(* traditional food retail *)
ϵyy3p4[p33_, p4_] = ((∂p4 yy3[p33, p4]) p4) / yy3[p33, p4];
(* traditional food retail *)
{ϵyy3p33[1, 1], ϵyy3p4[1, 1]}
{5.36441, -8.47965}
```

```
ϵyy4p33[p33_, p4_, k_] =
  ((∂p33 yy4[p33, p4, k]) p33) / yy4[p33, p4, k]; (* services *)
ϵyy4p4[p33_, p4_, k_] =
  ((∂p4 yy4[p33, p4, k]) p4) / yy4[p33, p4, k]; (* services *)
ϵyy4k[p33_, p4_, k_] = ((∂k yy4[p33, p4, k]) k) / yy4[p33, p4, k];
(* services *)
{ϵyy4p33[1, 1, K], ϵyy4p4[1, 1, K], ϵyy4k[1, 1, K]}
{-3.82514, 10.2648, -0.848908}
```

14.2 Growth Effects in Level Variables

```
KS[t_] = kk[t] Exp[(x + n) t]; (* Growth path of K *)
```

```
Plot[{KS[t]}, {t, 0, 100},
 PlotLabel → "Growth Path of K", PlotStyle → {Thin}]
```




```
(* Y1 effects *)
```

$$\text{yy1p33[t\_]} = \epsilon\text{yy1p33[p33t[t], p4t[t], kk[t]]} \times \frac{(\partial_t \text{ p33t[t]})}{\text{p33t[t]}};$$

```
(* p33 effect on Y1 *)
```

$$\text{yy1p4[t\_]} = \epsilon\text{yy1p4[p33t[t], p4t[t], kk[t]]} \times \frac{(\partial_t \text{ p4t[t]})}{\text{p4t[t]}};$$

```
(* p4 effect on Y1 *)
```

$$\text{yy1kk[t\_]} = \epsilon\text{yy1k[p33t[t], p4t[t], kk[t]]} \times \frac{(\partial_t \text{ KS[t]})}{\text{KS[t]}};$$

```
(* K effect on Y1 *)

yy1L[t_] = (1 - ϵyy1k[p33t[t], p4t[t], kk[t]]) (x + n);
(* Tech and labor effect *)

yy1tot[t_] = yy1p33[t] + yy1p4[t] + yy1kk[t] + yy1L[t];
(* Total effect *)

{yy1p33[0], yy1p4[0], yy1kk[0], yy1L[0]}
{0.00694039, -0.0256211, 0.0776747, -0.0203386}


(* Y222 effects *)
```

```
y222p33[t_] = ϵy222p33[p33t[t], p4t[t]] × (∂t p33t[t])/p33t[t];
(* p33 effect on Y222 *)
y222p4[t_] = ϵy222p4[p33t[t], p4t[t]] × (∂t p4t[t])/p4t[t];
(* p4 effect on Y222 *)
y222H = ϵy222H (x + n);
y222tot[t_] = y222p33[t] + y222p4[t] + y222H;(* Total effect *)
{y222p33[0], y222p4[0], y222H}
{0.0461598, -0.0418303, 0.0233}

y222tot[0]
0.0276295


(* Y2 effects *)
yy2p33[t_] = ϵyy2p33[p33t[t], p4t[t]] × (∂t p33t[t])/p33t[t];
(* p33 effect on Y2 *)
yy2p4[t_] = ϵyy2p4[p33t[t], p4t[t]] × (∂t p4t[t])/p4t[t];
(* p4 effect on Y2 *)
yy2tot[t_] = yy2p33[t] + yy2p4[t];(* Total effect *)
{yy2p33[0], yy2p4[0]}
{0.0461598, -0.0437396}

yy2tot[0]
0.00242021


(* Y333 effects *)
y333p33[t_] = ϵy333p33[p33t[t], p4t[t]] × (∂t p33t[t])/p33t[t];
(* p33 effect on Y333 *)
```

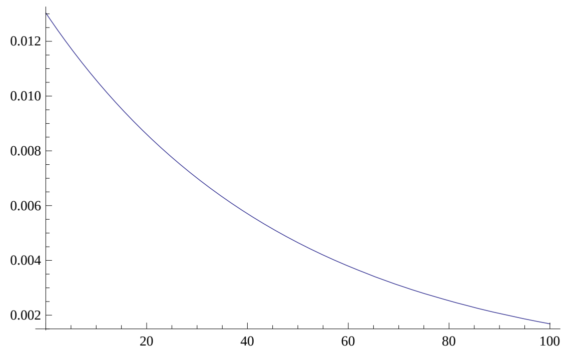
```
y333p4[t_] = ϵy333p4[p33t[t], p4t[t]] × (∂t p4t[t]) / p4t[t];
(* p4 effect on Y333 *)
y333H = ϵy333H (x + n);
y333tot[t_] = y333p33[t] + y333p4[t] + y333H;(* Total effect *)
{y333p33[0], y333p4[0], y333H}
{0.0485015, -0.0479644, 0.0233}

y333tot[0]
0.0238372


(* Y3 effects *)
yy3p33[t_] = ϵyy3p33[p33t[t], p4t[t]] × (∂t p33t[t]) / p33t[t];
(* p33 effect on Y3 *)
yy3p4[t_] = ϵyy3p4[p33t[t], p4t[t]] × (∂t p4t[t]) / p4t[t];
(* p4 effect on Y3 *)
yy3tot[t_] = yy3p33[t] + yy3p4[t];(* Total effect *)
{yy3p33[0], yy3p4[0]}
{0.0506693, -0.0493978}

yy3tot[0]
0.00127151

(* Y4 effects *)
yy4p33[t_] = ϵyy4p33[p33t[t], p4t[t], kk[t]] × (∂t p33t[t]) / p33t[t];
(* p33 effect on Y4 *)
yy4p4[t_] = ϵyy4p4[p33t[t], p4t[t], kk[t]] × (∂t p4t[t]) / p4t[t];
(* p4 effect on Y4 *)
```

```
yy4kk[t_] = ϵyy4k[p33t[t], p4t[t], kk[t]] × (∂t KS[t]) / KS[t];
(* K effect on Y4 *)

yy4L[t_] = (1 - ϵyy4k[p33t[t], p4t[t], kk[t]]) (x + n);
(* Tech and labor effect *)

yy4tot[t_] = yy4p33[t] + yy4p4[t] + yy4kk[t] + yy4L[t];
(* Total effect *)

{yy4p33[0], yy4p4[0], yy4kk[0], yy4L[0]}
{-0.0530639, 0.0973928, -0.0811285, 0.0688789}

yy4tot[0]
0.0320792
```

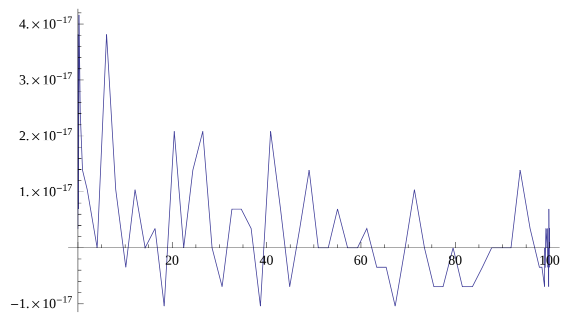
14.3 Growth in Total Output

```
ymtdoT[t_] = (∂t (ymt[t] Exp[(x + n) t])) / (ymt[t] Exp[(x + n) t]);
(* commercial agriculture *)

yttdoT[t_] = (∂t (ytt[t] Exp[(x + n) t])) / (ytt[t] Exp[(x + n) t]);
(* smallholder agriculture *)

yt1doT[t_] = (∂t (yy1t[t] Exp[(x + n) t])) /
   (yy1t[t] Exp[(x + n) t]); (* industry *)

yt2doT[t_] =
  (∂t (yy2t[t] Exp[(x + n) t])) / (yy2t[t] Exp[(x + n) t]);
(* modern food retail *)

yt3doT[t_] =
  (∂t (yy3t[t] Exp[(x + n) t])) / (yy3t[t] Exp[(x + n) t]);
(* traditional food retail *)

yt4doT[t_] = (∂t (yy4t[t] Exp[(x + n) t])) /
   (yy4t[t] Exp[(x + n) t]); (* services *)

(* check consistency -- these growth rates should be equal. *)

{y222tot[0], ymtdoT[0]}
{0.0276295, 0.0145981}
```

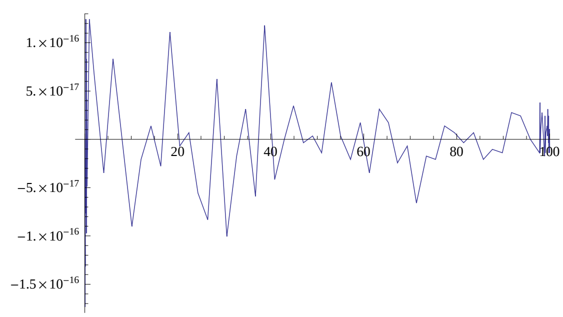
```
Plot[{y222tot[t] - ymtdoT[t]}, {t, 0, 100}]
```



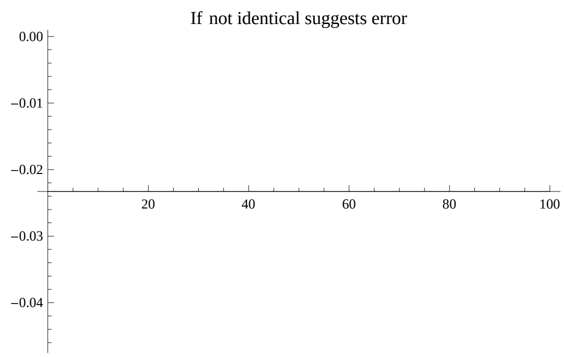

```
Plot[{y333tot[t] - yttdoT[t]}, {t, 0, 100}]
```



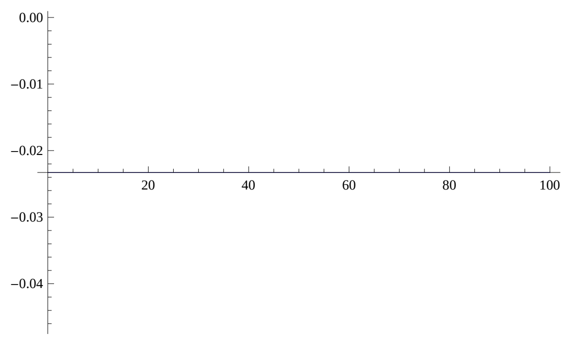

```
Plot[{yy1tot[t] - yt1doT[t]}, {t, 0, 100}]
```



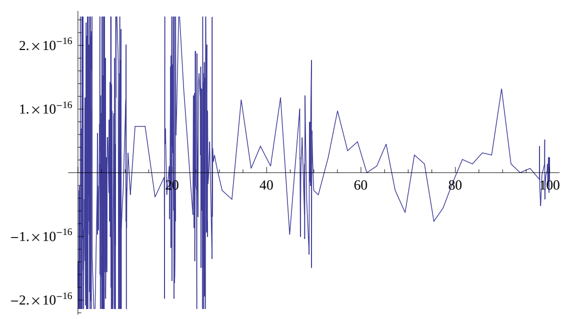
```
Plot[{yy2tot[t] - yt2doT[t] + 0.00001}, {t, 0, 100},
 PlotLabel → "If not identical suggests error"]
```




```
Plot[yy3tot[t] - yt3doT[t] + 0.00001, {t, 0, 100}]
```

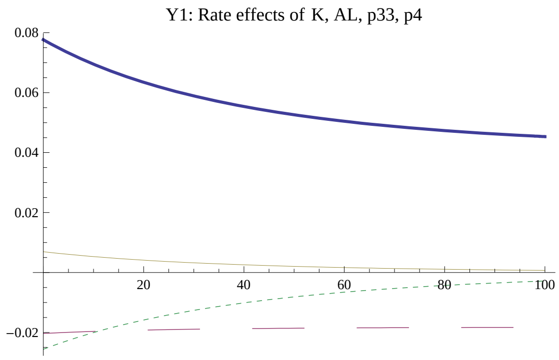



```
Plot[{yy4tot[t] - yt4doT[t]}, {t, 0, 100}]
```



14.4 Rate Effects

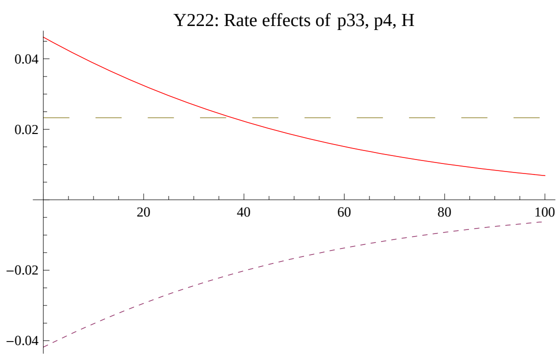
```
Plot[{yy1kk[t], yy1L[t], yy1p33[t], yy1p4[t]}, {t, 0, 100},
 PlotLabel → "Y1: Rate effects of K, AL, p33, p4",
 PlotStyle → {Thick, Dashing[{0.1}], Thin, Dashing[{0.01}]}]
```



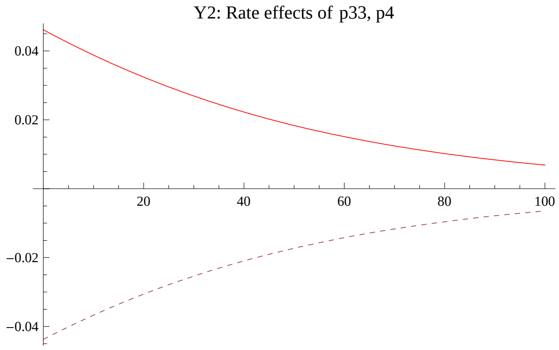

```
"K effect = thick line, A(t)L(t) effect = large
  dash, p33 effect = thin line, p4 effect small dash"
```

```
K effect = thick line, A(t)L(t) effect = large
  dash, p33 effect = thin line, p4 effect small dash
```

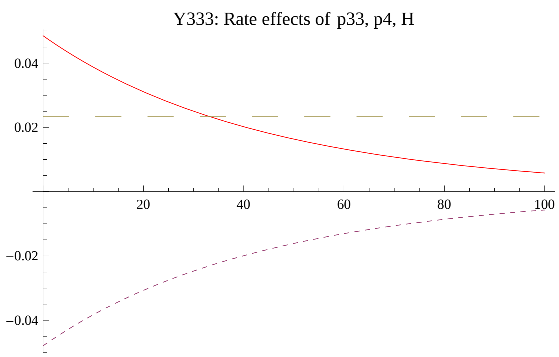
```
Plot[{y222p33[t], y222p4[t], y222H}, {t, 0, 100},
 PlotLabel → "Y222: Rate effects of p33, p4, H",
 PlotStyle → {Hue[2], Dashing[{0.01}], Dashing[{0.05}]}]
```



```
"K effect = line, p4 effect
  = small dash, H effect = large dash"
K effect = line, p4 effect = small dash, H effect = large dash

Plot[{yy2p33[t], yy2p4[t]}, {t, 0, 100},
 PlotLabel → "Y2: Rate effects of p33, p4",
 PlotStyle → {Hue[2], Dashing[{0.01}]}]
```



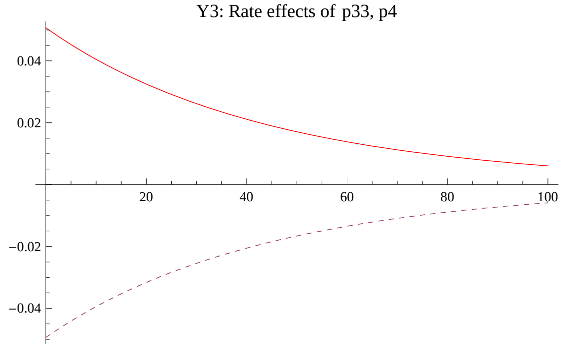

```
Plot[{y333p33[t], y333p4[t], y333H}, {t, 0, 100},
 PlotLabel → "Y333: Rate effects of p33, p4, H",
 PlotStyle → {Hue[2], Dashing[{0.01}], Dashing[{0.05}]}]
```




```
"K effect = line, p4 effect
  = small dash, H effect = large dash"
K effect = line, p4 effect = small dash, H effect = large dash
```

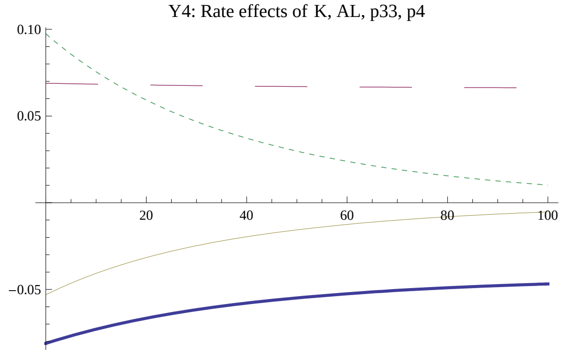
```
Plot[{yy3p33[t], yy3p4[t]}, {t, 0, 100},
 PlotLabel → "Y3: Rate effects of p33, p4",
 PlotStyle → {Hue[2], Dashing[{0.01}]}]
```

Y3: Rate effects of p33, p4




```
Plot[{yy4kk[t], yy4L[t], yy4p33[t], yy4p4[t]}, {t, 0, 100},
 PlotLabel → "Y4: Rate effects of K, AL, p33, p4",
 PlotStyle → {Thick, Dashing[{0.1}], Thin, Dashing[{0.01}]}]
```

Y4: Rate effects of K, AL, p33, p4

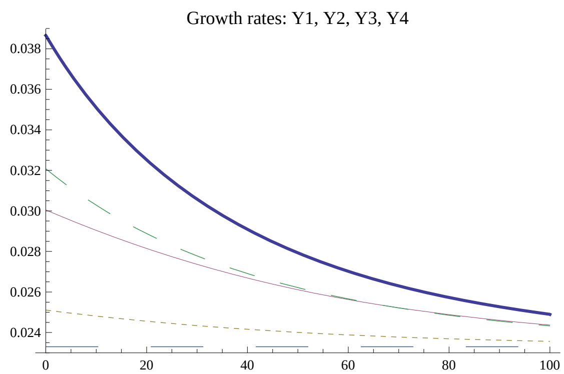



```
"K effect = thick line, A(t)L(t) effect = large
  dash, p33 effect = thin line, p4 effect small dash"
K effect = thick line, A(t)L(t) effect = large
  dash, p33 effect = thin line, p4 effect small dash
```

14.5 Growth Accounting Calculations

14.6 Growth Rates

```
Plot[{yy1tot[t], (yy2tot[t] + y222tot[t]),
   (yy3tot[t] + y333tot[t]), yy4tot[t], x + n},
  {t, 0, TT}, PlotLabel → "Growth rates: Y1, Y2, Y3, Y4",
  PlotStyle → {Thick, Thin, Dashing[{0.01}], Dashing[{0.05}],
    Dashing[{0.1}]}] (* interpretation ??? *)
```




```
"Y1 rate = thick, Y2 rate = thin, Y3 rate =
  small dash,Y4 medium dash, LR rate = large dash "
```

```
Y1 rate = thick, Y2 rate = thin, Y3 rate =
  small dash,Y4 medium dash, LR rate = large dash
```

```
Print["Growth in Industry Output & Factor Contribution"]
TableForm[GrRateIndustry = Table[{yrcal + t, t,
    yy1tot[t], yy1p33[t], yy1p4[t], yy1kk[t], yy1L[t]},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", "Y1", "p33", "p4", "K", "L"}}]
```

Growth in Industry Output & Factor Contribution

	Year	t	Y1	p33	p4	K
1	1980	0	0.0386555	0.00694039	−0.0256211	0.07
2	1985	5	0.036731	0.00605051	−0.0226266	0.07
3	1990	10	0.0351038	0.00530104	−0.0200469	0.06
4	1995	15	0.0337142	0.00466358	−0.0178086	0.06
5	2000	20	0.0325177	0.00411696	−0.0158555	0.06
6	2005	25	0.0314805	0.00364508	−0.0141432	0.06
7	2010	30	0.0305766	0.00323535	−0.0126361	0.05
8	2015	35	0.0297851	0.00287787	−0.0113052	0.05
9	2020	40	0.0290893	0.00256463	−0.0101264	0.05
10	2025	45	0.0284756	0.00228921	−0.0090801	0.05
11	2030	50	0.0279327	0.00204624	−0.00814923	0.05
12	2035	55	0.0274514	0.00183134	−0.00731966	0.05
13	2040	60	0.0270236	0.00164079	−0.00657914	0.05
14	2045	65	0.0266427	0.00147149	−0.00591719	0.04
15	2050	70	0.0263031	0.00132078	−0.00532476	0.04
16	2055	75	0.0259997	0.0011864	−0.00479399	0.04

```
GrRateIndustry =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\GrRateIndustrytable.xls", GrRateIndustry]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\GrRateIndustrytable.xls

```
Print["Growth in Com Agr Output & Factor Contribution"]
TableForm[GrRateComAgr =
  Table[{yrcal + t, t, y222tot[t], y222p33[t], y222p4[t], y222H},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", "Y222", "p33", "p4", "H"}}]
```

Growth in Com Agr Output & Factor Contribution

	Year	t	Y222	p33	p4	H
1	1980	0	0.0276295	0.0461598	−0.0418303	0.0233
2	1985	5	0.0272701	0.0423791	−0.038409	0.0233
3	1990	10	0.0269349	0.0388225	−0.0351876	0.0233
4	1995	15	0.0266236	0.0354988	−0.0321753	0.0233
5	2000	20	0.0263352	0.0324094	−0.0293742	0.0233
6	2005	25	0.0260688	0.0295502	−0.0267814	0.0233
7	2010	30	0.0258235	0.0269134	−0.02439	0.0233
8	2015	35	0.0255979	0.0244889	−0.022191	0.0233
9	2020	40	0.0253909	0.0222646	−0.0201737	0.0233
10	2025	45	0.0252013	0.0202285	−0.0183272	0.0233
11	2030	50	0.0250278	0.0183676	−0.0166398	0.0233
12	2035	55	0.0248693	0.0166694	−0.0151001	0.0233
13	2040	60	0.0247247	0.0151214	−0.0136967	0.0233
14	2045	65	0.0245929	0.0137119	−0.012419	0.0233
15	2050	70	0.0244728	0.0124296	−0.0112568	0.0233
16	2055	75	0.0243635	0.0112639	−0.0102003	0.0233

```
GrRateComAgr = Export["c:\users\lars1102\desktop\Zambia
    Output Tables\GrRateComAgrtable.xls", GrRateComAgr]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\GrRateComAgrtable.xls

```
Print["Growth in Modern Retail Output & Factor Contribution"]
TableForm[GrRateModRet =
  Table[{yrcal + t, t, yy2tot[t], yy2p33[t], yy2p4[t]},
   {t, yrstart - yrcal, 75, 5}],
 TableHeadings → {Automatic, {Year, "t", "yy2tot", "p33", "p4"}}]
```

Growth in Modern Retail Output & Factor Contribution

	Year	t	yy2tot	p33	p4
1	1980	0	0.00242021	0.0461598	−0.0437396
2	1985	5	0.00226491	0.0423791	−0.0401142
3	1990	10	0.00211041	0.0388225	−0.0367121
4	1995	15	0.0019592	0.0354988	−0.0335396
5	2000	20	0.00181297	0.0324094	−0.0305964
6	2005	25	0.00167302	0.0295502	−0.0278772
7	2010	30	0.00154025	0.0269134	−0.0253732
8	2015	35	0.00141502	0.0244889	−0.0230738
9	2020	40	0.00129763	0.0222646	−0.020967
10	2025	45	0.0011881	0.0202285	−0.0190404
11	2030	50	0.00108629	0.0183676	−0.0172813
12	2035	55	0.000991985	0.0166694	−0.0156774
13	2040	60	0.000904891	0.0151214	−0.0142165
14	2045	65	0.000824665	0.0137119	−0.0128872
15	2050	70	0.000750926	0.0124296	−0.0116786
16	2055	75	0.000683263	0.0112639	−0.0105806

```
GrRateModRet = Export["c:\users\lars1102\desktop\Zambia
    Output Tables\GrRateModRettable.xls", GrRateModRet]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\GrRateModRettable.xls
```

```
Print["Growth in Smallh Agr Output & Factor Contribution"]
TableForm[GrRateSmlhAgr =
  Table[{yrcal + t, t, y333tot[t], y333p33[t], y333p4[t], y333H},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", "Y333", "p33", "p4", "H"}}]
```

Growth in Smallh Agr Output & Factor Contribution

	Year	t	Y333	p33	p4	H
1	1980	0	0.0238372	0.0485015	−0.0479644	0.02
2	1985	5	0.0237994	0.0433353	−0.0428359	0.02
3	1990	10	0.0237625	0.03876	−0.0382975	0.02
4	1995	15	0.023727	0.0347016	−0.0342746	0.02
5	2000	20	0.0236931	0.0310962	−0.0307031	0.02
6	2005	25	0.023661	0.0278887	−0.0275276	0.02
7	2010	30	0.023631	0.025031	−0.0246999	0.02
8	2015	35	0.0236029	0.0224817	−0.0221788	0.02
9	2020	40	0.0235768	0.0202046	−0.0199278	0.02
10	2025	45	0.0235526	0.0181687	−0.0179161	0.02
11	2030	50	0.0235303	0.0163463	−0.016116	0.02
12	2035	55	0.0235098	0.0147138	−0.014504	0.02
13	2040	60	0.0234909	0.0132498	−0.0130589	0.02
14	2045	65	0.0234736	0.0119361	−0.0117625	0.02
15	2050	70	0.0234578	0.0107564	−0.0105986	0.02
16	2055	75	0.0234433	0.00969636	−0.00955302	0.02

```
GrRateSmlhAgr =
 Export["c:\users\lars1102\desktop\Zambia Output
   Tables\GrRateSmlhAgrtable.xls", GrRateSmlhAgr]
```

c:\users\lars1102\desktop\Zambia
Output Tables\GrRateSmlhAgrtable.xls

```
Print[
 "Growth in Traditional Retail Output & Factor Contribution"]
TableForm[GrRateTraRet =
  Table[{yrcal + t, t, yy3tot[t], yy3p33[t], yy3p4[t]},
   {t, yrstart - yrcal, 75, 5}],
 TableHeadings → {Automatic, {Year, "t", "yy3tot", "p33", "p4"}}]
```

Growth in Traditional Retail Output & Factor Contribution

	Year	t	yy3tot	p33	p4
1	1980	0	0.00127151	0.0506693	−0.0493978
2	1985	5	0.00115614	0.0452722	−0.0441161
3	1990	10	0.00105038	0.0404925	−0.0394421
4	1995	15	0.000953709	0.0362527	−0.035299
5	2000	20	0.000865389	0.0324861	−0.0316207
6	2005	25	0.000784868	0.0291352	−0.0283503
7	2010	30	0.000711608	0.0261497	−0.0254381
8	2015	35	0.000644917	0.0234865	−0.0228416
9	2020	40	0.000584316	0.0211077	−0.0205234
10	2025	45	0.000529277	0.0189808	−0.0184515
11	2030	50	0.00047931	0.017077	−0.0165977
12	2035	55	0.000433973	0.0153714	−0.0149374
13	2040	60	0.000392857	0.013842	−0.0134492
14	2045	65	0.000355592	0.0124696	−0.012114
15	2050	70	0.000321826	0.0112372	−0.0109153
16	2055	75	0.000291228	0.0101297	−0.00983852

```
GrRateTraRet = Export["c:\users\lars1102\desktop\Zambia
    Output Tables\GrRateTraRettable.xls", GrRateTraRet]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\GrRateTraRettable.xls
```

```
Print["Growth in Services Output & Factor Contribution"]
TableForm[GrRateServices = Table[{yrcal + t, t,
    yy4tot[t], yy4p33[t], yy4p4[t], yy4kk[t], yy4L[t]},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", "Y4", "p33", "p4", "K", "L"}}]
```

Growth in Services Output & Factor Contribution

	Year	t	Y4	p33	p4	K
1	1980	0	0.0320792	−0.0530639	0.0973928	−0.081
2	1985	5	0.0311237	−0.0463929	0.0856468	−0.076
3	1990	10	0.0302825	−0.0407044	0.0755347	−0.072
4	1995	15	0.0295398	−0.0358258	0.0667873	−0.069
5	2000	20	0.0288826	−0.0316204	0.0591882	−0.066
6	2005	25	0.0283	−0.0279783	0.0525614	−0.063
7	2010	30	0.0277823	−0.0248108	0.0467616	−0.061
8	2015	35	0.0273217	−0.0220456	0.04167	−0.059
9	2020	40	0.0269111	−0.0196231	0.0371868	−0.057
10	2025	45	0.0265446	−0.0174946	0.0332296	−0.056
11	2030	50	0.0262171	−0.0156189	0.0297282	−0.054
12	2035	55	0.0259242	−0.0139621	0.0266238	−0.053
13	2040	60	0.0256618	−0.0124952	0.0238661	−0.052
14	2045	65	0.0254266	−0.0111937	0.0214121	−0.051
15	2050	70	0.0252156	−0.010037	0.019225	−0.050
16	2055	75	0.0250261	−0.0090072	0.0172732	−0.049

```
GrRateServices =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\GrRateServicestable.xls", GrRateServices]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\GrRateServicestable.xls

```
Print["Growth Rates: Final Goods Sectors"]
TableForm[GrRateFinalGoods =
  Table[{yrcal + t, t, yy1tot[t], (yy2tot[t] + y222tot[t]),
    (yy3tot[t] + y333tot[t]), yy4tot[t], x + n},
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", "Y1", "Y2", "Y3", "Y4", LR rate}}]
```

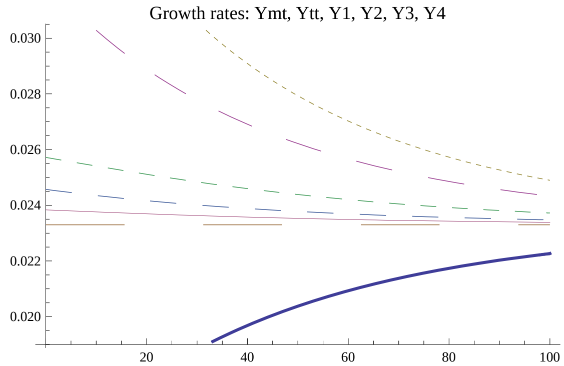
Growth Rates: Final Goods Sectors

	Year	t	Y1	Y2	Y3	Y4
1	1980	0	0.0386555	0.0300497	0.0251087	0.03207
2	1985	5	0.036731	0.029535	0.0249556	0.03112
3	1990	10	0.0351038	0.0290453	0.0248129	0.03028
4	1995	15	0.0337142	0.0285828	0.0246807	0.02953
5	2000	20	0.0325177	0.0281481	0.0245585	0.02888
6	2005	25	0.0314805	0.0277418	0.0244459	0.0283
7	2010	30	0.0305766	0.0273637	0.0243426	0.02778
8	2015	35	0.0297851	0.0270129	0.0242478	0.02732
9	2020	40	0.0290893	0.0266885	0.0241611	0.02691
10	2025	45	0.0284756	0.0263894	0.0240819	0.02654
11	2030	50	0.0279327	0.0261141	0.0240096	0.02621
12	2035	55	0.0274514	0.0258613	0.0239438	0.02592
13	2040	60	0.0270236	0.0256296	0.0238838	0.02566
14	2045	65	0.0266427	0.0254176	0.0238292	0.02542
15	2050	70	0.0263031	0.0252237	0.0237796	0.02521
16	2055	75	0.0259997	0.0250468	0.0237346	0.02502

```
GrRateFinalGoods =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\GrRateFinalGoodstable.xls", GrRateFinalGoods]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\GrRateFinalGoodstable.xls
```

```
Plot[{ymtdoT[t], yttdoT[t], yt1doT[t],
  yt2doT[t], yt3doT[t], yt4doT[t], x + n}, {t, 0, TT},
 PlotLabel → "Growth rates: Ymt, Ytt, Y1, Y2, Y3, Y4",
 PlotStyle → {Thick, Thin, Dashing[{0.01}], Dashing[{0.03}],
   Dashing[{0.05}], Dashing[{0.07}], Dashing[{0.15}]}]
```




```
"RATES: Ymt=thick, Ytt=thin, Y1=tiny dash, Y2=small dash,
  Y3=medium dash, Y4=large dash, LR rate=huge dash "
```

```
RATES: Ymt=thick, Ytt=thin, Y1=tiny dash, Y2=small dash,
  Y3=medium dash, Y4=large dash, LR rate=huge dash
```

```
Print["Growth Rates: Intermediate & Final Sectors"]
TableForm[
 GrRateAllGoods = Table[{yrcal + t, t, ymtdoT[t], yttdoT[t],
    yt1doT[t], yt2doT[t], yt3doT[t], yt4doT[t], x + n},
   {t, yrstart - yrcal, 75, 5}], TableHeadings → {Automatic,
   {Year, "t", Com Agr, SmH Agr, "Y1", "Y2", "Y3", "Y4", LR rate}}]
```

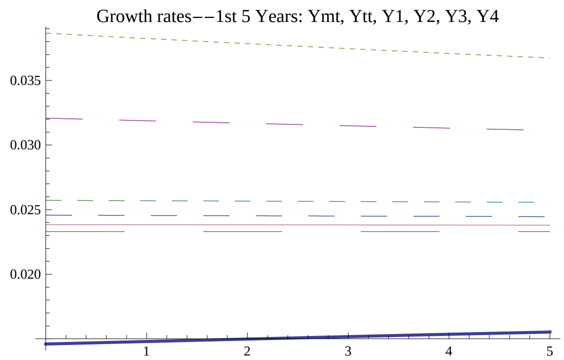
Growth Rates: Intermediate & Final Sectors

	Year	t	Agr Com	Agr SmH	Y1	Y2
1	1980	0	0.0145981	0.0238372	0.0386555	0.02572
2	1985	5	0.0155285	0.0237994	0.036731	0.02556
3	1990	10	0.0163519	0.0237625	0.0351038	0.02541
4	1995	15	0.0170818	0.023727	0.0337142	0.02525
5	2000	20	0.0177297	0.0236931	0.0325177	0.02511
6	2005	25	0.0183058	0.023661	0.0314805	0.02497
7	2010	30	0.0188188	0.023631	0.0305766	0.02484
8	2015	35	0.0192762	0.0236029	0.0297851	0.02471
9	2020	40	0.0196846	0.0235768	0.0290893	0.02459
10	2025	45	0.0200496	0.0235526	0.0284756	0.02448
11	2030	50	0.0203762	0.0235303	0.0279327	0.02438
12	2035	55	0.0206686	0.0235098	0.0274514	0.02429
13	2040	60	0.0209308	0.0234909	0.0270236	0.02420
14	2045	65	0.021166	0.0234736	0.0266427	0.02412
15	2050	70	0.0213772	0.0234578	0.0263031	0.02405
16	2055	75	0.0215669	0.0234433	0.0259997	0.02398

```
GrRateAllGoods =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\GrRateAllGoodstable.xls", GrRateAllGoods]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\GrRateAllGoodstable.xls
```

```
Plot[{ymtdoT[t], yttdoT[t], yt1doT[t], yt2doT[t],
  yt3doT[t], yt4doT[t], x + n}, {t, 0, TT - 95}, PlotLabel →
  "Growth rates--1st 5 Years: Ymt, Ytt, Y1, Y2, Y3, Y4",
 PlotStyle → {Thick, Thin, Dashing[{0.01}], Dashing[{0.03}],
   Dashing[{0.05}], Dashing[{0.07}], Dashing[{0.15}]}]
```




```
"RATES: Ymt=thick, Ytt=thin, Y1=tiny dash, Y2=small dash,
  Y3=medium dash, Y4=large dash, LR rate=huge dash "
```

```
RATES: Ymt=thick, Ytt=thin, Y1=tiny dash, Y2=small dash,
  Y3=medium dash, Y4=large dash, LR rate=huge dash
```

```
Print[" MACROECONOMIC DATA
   ALL VARIABLES ARE IN PER WORKER TERMS "]
TableForm[basemacro = Table[{yrcal + t, t,
    gdpt[t] mn aa[t] / wkr[t],
    (* gdp by Income Method per worker at time t *)
    savt[t] mn aa[t] / wkr[t], (* savings per worker *)
    savt[t]/gdpt[t], (*ratio of savings to gdp *)
    kk[t] mn aa[t] / wkr[t], (* capital stock per worker *)
    kk[t]/gdpt[t], (* ratio of capital stock to gdp *)
    exy1[t] mn aa[t] / wkr[t],
    (* excess demand for industrial goods *)
    exym[t] mn aa[t] / wkr[t]}, (* excess demand
    for commercial agriculture goods *)
   {t, yrstart - yrcal, 75, 5}], TableHeadings → {Automatic,
   {Year, "t", gdpt, savt, savt/gdpt, kk, kk/gdpt, exy1, exym}}]
```

MACROECONOMIC DATA ALL VARIABLES ARE IN PER WORKER TERMS

	Year	t	gdpt	savt	$\frac{\text{savt}}{\text{gdpt}}$	kk
1	1980	0	1.15937×10^6	521 293.	0.449634	6.39835
2	1985	5	1.23194×10^6	553 954.	0.449659	6.9711 ×
3	1990	10	1.30049×10^6	584 632.	0.449548	7.52398
4	1995	15	1.36492×10^6	613 317.	0.449344	8.05385
5	2000	20	1.42522×10^6	640 035.	0.449079	8.55845
6	2005	25	1.48144×10^6	664 838.	0.448777	9.03633
7	2010	30	1.5337×10^6	687 794.	0.448454	9.48667
8	2015	35	1.58212×10^6	708 987.	0.448124	9.90921
9	2020	40	1.62688×10^6	728 508.	0.447794	1.03041
10	2025	45	1.66816×10^6	746 452.	0.447471	1.0672 ×
11	2030	50	1.70614×10^6	762 919.	0.44716	1.10136
12	2035	55	1.74103×10^6	778 005.	0.446863	1.13299
13	2040	60	1.77304×10^6	791 807.	0.446582	1.16222
14	2045	65	1.80235×10^6	804 420.	0.446319	1.18916
15	2050	70	1.82915×10^6	815 933.	0.446072	1.21395
16	2055	75	1.85364×10^6	826 432.	0.445842	1.23671

```
Basemacrodata =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\macrobasetable.xls", basemacro]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\macrobasetable.xls
```

Macrohd = $\left\{\text{"Year"}, \text{"t"}, \text{"gdpt"}, \text{"savt"}, \frac{\text{"savt"}}{\text{"gdpt"}}, \text{"kk"}, \frac{\text{"kk"}}{\text{"gdpt"}}, \text{"exy1"}, \text{"exym"}\right\}$;

```
Export[
 "c:\Documents and Settings\lars1102\Desktop\macrohd.xls",
 marohd]
```

```
c:\Documents and Settings\lars1102\Desktop\macrohd.xls
```

```
Print[
 "PRICES OF INPUTS, INTERMEDIATE GOODS, AND FINAL GOODS"]
TableForm[basepricesinputs = Table[{yrcal + t, t,
    wt[t] mn aa[t] / wkr[t], (* cost of labor per worker *)
    rkt[t], (* rate of return on capital *)
    p2t[t], (* price of modern retail food *)
    p3t[t], (* price of traditional retail food *)
    p33t[t],
    (* price of smallholder agricultural products *)
    p2equiv[t], (* price received by commercial
     farmers in modern retail food equivalent prices *)
    p3equiv[t], (* price received by traditional farmers
     in traditional retail food equivalent prices *)
    p4t[t]}, (* price of services *)
   {t, yrstart - yrcal, 75, 5}], TableHeadings → {Automatic,
   {Year, "t", wt, rkt, p2t, p3t, p33t, p2equiv, p3equiv, p4t}}]
```

PRICES OF INPUTS, INTERMEDIATE GOODS, AND FINAL GOODS

	Year	t	wt	rkt	p2t	p3t
1	1980	0	488 760.	0.100093	0.95909	0.81348
2	1985	5	518 832.	0.0978394	0.967785	0.847684
3	1990	10	547 266.	0.0958687	0.975622	0.879474
4	1995	15	574 017.	0.0941395	0.982686	0.908929
5	2000	20	599 077.	0.0926178	0.989054	0.936147
6	2005	25	622 464.	0.0912749	0.994796	0.961238
7	2010	30	644 216.	0.090087	0.999974	0.98432
8	2015	35	664 387.	0.0890339	1.00465	1.00552
9	2020	40	683 043.	0.0880985	1.00886	1.02495
10	2025	45	700 258.	0.0872662	1.01266	1.04273
11	2030	50	716 108.	0.0865244	1.01609	1.05899
12	2035	55	730 676.	0.0858624	1.01919	1.07385
13	2040	60	744 043.	0.0852708	1.02199	1.08739
14	2045	65	756 290.	0.0847415	1.02451	1.09974
15	2050	70	767 495.	0.0842675	1.02679	1.11099
16	2055	75	777 736.	0.0838426	1.02885	1.12122

```
Basepricesinputsdata =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\pricesinputsbasetable.xls", basepricesinputs]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\pricesinputsbasetable.xls

```
Pricesinputshd = {"Year", "t", "wt", "rkt",
   "p2t", "p3t", "p33t", "p2equiv", "p3equiv", "p4t"};
```

```
Export["c:\users\lars1102\desktop\Zambia
   Output Tables\pricesinputshd.xls", Pricesinputshd]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\pricesinputshd.xls
```

```
Print[
 "COMMERCIAL AND SMALLHOLDER FARM SECTOR DATA PER WORKER"]
TableForm[baseagric = Table[{yrcal + t, t,
    πmt[t] mn aa[t] / (lmt[t] wkr[t]),
    (* commercial farm profit per worker *)
    ymt[t] mn aa[t] / (lmt[t] wkr[t]),
    (* commercial farm output per worker *)
    lmt[t] wkr[t], (* # of workers employed
     on commercial farms *)
    kmt[t] mn aa[t] / (lmt[t] wkr[t]), (* quantity of
     capital deployed on commercial farms per worker *)
    πtt[t] mn aa[t] / (ltt[t] wkr[t]),
    (* smallholder farm profit per worker *)
    ytt[t] mn aa[t] / (ltt[t] wkr[t]),
    (* smallholder farm output per worker*)
    ltt[t] wkr[t], (* # of workers employed
     on smallholder farms *)
    ktt[t] mn aa[t] / (ltt[t] wkr[t])},
   (* capital deployed on smallholder farms per worker*)
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", πmt, ymt, lmt, kmt, πtt, ytt, ltt, ktt}}]
```

COMMERCIAL AND SMALLHOLDER FARM SECTOR DATA PER WORKER

	Year	t	πmt	ymt	lmt	kmt
1	1980	0	164 526.	1.63763×10^{6}	82 854.3	9.83431 ×
2	1985	5	174 649.	1.73839×10^{6}	84 161.7	1.06798 ×
3	1990	10	184 220.	1.83366×10^{6}	86 412.2	1.14967 ×
4	1995	15	193 225.	1.92329×10^{6}	89 570.3	1.22802 ×
5	2000	20	201 661.	2.00726×10^{6}	93 630.2	1.30269 ×
6	2005	25	209 533.	2.08562×10^{6}	98 610.2	1.37346 ×
7	2010	30	216 855.	2.1585×10^{6}	104 550.	1.44019 ×
8	2015	35	223 645.	2.22609×10^{6}	111 507.	1.50286 ×
9	2020	40	229 925.	2.28859×10^{6}	119 560.	1.56146 ×
10	2025	45	235 720.	2.34627×10^{6}	128 803.	1.61608 ×
11	2030	50	241 056.	2.39938×10^{6}	139 349.	1.66683 ×
12	2035	55	245 960.	2.44819×10^{6}	151 330.	1.71385 ×
13	2040	60	250 459.	2.49298×10^{6}	164 901.	1.75731 ×
14	2045	65	254 582.	2.53401×10^{6}	180 237.	1.7974 ×
15	2050	70	258 354.	2.57156×10^{6}	197 538.	1.83429 ×
16	2055	75	261 801.	2.60587×10^{6}	217 033.	1.86818 ×

```
Baseagricdata =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\agricbasetable.xls", baseagric]

c:\users\lars1102\desktop\Zambia
  Output Tables\agricbasetable.xls

Agrichd = {"Year", "t", "πmt", "ymt",
   "lmt", "kmt", "πtt", "ytt", "ltt", "ktt"};

Export[
 "c:\users\lars1102\desktop\Zambia Output Tables\agrichd.xls",
 Agrichd]

c:\users\lars1102\desktop\Zambia Output Tables\agrichd.xls
```

```
Print["SUPPLY OF INTERMEDIATE AND FINAL GOODS PER WORKER"]
TableForm[basesupply = Table[{yrcal + t, t,
    yy1t[t] mn aa[t] / wkr[t],
    (* industry sector supply per worker *)
    yy2t[t] mn aa[t] / wkr[t],
    (* modern retail supply per worker *)
    y222t[t] mn aa[t] / wkr[t],
    (* commercial farm supply per worker *)
    yy3t[t] mn aa[t] / wkr[t],
    (* traditional retail supply per worker *)
    y333t[t] mn aa[t] / wkr[t],
    (* smallholder farm supply per worker *)
    yy4t[t] mn aa[t] / wkr[t]},
   (* supply of services per worker *)
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", yy1t, yy2t, y222t, yy3t, y333t, yy4t}}]
```

SUPPLY OF INTERMEDIATE AND FINAL GOODS PER WORKER

	Year	t	yy1t	yy2t	y222t	yy3t
1	1980	0	624 709.	27 460.3	15 731.9	231 462.
2	1985	5	671 231.	27 783.8	16 061.6	232 870.
3	1990	10	714 863.	28 089.4	16 369.7	234 157.
4	1995	15	755 626.	28 376.6	16 656.8	235 333.
5	2000	20	793 579.	28 645.4	16 923.6	236 405.
6	2005	25	828 808.	28 896.	17 170.8	237 381.
7	2010	30	861 418.	29 129.	17 399.3	238 270.
8	2015	35	891 532.	29 344.9	17 610.2	239 079.
9	2020	40	919 279.	29 544.5	17 804.3	239 814.
10	2025	45	944 797.	29 728.6	17 982.8	240 482.
11	2030	50	968 224.	29 898.	18 146.5	241 089.
12	2035	55	989 698.	30 053.7	18 296.6	241 640.
13	2040	60	1.00935×10^6	30 196.4	18 434.	242 139.
14	2045	65	1.02733×10^6	30 327.2	18 559.6	242 592.
15	2050	70	1.04374×10^6	30 446.8	18 674.2	243 003.
16	2055	75	1.05871×10^6	30 556.1	18 778.8	243 376.

```
Basesupplydata =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\supplybasetable.xls", basesupply]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\supplybasetable.xls

```
Supplyhd = {"Year", "t", "yy1t",
   "yy2t", "y222t", "yy3t", "y333t", "yy4t"};
```

```
Export["c:\users\lars1102\desktop\Zambia
   Output Tables\supplyhd.xls", Supplyhd]
```

c:\users\lars1102\desktop\Zambia Output Tables\supplyhd.xls

```
Print["LABOR AND CAPITAL INPUTS TO FINAL GOODS"]
TableForm[baselaborcapinputs = Table[{yrcal + t, t,
    l1t[t], (* labor input to industry *)
    l2t[t], (* labor input to modern retail *)
    l3t[t], (* labor input to traditional retail *)
    l4t[t], (* labor input to services *)
    k1t[t] mn aa[t] / wkr[t],
    (* capital input to industry per worker *)
    k2t[t] mn aa[t] / wkr[t], (* capital input
     to modern retail per worker *)
    k3t[t] mn aa[t] / wkr[t], (* capital input
     to traditional retail per worker *)
    k4t[t] mn aa[t] / wkr[t]}, (* capital input
    to services per worker *)
   {t, yrstart - yrcal, 75, 5}], TableHeadings → {Automatic,
   {Year, "t", l1t, l2t, l3t, l4t, k1t , k2t, k3t , k4t}}]
```

LABOR AND CAPITAL INPUTS TO FINAL GOODS

	Year	t	l1t	l2t	l3t	l4t
1	1980	0	0.352882	0.0118869	0.05606	0.33785
2	1985	5	0.357184	0.0114326	0.055366	0.34101
3	1990	10	0.360638	0.0110466	0.054759	0.34382
4	1995	15	0.363437	0.0107164	0.0542263	0.34634
5	2000	20	0.365725	0.0104326	0.0537576	0.34860
6	2005	25	0.367609	0.0101873	0.053344	0.35063
7	2010	30	0.369173	0.00997433	0.0529782	0.35245
8	2015	35	0.370478	0.00978871	0.052654	0.35408
9	2020	40	0.371575	0.00962632	0.0523661	0.35555
10	2025	45	0.372501	0.00948379	0.05211	0.35687
11	2030	50	0.373288	0.00935834	0.0518818	0.35806
12	2035	55	0.37396	0.00924761	0.0516782	0.35913
13	2040	60	0.374535	0.00914965	0.0514963	0.36010
14	2045	65	0.375031	0.00906281	0.0513336	0.36097
15	2050	70	0.375459	0.00898567	0.0511879	0.36175
16	2055	75	0.37583	0.00891703	0.0510574	0.36246

```
Baselaborcapinputsdata =
 Export["c:\users\lars1102\desktop\Zambia
    Output Tables\laborcapsinputsbasetable.xls",
  baselaborcapinputs]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\laborcapsinputsbasetable.xls
```

```
Laborcapsinputshd = {"Year", "t", "l1t",
   "l2t", "l3t", "l4t", "k1t" , "k2t", "k3t" , "k4t"};
```

```
Export["c:\users\lars1102\desktop\Zambia Output
   Tables\laborcapsinputshd.xls", Laborcapsinputshd]
```

```
c:\users\lars1102\desktop\Zambia
  Output Tables\laborcapsinputshd.xls
```

```
Print["HOUSEHOLD EXPENDITURE AND CONSUMPTION"]
TableForm[basehhexp = Table[{yrcal + t, t,
    hhexp[t] mn aa[t] / wkr[t],
    (* household expenditures per worker *)
    pindex[t], (* aggregated price index *)
    (hq[t] mn aa[t] / wkr[t]), (* felicity per worker *)
    c1[t] mn aa[t] / wkr[t],
    (* consumption of industrial goods *)
    c2[t] mn aa[t] / wkr[t], (* consumption
     of modern retail food *)
    c3[t] mn aa[t] / wkr[t], (* consumption
     of traditional retail food *)
    c4[t] mn aa[t] / wkr[t]}, (* consumption of services *)
   {t, yrstart - yrcal, 75, 5}], TableHeadings →
  {Automatic, {Year, "t", hhexp, pindex, hq, c1, c2, c3, c4}}]
```

HOUSEHOLD EXPENDITURE AND CONSUMPTION

	Year	t	hhexp	pindex	hq	c1
1	1980	0	582 020.	0.912218	514 237.	152 728.
2	1985	5	629 575.	0.930233	540 299.	163 637.
3	1990	10	674 820.	0.946632	564 661.	174 031.
4	1995	15	717 625.	0.961548	587 350.	183 876.
5	2000	20	757 921.	0.975102	608 413.	193 155.
6	2005	25	795 690.	0.987412	627 911.	201 861.
7	2010	30	830 956.	0.998586	645 915.	209 999.
8	2015	35	863 773.	1.00872	662 502.	217 578.
9	2020	40	894 218.	1.01792	677 754.	224 616.
10	2025	45	922 388.	1.02625	691 754.	231 133.
11	2030	50	948 392.	1.03381	704 585.	237 153.
12	2035	55	972 344.	1.04065	716 328.	242 702.
13	2040	60	994 366.	1.04685	727 062.	247 807.
14	2045	65	1.01458×10^6	1.05247	736 863.	252 494.
15	2050	70	1.0331×10^6	1.05755	745 803.	256 793.
16	2055	75	1.05006×10^6	1.06216	753 951.	260 728.

```
BaseHHExpdata =
 Export["c:\users\lars1102\desktop\Zambia Output
    Tables\hhexpbasetable.xls", basehhexp]
```

c:\users\lars1102\desktop\Zambia
  Output Tables\hhexpbasetable.xls

```
HHExphd =
  {"Year", "t", "hhexp", "pindex", "hq", "c1", "c2", "c3", "c4"};
```

```
Export[
 "c:\users\lars1102\desktop\Zambia Output Tables\hhexphd.xls",
 HHExphd]
c:\users\lars1102\desktop\Zambia Output Tables\hhexphd.xls
```