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Dedication

To my parents, Gabriela and Dragan Simonovski

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Introduction

This thesis consists of three papers that explore different topics in international economics.

In the first chapter, I examine the relationship between income and prices across different countries. Empirical studies find a strong positive relationship between a country's per-capita income and price level of final tradable goods. Among alternative explanations of this observation, I focus on variable mark-ups by firms. Mark-ups that vary with destinations' incomes are evident from a clothing manufacturer's online catalogue featuring unit prices of identical goods sold in 24 countries. Such price discrimination on the basis of income suggests that firms exploit lower price elasticity of demand for identical goods in richer countries. In order to capture that, I introduce non-homothetic preferences in a model of trade with product differentiation and heterogeneity in firm productivity. The model helps bring theory and data closer along a key dimension: it generates positively related prices and incomes, while preserving desirable features of firm behavior and trade flows of existing frameworks. Quantitatively, the model suggests that variable mark-ups can account for as much as 50% of the observed positive relationship between prices of tradables and income across a large sample of countries.

The relationship between prices of tradables and income is also largely affected by the elasticity of trade with respect to trade barriers. More generally, quantitative results from structural gravity models depend critically on a single parameter governing the

elasticity of trade with respect to trade frictions. Despite its importance, the current literature provides little evidence regarding this parameter for developing nations, which are responsible for a rising portion of world trade. In the second chapter of the thesis, I estimate the value of this parameter for 129 developed and developing countries for the year 2004 using new disaggregate price and trade flow data. The benchmark estimate for all countries is 7.5, with standard error of 0.60, and there is little evidence that the elasticity of trade differs dramatically across developed and developing nations.

Finally, in the the third paper of the thesis, I investigate sources of economic fluctuations in the open economy of Chile during 1998-2007 within the framework of a standard neoclassical growth model with time-varying frictions (wedges). I analyze the relative importance of efficiency, labor, investment, and government/trade wedges for business cycles in Chile. The purpose of this exercise is twofold: (i) focus the policy discussion on the most important wedges in the economy; and (ii) identify which broad class of models would present fruitful avenues for further research. I find that different wedges have played different roles during the studied period, but that the efficiency and labor wedges have had the greatest impact. I also compare the results with existing studies on Argentina, Brazil, and Mexico.

The three chapters follow below.

Chapter 1

Income Differences and Prices of Tradables

1.1 Introduction

A large empirical literature has established a strong positive relationship between coun-
tries' per-capita incomes and price levels of tradable goods. Using 1996 data, Hsieh and Klenow
(2007) demonstrate that the relationship is mainly driven by cross-country differences
in prices of consumption goods. Although alternative explanations of this observation
exist, I argue that pricing-to-market is a viable one. I present evidence from a clothing
manufacturer that sells identical goods online to 24 countries and charges higher prices
in richer markets. Such price discrimination on the basis of income suggests that firms
exploit different price elasticity of demand across countries that differ in income. In

particular, if rich consumers are less responsive to price changes than poor ones, firms find it optimal to price identical products higher in more affluent markets.

In order to capture this mechanism, I introduce non-homothetic preferences in a model of trade with product differentiation and heterogeneity in firm productivity à la Melitz (2003) and Chaney (2008). These models successfully explain firm exporting behavior and bilateral trade flows. However, they assume that consumers value a continuum of varieties in a symmetric CES fashion, resulting in firms following a simple pricing rule of a constant mark-up over marginal cost of production and delivery. In the absence of trade barriers, the models predict that identical goods sell at equal prices across countries. But, in order to match observed bilateral trade patterns, the models require poor countries to face systematically high trade barriers and low productivity levels. The latter yield high marginal costs of production, which coupled with high trade barriers, keep the trade shares of poor countries low and prices of tradable goods high[1].

To retain the desirable features of these models regarding firm exporting behavior and trade flows, but also generate positively related incomes and prices, I model consumers to have non-homothetic preferences[2]. In particular, the utility specification I propose has the property that the marginal satisfaction agents derive from consuming

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[1]Waugh (2007) demonstrates this finding for models that rely on the Ricardian structure introduced by Eaton and Kortum (2002).

[2]The assumption of non-homothetic preferences is supported by recent empirical literature. In particular, Hunter (1991), Hunter and Markusen (1988), and Movshuk (2004) use cross-country expenditure data on groups of commodities and find that consumption shares of different classes of goods vary considerably across the sample, thus rejecting the assumption of homothetic preferences.

each good is bounded at any level of consumption. Since a tiny amount of consumption of a good does not give infinite increase in utility, a consumer spends her limited income on the subset of potentially produced items whose prices do not exceed marginal valuations. An increase in income spurs consumers, who value variety, to buy a greater pool of goods. For a monopolistic competitor selling a particular item, the presence of more goods in the market raises competition, forcing it to reduce the good's price. However, an increase in income also drives consumers to buy more of each good, allowing the firm to raise the good's price. In equilibrium, the latter effect dominates, resulting in higher prices of identical goods in more affluent markets.

Moreover, since firms differ in productivity levels, only certain manufacturers can cover production and shipping costs in order to place their good in the market. The marginal firm sells its product at a price that barely covers its production and delivery cost, while maintaining positive demand, thus realizing zero sales. Trade barriers keep exporters in the minority and more productive firms sell more in each market. Facing higher demand in richer countries, firms realize higher sales there, and more firms serve the affluent markets. Moreover, if firm productivities are Pareto-distributed, the distribution of their sales in a market is Pareto in the tail. These predictions are qualitatively in line with the behavior of French exporters in 1986 reported by Eaton, Kortum, and Kramarz (2004), Eaton, Kortum, and Kramarz (2008) and Arkolakis (2008)[3]. In addition, under some parametrizations, the model can deliver

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[3]Arkolakis (2008) and Eaton, Kortum, and Kramarz (2008) propose models that are not only qualitatively, but also quantitatively in line with firm exporting behavior, however, they rely on a CES

the reported relationships quantitatively.

Under alternative parameterizations, the model yields a standard gravity equation of trade relating bilateral trade flows and trade barriers. Similarly to previous frameworks, the model matches observed trade flows when calibrated trade barriers are high and productivity levels are low for poor countries. However, since price elasticities of demand are high in poor countries, exporters sell their products at low prices there. The calibrated model suggests that the elasticity of the price level of tradable goods with respect to per-capita income for a set of 119 countries that comprised 91% of world output in 2004 is 0.06. The corresponding estimate arising from 2004 income and price data for the same set of countries is 0.11, as can be seen in figure 1.1 below. Since the model can account for up to 60% of observed cross-country price differences, it is reasonable to conclude that variable mark-ups are quantitatively important.

The portion of cross-country price differences that is not captured by the model can be explained by a variety of factors. Indeed, the price indices of tradable goods plotted in figure 1.1 are computed at the retail level and necessarily reflect non-tradable components, trade barriers and taxes[4]. To correct for such components, the empirical literature has analyzed unit values from data collected at the port of shipping. Using Harmonized System (HS) 10-digit-level commodity classification data, the most highly disaggregated US commodities trade data publicly available, Schott (2004) finds that

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framework that cannot capture the price-income relationship.

[4]In a series of studies, Crucini, Telmer, and Zachariadis (2005a), Crucini, Telmer, and Zachariadis (2005b) and Crucini and Shintani (2008) document large and persistent deviations from the law of one price using disaggregated unit price data at the retail level for a large sample of countries. Further, Burstein, Neves, and Rebelo (2003) quantify the effect of large distribution costs on retail prices.
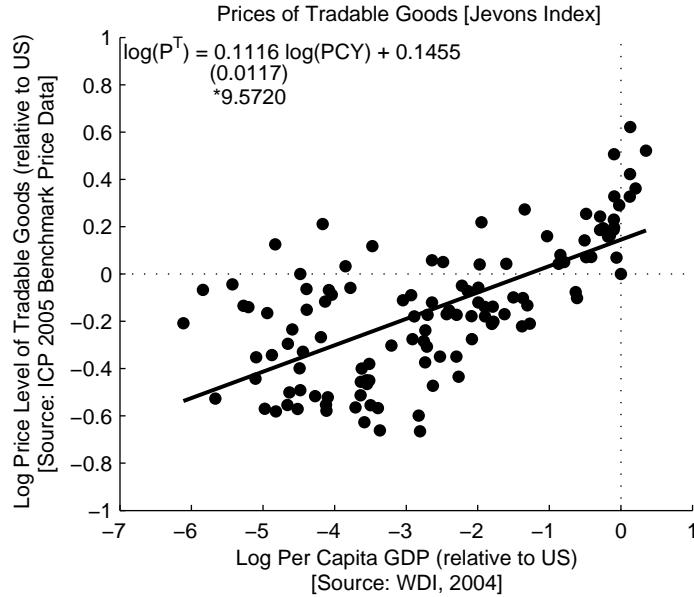
FIGURE 1.1: Price Level of Tradable Goods and Per-Capita GDP for 119 Countries

"unit values of US imports are higher for varieties originating in capital- and skill-abundant countries than they are for varieties sourced from labor-abundant countries." A large subsequent literature interprets this finding to indicate that imports from richer countries are of higher quality. Yet, Alessandria and Kaboski (2007) find that unit values of US exports to richer markets are higher, interpreting this as evidence of pricing-to-market: the decision of firms to set higher mark-ups on identical goods in richer markets.

Since the latter experiment likely reflects both phenomena, an empirical literature attempting to directly measure variable mark-ups has emerged. These studies track the prices of identical goods across countries. Goldberg and Verboven (2001) and Goldberg and Verboven (2005) analyze the car market in five European countries over

time and find persistent deviations from the law of one price. Haskel and Wolf (2001)

collect prices of items sold in IKEA stores across countries and find typical deviations in

prices of identical products of twenty to fifty percent. Finally, Ghosh and Wolf (1994)

study the listed price of the Economist magazine across markets and find it considerably

differs.

These experiments convey convincing evidence that goods of identical qualities are

sold at different prices across countries. But, they employ in-store prices, which nec-

essarily reflect non-tradable components, taxes and trade barriers[5]. Instead, I collect

prices of identical items featured in the clothing manufacturer Mango's online catalogues

across 24 countries, allowing me to overcome the problems posed by both varying prod-

uct quality and non-tradable price components. In addition, the prices I analyze are

adjusted for tariffs and sales taxes. However, they account for transportation costs, since

products sold above a minimum price ship at no fee. After controlling for transportation

costs and good-specific characteristics, I find that the estimated elasticity of an item's

price with respect to per-capita income of a destination is 0.1221. Thus, countries that

are twice as rich in per capita terms pay 12% more for the same good.

Complementary to the empirical findings of variable mark-ups, a theoretical litera-

ture studying pricing-to-market within an international trade framework exists, building

on the seminal work of Krugman (1986). Recently, Atkeson and Burstein (2005) explore

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[5]Goldberg and Verboven (2001) and Goldberg and Verboven (2005) control for such components and conclude that deviations from the law of one price persist.

the implications of pricing-to-market on the fluctuations of relative producers' and consumers' prices of tradable and traded goods. Moreover, Bergin and Feenstra (2001) propose an explanation of real exchange rate persistence by introducing a symmetric translog expenditure function in a monopolistic competition framework with a fixed number of producers. Feenstra (2003) further allows for firm free entry, but does not account for consumer income differences. In such environment, monopolistic competitors set lower mark-ups when the number of available varieties is larger[6]. However, Jackson (1984) presents evidence that the pool of consumed goods varies positively with consumer income and indeed suggests that non-homothetic preferences may be an underlying reason.

Melitz and Ottaviano (2008) introduce non-homothetic preferences, represented by a quadratic utility function, in a model of trade with product differentiation and firm productivity heterogeneity. However, their focus lies on the interaction between mark-ups and market size, measured by the population of each destination. In fact, income effects are absent from their analysis due to the presence of a homogenous commodity that is freely traded, thus ensuring (per-capita) income equalization across countries[7]. Finally, Alessandria and Kaboski (2007) explore the implications of pricing-to-market on prices of tradables across countries in a very different setting from the one analyzed

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[6]It would be interesting to extend the model of Feenstra (2003) to a multi-country general equilibrium setting that allows for income heterogeneity and to study the cross-country prices of tradables arising from that framework both qualitatively and quantitatively.

[7]In an online appendix, I analyze the model of Melitz and Ottaviano (2008) in the absence of a homogenous good, thus allowing for heterogeneous incomes across countries. I am currently studying the quantitative predictions of such model.

in this paper. In their model, pricing-to-market arises due to costly search frictions between consumers and retailers in countries that differ in their wage levels.

To summarize, the present paper contributes toward the understanding of the positive relationship between per-capita income and price level of tradable consumption goods, which Hsieh and Klenow (2007) convincingly argue is central toward the understanding of relative investment and growth patterns across countries. First, the paper provides direct evidence of variable mark-ups from a unique database, thus enriching the empirical pricing-to-market literature. Second, it proposes a theoretical framework that is consistent with firm exporting behavior, bilateral trade patterns and prices of tradable goods. Finally, it carries out a quantitative exercise, whose results suggests that variable mark-ups by firms play an important role in explaining cross-country price differences.

The remainder of the paper is organized as follows: section 1.2 discusses evidence of pricing-to-market extracted from a new database featuring prices of items sold online by the Spanish clothing manufacturer Mango; section 1.3 describes the model and its qualitative predictions; section 1.4 discusses the calibration and quantitative predictions of the model; and section 1.5 concludes. Finally, the appendices are organized as follows: appendix A.1 describes a model with consumers represented by CES preferences; appendix A.2 outlines the price-accounting procedure; and the remaining appendices support data findings and provide algebraic expressions used throughout the paper.

1.2 Pricing-to-Market: Evidence from Mango

In this section, I present direct evidence of variable mark-ups from a data set that has not been used in previous empirical studies. I find that the Spanish clothing manufacturer Mango systematically price-discriminates according to the per-capita income level of the market to which it sells.

1.2.1 Data Description

I collect price data from the clothing manufacturer Mango, a producer based in Barcelona, Spain, that offers a line of clothing targeted at middle-income female consumers.

Mango sells items both online and in stores around the world[8]. To facilitate data collection, I only consider Mango's online store. I use data from 24 countries in Europe as well as Canada. Each country has a website and customers from one country cannot buy products from another country's website due to shipping restrictions. Thus, a customer with a physical shipping address in Germany can only have items delivered to her when purchased from the German Mango website. A list of countries I study is given in Table A.1 located in appendix A.4.

I collect data on all items featured in the Summer 2008 online catalogue, which became available in March of 2008. In each country, the catalogue lists item prices in the local currency. I use average monthly exchange rates for February of 2008 to convert all values into Euro, the currency used in the home country, Spain[9].

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[8]Sometimes items sold online do not appear in stores and vice verse.

[9]I choose to work with February data because the catalogue became available in March and the

Each item in the catalogue has a distinct name and an 8-digit code reported in every country. This enables me to collect prices of identical products across markets. Prices listed on the website include sales taxes (VAT), which I adjust for accordingly, but exclude tariffs since all countries are members of the European Union[10]. Thus, once I remove the sales tax, prices include production costs, mark-ups and transportation costs[11].

The shipping and handling policy of Mango is such that no fee is incurred for purchases above a minimum value, which differs across countries. Thus, not only does a single product, whose price is above this minimum, incur no shipping charge, but also any bundle of goods with value above the minimum satisfies the free-shipping requirement. All other purchases incur a shipping and handling fee. Table A.2 in appendix A.4 lists the free-shipping minimum requirement for every country in Euros, using February 2008 exchange rates.

Many items sold by Mango classify for free shipping. However, it is not always the case that the same product ships at no fee to different destinations, since the minimum price requirement as well as the actual Euro-denominated price of the product often

company would have had to set the price before placing the catalogue into circulation. I repeat the analysis with exchange rate data for the months of January and March of 2008 and although the coefficients differ, the results remain unchanged. I do not perform robustness checks with data from 2007 (for ex. December of 2007) because three of my sample countries, Cyprus, Malta and Slovenia, used their respective national currencies at the time, which were replaced with the Euro starting January 1, 2008.

[10]Canada applies sales taxes and import duties at checkout, so no price adjustment is necessary.

[11]Quality differences are not an issue since for the set of countries that I study, items are shipped from the same location. Different items (ex. skirt vs. shirt) may be produced in different countries, but the same item (ex. skirt) is sourced from a single location and sold to all destinations. Since I study relative prices, the actual marginal cost of producing a particular good is irrelevant, for it is the same regardless of the market to which an item is sold.

differ. Thus, it is necessary to control for shipping costs in the analysis [12].

Out of potentially 124 products, I reduce the sample to 93 items. The 31 items I drop are not available in every country in my sample, so I exclude them from my study as the objective is to compare the prices of identical items in every destination. Finally, I use 2006 PPP-adjusted per-capita income from the World Bank in my analysis of the relationship between prices and incomes.[13].

1.2.2 Data Analysis

The data set I analyze displays large heterogeneity in per-capita incomes and prices across countries. In my sample of 24 countries, the richest country in per-capita terms, Luxembourg, is over 4 times richer than the poorest one, Slovakia. Similarly, the average price of identical goods is almost 1.6 times as much in the most expensive country, Switzerland, as it is in the cheapest, Portugal[14]. In fact, when looking at all items sold to the 24 markets, the elasticity of the average priced item with respect to the per-capita income of the destination is 0.12[15].

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[12]Mango uses a third-party international courier to ship its products. Mango's website lists the shipping fee charged on items priced below the free-shipping minimum. The fee does not generally vary with the weight and type of the item shipped. Table A.2 in appendix A.4 summarizes the per-item shipping and handling fee for each country in Euro, using February 2008 exchange rates.

[13]I conduct the same analysis with nominal per-capita income, real per-capita income (base year 2000) and for a subset of the countries (for which data is available), I repeat the analysis using wages since this statistic corresponds to the measure of per-capita income in the model. Although estimated elasticities change, the nature of the results remains unaltered. Results are available upon request.

[14]Table A.3 in appendix A.4 lists the average price of items sold in every destination and the per-capita income of each country, relative to Spain.

[15]Figure A.1 in appendix A.4 summarizes this discussion graphically.

Equation (1.1) below summarizes the regression framework used to analyze the pricing practices of Mango:

$$\log p_{ij} = \alpha_i + \beta_y \log y_j + \epsilon_{ij}, \tag{1.1}$$

where p_{ij} is the pre-tax price of good i in country j in Euros and y_j is the PPP-adjusted per-capita income of country j. The coefficient β_y is the estimated elasticity of price with respect to per-capita income, while α_i is a good i-specific fixed effect[16].

I use the "within" (fixed-effects) estimator and report White robust standard errors for the income coefficient as well as the t-statistic in table A.4 found in appendix A.4. The regression yields an estimate of β_y of 0.1185 with standard error 0.0065.

The prices used in the above estimation, however, implicitly include transportation costs due to Mango's pricing policy discussed earlier. Since many items satisfy the minimum-price requirement for free shipping, their final price contains (a fraction of) the shipping cost Mango incurs. Hence, I modify (1.1) to account for shipping costs as follows:

$$\log p_{ij} = \alpha_i + \beta_y \log y_j + \beta_\tau \log \tau_j + \epsilon_{ij}, \tag{1.2}$$

where τ_j is the distance between Barcelona and the capital city of the destination

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[16]I employ good-specific fixed effects to capture good-specific observable and unobservable characteristics that affect item prices.

country[17].

The regression yields estimates for β_y and β_τ of 0.1221 (0.0051) and 0.0331 (0.0008), respectively. Thus, controlling for transportation costs and good-specific characteristics, countries that are twice as rich in per-capita terms pay 12% more for identical items[18].

Table A.5 in appendix A.4 repeats all exercises for a subset of countries that belong to the Euro zone as of January 1, 2008, allowing to exclude exchange rates from the analysis. The estimated elasticity of prices with respect to income rises to 0.1565 (0.0086), after controlling for transportation costs and good-specific characteristics. Thus, per-capita income remains a strong candidate that potentially poses a wedge in prices of identical goods across countries[19].

1.3   Model

In this section, I propose a model in which firms practice pricing-to-market. The model incorporates the assumptions of product differentiation and firm productivity heterogeneity using the monopolistic competition framework proposed by Melitz (2003) and extended by Chaney (2008). It departs, however, from the existing literature in that

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[17]Using the most populated city instead of the capital does not change the results.

[18]I am currently performing a robustness check using quoted shipping fees of the international courier Mango uses. Although these fees are not entirely representative of Mango's shipping costs, as the firm likely receives preferential rates, they may capture the relationship between the shipping cost and the destination served. It may also be of interest to jointly estimate price elasticities of income and parameters determining the shipping fee Mango charges its customers, in order to better understand the firm's pricing practices.

[19]I am currently repeating the analysis using summer and winter catalogue data to ensure that seasonal effects are not driving the above relationships. In the present analysis, since consumers in some markets (ex. Mediterranean ones) may find summer items more desirable relative to others (ex. Scandinavian ones), I employ regional dummies, which do not alter the finding presented above.

consumers' preferences are non-homothetic, rather than being represented by a symmetric CES utility function. This novel framework yields a new set of predictions regarding exporter behavior, trade flows and price levels of tradable goods across rich and poor countries.

1.3.1 Consumers' Problem

I consider a world of I countries engaged in trade of final goods[20], where I is finite. Let i represent an exporter and j an importer, that is, i is the source country, while j is the destination country.

I assume each country is populated by identical consumers of measure L, whose utility function is given by:

$$U^c = \int_{\omega \in \Omega} \log(q^c(\omega) + \bar{q}) d\omega, \tag{1.3}$$

where $q^c(\omega)$ is individual consumption of variety ω and $\bar{q} > 0$ is a (non-country-specific) constant[21]. To ensure that the utility function is well defined, I assume $\Omega \subseteq \bar{\Omega}$, where $\bar{\Omega}$ is a compact set containing all potentially produced varieties in the world.

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[20]Throughout the paper I use the terms good and variety interchangeably.

[21]This function is the limiting case of the following generalized function:

$$U^g = \left(\int_{\omega \in \Omega} (q^c(\omega) + \bar{q})^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}},$$

where $\sigma \rightarrow 1$. Notice, $\bar{q} = 0$ yields homothetic CES preferences. Throughout the paper, I exploit the analytical tractability of the limiting case. Sections 1.4.3 and 1.4.4 describe the limitations of this highly tractable framework and explore quantitative predictions of the model using the generalized utility function.

Each variety is produced by a single firm, where firms are differentiated by their productivity, ϕ, and country of origin, i[22]. Any two firms originating from country i and producing with productivity level ϕ choose identical optimal pricing rules[23]. In every country i, there exists a pool of potential entrants who pay a fixed cost, $f_e > 0$, and subsequently draw a productivity from a distribution, $G(\phi)$, with support $[b, \infty)$. Only a measure J_i of them produce in equilibrium. Firm entry and exit drives average profits to zero. In addition, only a subset of producers, N_{ij}, sell to a particular market j. Hence, N_{ij} is the measure of goods of i-origin consumed in j. Finally, I denote the density of firms originating from i conditional on selling to j by $\mu_{ij}(\phi)$.

A representative consumer in country j has a unit labor endowment, which, when supplied (inelastically) to the labor market, earns her a wage rate of w_j. Since free entry of firms drives average profits to zero, the per-capita income of country j, y_j, corresponds to the wage rate, w_j.

The demand for variety of type ϕ originating from country i consumed in a positive

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[22]This assumption differentiates the present model from previous frameworks that employ similar preferences. In particular, Young (1991) uses the non-homothetic log-utility function, with the parameter $\bar{q}$ set to 1, in a Ricardian framework to analyze the growth patterns of countries in which firms experience learning-by-doing. Recently, Saure (2009) employs the same parameterization in a monopolistic competition framework featuring firms with homogeneous productivities to study the extensive margin of exporting. As it turns out, assuming firm productivities to be heterogeneous has two distinct advantages: first, it allows me to calibrate the parameters in the utility function in order to match the behavior of French exporters as reported in Eaton, Kortum, and Kramarz (2004) and Eaton, Kortum, and Kramarz (2008); second, it allows the model to yield constant average mark-ups across firms, thus making it very attractive for dynamic analysis.

[23]Thus, I can index each variety by the productivity of its producer.

amount in country j, $q_{ij}(\phi) > 0$, is given by[24]:

$$q_{ij}(\phi) = L_j \left\{ \frac{w_j + P_j}{N_j p_{ij}(\phi)} - \bar{q} \right\}, \tag{1.4}$$

where N_j is the total measure of varieties consumed in country j given by:

$$N_j = \sum_{v=1}^{I} N_{vj}, \tag{1.5}$$

and P_j is an aggregate price statistic summarized by:

$$P_j = \bar{q} \sum_{v=1}^{I} N_{vj} \int_{\phi_{vj}^*}^{\infty} p_{vj}(\phi) \mu_{vj}(\phi) d\phi. \tag{1.6}$$

1.3.2   Firms' Problem

An operating firm must choose the price of its good p, accounting for the demand for its product q. A firm with productivity draw ϕ faces a constant returns to scale production function, $x(\phi) = A\phi l$, where l represents the amount of labor used toward the production of final output and A summarizes the efficiency level in each country. Furthermore, each firm from country i wishing to sell to destination j faces an iceberg transportation cost incurred in terms of labor units, $\tau_{ij} > 1$, with $\tau_{ii} = 1$ ($\forall i$).

Substituting for the demand function using expression (1.4), the profit maximization problem of a firm with productivity draw ϕ originating in country i and contemplating

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[24]The consumers' problem and derivations of demand can be found in appendix A.3.1.

selling to country j is:

$$\pi_{ij}(\phi) = \max_{p_{ij} \geq 0} \quad p_{ij} L_j \left\{ \frac{w_j + P_j}{N_j p_{ij}} - \bar{q} \right\} - \frac{\tau_{ij} w_i}{A_i \phi} L_j \left\{ \frac{w_j + P_j}{N_j p_{ij}} - \bar{q} \right\} \quad (1.7)$$

The total profits of the firm are simply the summation of profits flowing from all desti-

nations it sells to. The resulting optimal price a firm charges for its variety supplied in

a positive amount is given by[25]:

$$p_{ij}(\phi) = \left(\frac{\tau_{ij} w_i}{A_i \phi} \frac{w_j + P_j}{N_j \bar{q}} \right)^{\frac{1}{2}}. \quad (1.8)$$

1.3.3 Productivity Thresholds and Firms' Mark-Ups

In this model, not all firms serve all destinations. In particular, for any source and

destination pair of countries, i, j, only firms originating from country i with productivity

draws $\phi \geq \phi_{ij}^*$ sell to market j, where ϕ_{ij}^* is a productivity threshold defined by[26]:

$$\phi_{ij}^* = \sup_{\phi \geq b} \{ \pi_{ij}(\phi) = 0 \}.$$

Thus, a productivity threshold is the productivity draw of a firm that is indifferent

between serving a market or not, namely one whose good's price barely covers the

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[25]The firm's problem is solved in appendix A.3.2.

[26]I restrict the model's parameters to ensure that $b \leq \phi_{ij}^*$, $\forall i, j$.

firm's marginal cost of production,

$$p_{ij}\left(\phi_{ij}^*\right) = \frac{\tau_{ij}w_i}{A_i\phi_{ij}^*}. \tag{1.9}$$

The price a firm would charge for its variety, however, is limited by the variety's demand, which diminishes as the variety's price rises. In particular, it is the case that consumers in destination j are indifferent between buying the variety of type ϕ_{ij}^* or not. To see this, from (1.4), notice that consumers' demand is exactly zero for the variety whose price satisfies:

$$p_{ij}\left(\phi_{ij}^*\right) = \frac{w_j + P_j}{N_j\bar{q}}. \tag{1.10}$$

Combining expressions (1.9) and (1.10) yields a simple characterization of the threshold:

$$\phi_{ij}^* = \frac{\tau_{ij}w_i N_j\bar{q}}{A_i(w_j + P_j)}. \tag{1.11}$$

Using (1.11), the optimal pricing rule of a firm with productivity draw $\phi \geq \phi_{ij}^*$ becomes:

$$p_{ij}(\phi) = \left(\frac{\phi}{\phi_{ij}^*}\right)^{\frac{1}{2}} \frac{\tau_{ij}w_i}{A_i\phi} \tag{1.12}$$

Appendix A.1 describes a typical model with symmetric CES preferences. The optimal pricing rule of a firm with productivity draw $\phi \geq \phi_{ij}^*$ in such model is given by[27]:

$$p_{ij}(\phi) = \frac{\sigma}{\sigma - 1} \frac{\tau_{ij} w_i}{A_i \phi}, \tag{1.13}$$

where $\sigma > 0$ is the constant elasticity of substitution between two varieties in this model.

Clearly, the optimal mark-up rules of firms differ in the two frameworks. The CES model predicts that every firm charges an identical constant mark-up over its marginal cost of production and delivery. The non-homothetic model suggests that mark-ups are not only firm-specific, but are also determined by the local conditions of the destination market, summarized by the threshold firms must surpass in order to serve a destination. I proceed to characterize these thresholds in the following section.

1.3.4 Equilibrium of the World Economy

In this model, a potential entrant from country i pays a fixed cost $f_e > 0$ in labor units, and subsequently draws a productivity from a cdf, $G(\phi)$, with corresponding pdf, $g(\phi)$, and support $[b, \infty)$. A measure J_i of firms produce in equilibrium. Firm entry and exit drives average profits to zero. In addition, only a subset of producers, N_{ij}, sell to market j. These firms, in turn, are productive enough so as to surpass the productivity

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[27]The two models give different solutions to the firms' problem, so productivity thresholds also differ.

threshold characterizing destination j, ϕ_{ij}^*. Hence, N_{ij} satisfies:

$$N_{ij} = J_i[1 - G(\phi_{ij}^*)]. \tag{1.14}$$

Furthermore, the conditional density of firms operating in j is:

$$\mu_{ij}(\phi) = \begin{cases} \frac{g(\phi)}{1 - G(\phi_{ij}^*)} & \text{if } \phi \geq \phi_{ij}^* \\ 0 & otherwise. \end{cases} \tag{1.15}$$

Using these objects, total sales to country j by firms originating in country i become:

$$T_{ij} = N_{ij} \int_{\phi_{ij}^*}^{\infty} p_{ij}(\phi) x_{ij}(\phi) \mu_{ij}(\phi) d\phi. \tag{1.16}$$

In addition, the ex-ante average profits of firms originating from country i are:

$$\pi_i = \sum_{\upsilon=1}^{I} [1 - G(\phi_{i\upsilon}^*)] \int_{\phi_{i\upsilon}^*}^{\infty} \pi_{i\upsilon}(\phi) \mu_{i\upsilon}(\phi) d\phi, \tag{1.17}$$

where potential profits from destination υ are weighted by the probability that they are realized, $1 - G(\phi_{i\upsilon}^*)$. The average profit, in turn, barely covers the fixed cost of entry:

$$w_i f_e = \sum_{\upsilon=1}^{I} [1 - G(\phi_{i\upsilon}^*)] \int_{\phi_{i\upsilon}^*}^{\infty} \pi_{i\upsilon}(\phi) \mu_{i\upsilon}(\phi) d\phi. \tag{1.18}$$

Finally, the income of consumers from country i, spent on final goods produced domestically and abroad, becomes:

$$w_i L_i = \sum_{v=1}^{I} T_{vi}. \tag{1.19}$$

I now proceed to define equilibrium in this economy.

Definition 1. *Given trade barriers τ_{ij} and a productivity distribution $G(\phi)$, an equilibrium for $i, j = 1, ..., I$ is given by a productivity threshold $\hat{\phi}_{ij}^*$; measure of entrants $\hat{J}_i$; measure of firms from country i serving market j $\hat{N}_{ij}$; total measure of firms serving market j $\hat{N}_j$; conditional pdf of serving a market $\hat{\mu}_{ij}(\phi)$; aggregate price statistic $\hat{P}_j$; wage rate $\hat{w}_j$; per-consumer allocation $\hat{q}_{ij}^c(\phi)$; total consumer allocation $\hat{q}_{ij}(\phi)$; decision rule $\hat{p}_{ij}(\phi)$ for firm ϕ, $\forall \phi \in [b, \infty)$, such that:*

- *Given $\hat{P}_j, \hat{w}_j, \hat{p}_{ij}$, the representative consumer solves her maximization problem by choosing $\hat{q}_{ij}^c(\phi)$ according to (1.3);*

- *Total demand function for good of type ϕ originating from country i by consumers in country j, $\hat{q}_{ij}(\phi) = \hat{q}_{ij}\left(\hat{p}_{ij}(\phi); \hat{P}_j, \hat{N}_j, \hat{w}_j\right)$ satisfies (1.4);*

- *Given $\hat{P}_j, \hat{w}_j$ and the demand function $q_{ij}(\phi) = q_{ij}\left(p_{ij}(\phi); \hat{P}_j, \hat{N}_j, \hat{w}_j\right)$ in (1.4), firm ϕ chooses $\hat{p}_{ij}(\phi)$ to solve its maximization problem in (1.7) $\forall j = 1, ..., I$[28];*

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[28]An additional equilibrium restriction for this class of models is that there is no cross-country arbitrage, that is, it must be the case that $p_{ij}(\phi) \leq p_{iv}(\phi)\tau_{vj}$ ($\forall i, v, j$). In the CES model, it is sufficient to assume that the triangle inequality for trade barriers holds, $\tau_{ij} \leq \tau_{iv}\tau_{vj}$ ($\forall i, v, j$). In the non-homothetic model, the inequality involves equilibrium objects, in particular, productivity thresholds, which in turn reflect trade barriers. As I discuss in section 1.4, once I calibrate the two models, it turns out that

- *The productivity threshold $\hat{\phi}_{ij}^*$ satisfies (1.11);*

- *The measure of firms from country i serving market j, $\hat{N}_{ij}$, satisfies (1.14);*

- *The total measure of firms serving market j, $\hat{N}_j$, satisfies (1.5);*

- *The conditional pdf of serving each market, $\hat{\mu}_{ij}(\phi)$, satisfies (1.15);*

- *The aggregate price statistic $\hat{P}_j$ satisfies (1.6);*

- *The wage rate $\hat{w}_i$ and the measure of entrants $\hat{J}_i$ together satisfy (2.9) and (2.10);*

- *The individual goods market clears $\hat{q}_{ij}(\phi) = \hat{x}_{ij}(\phi)$.*

In order to analytically solve the model and derive predictions at the firm and aggregate levels, I assume that the productivities of firms are drawn from a Pareto[29] distribution with cdf $G(\phi) = 1 - b^\theta/\phi^\theta$, pdf $g(\phi) = \theta b^\theta/\phi^{\theta+1}$ and shape parameter $\theta > 0$[30]. I retain the support of the distribution as $[b, \infty)$ and let A_i summarize the level of technology in country i. This parameter, in turn, is the source of per-capita income differences across countries. In particular, a relatively high A_i represents a more technologically-advanced country. Such a country is characterized by relatively more productive firms, whose marginal cost of production is low, and by richer consumers,

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arbitrage opportunities arise more frequently in the CES model than in the non-homothetic model. Ideally, restrictions in the calibration procedure are necessary to prevent arbitrage. To my knowledge, previous quantitative studies do not address this issue. For the purpose of this paper, I assume that the cost a consumer faces in order to re-export a final good is arbitrarily large. In the previous section, I show that the clothing manufacturer Mango practices pricing-to-market within the EU, suggesting that costs of re-exporting may be high.

[29]Kortum (1997), Eaton, Kortum, and Kramarz (2008), Luttmer (2007) and Arkolakis (2007), among others, provide theoretical justifications for the use of the Pareto distribution.

[30]This parameter restriction is sufficient to solve the non-homothetic model. Throughout the quantitative analysis, I restrict $\theta > \sigma - 1$ to ensure a solution to the CES model exists.

who enjoy higher wages. The upcoming sections study how exporters respond to such market conditions.

1.3.5 Firms' Prices and Mark-Ups

The different optimal mark-ups that arise from the two frameworks play a key role in delivering a relationship between price levels of tradables and per-capita incomes across countries. In particular, consider two firms with productivity draws ϕ_1 and ϕ_2 originating from countries 1 and 2, respectively, and selling to market j. Expression (1.8) shows that, in the non-homothetic model, the relative prices of the goods these firms sell are determined by the firms' relative marginal costs of production and delivery. The CES model obtains a similar prediction. In particular, the two models deliver the following relative prices:

$$
\begin{aligned}
NH : \frac{p_{1j}(\phi_1)}{p_{2j}(\phi_2)} &= \left(\frac{\tau_{1j} w_1}{\tau_{2j} w_2} \frac{A_2 \phi_2}{A_1 \phi_1} \right)^{\frac{1}{2}} \\
CES : \frac{p_{1j}(\phi_1)}{p_{2j}(\phi_2)} &= \left(\frac{\tau_{1j} w_1}{\tau_{2j} w_2} \frac{A_2 \phi_2}{A_1 \phi_1} \right).
\end{aligned}
$$

Thus, both models predict that, within a country, relative prices of goods are determined entirely by marginal costs of production and delivery firms face. These costs, by affecting relative demands for goods originating from different source countries, ultimately guide bilateral trade patterns across countries. Hence, the two models do not differ in their predictions on bilateral trade flows and result in identical gravity equations of trade.

In addition, both models yield constant average mark-ups. The average mark-up in the CES model is given by $\sigma/(\sigma - 1)$, the mark-up all operating firms charge. In the non-homothetic model, the average mark-up is given by:

$$\bar{m} = \int_{\phi_{ij}^*}^{\infty} \left(\frac{\phi}{\phi_{ij}^*}\right)^{\frac{1}{2}} \frac{\theta(\phi_{ij}^*)^\theta}{\phi^{\theta+1}} d\phi = \frac{\theta}{\theta - 0.5},$$

assuming $\theta > 0.5$.

Now, consider a firm with productivity draw ϕ, originating from country i and selling an identical variety to markets j and k, that is, $\phi \geq \max[\phi_{ij}^*, \phi_{ik}^*]$. The relative price this firm charges across the two markets in the two models is:

$$NH : \frac{p_{ij}(\phi)}{p_{ik}(\phi)} = \frac{\tau_{ij}}{\tau_{ik}} \left(\frac{\phi_{ik}^*}{\phi_{ij}^*}\right)^{\frac{1}{2}} \tag{1.20}$$

$$CES : \frac{p_{ij}(\phi)}{p_{ik}(\phi)} = \frac{\tau_{ij}}{\tau_{ik}}. \tag{1.21}$$

The CES model predicts that the relative prices this firm charges across countries purely reflect the transportation cost incurred to ship the good to each destination. Expression (1.8) for the non-homothetic model, on the other hand, suggests that the firm not only accounts for shipping costs, but it also responds to local conditions, such as the destination's wage, aggregate price statistic, and the presence of competition, described by the total number of firms selling there. All of these characteristics are reflected in the productivity threshold the firm must surpass in order to sell to the particular market as seen in expression (1.20).

The productivity threshold in the non-homothetic model is[31]:

$$\phi_{ij}^* = \frac{\tau_{ij} w_i}{A_i} \left[\frac{\bar{q}(\theta+1) - \theta}{f_e(\theta+1)(\theta+0.5)} \left(\frac{L_j(bA_j)^\theta}{w_j^{\theta+1}} + \sum_{v \neq j} \frac{L_v(bA_v)^\theta}{(\tau_{vj} w_v)^\theta w_j} \right) \right]^{\frac{1}{\theta+1}} \tag{1.22}$$

Looking at comparative statics, expression (1.22) clearly shows that productivity thresholds respond positively to the population and negatively to the per-capita income of the destination market. Thus, richer markets are more easily accessible for firms in this model, in that the productivity threshold they need to surpass is lower there. Hence, rich countries consume a larger pool of varieties than poor ones. Since consumers enjoy buying varieties, as their income increases, they buy not only more of each good, but also more goods.

Revisiting the mark-ups arising in the two models described in expression (1.20), costless trade leads to price equalization across countries in the CES model. However, since thresholds fall in destination per-capita income in the non-homothetic model, mark-ups, which are inversely related to thresholds, necessarily rise, thus yielding higher prices.

In order to better understand why, in the non-homothetic model, firms charge higher prices for identical products in richer markets, it is useful to examine the (absolute value

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[31]I refer the reader to appendix A.3.3 for a characterization of all equilibrium objects.

of the) price-elasticity of demand for variety of type (ϕ, i, j), given by:

$$\epsilon_{ij}(\phi) = \left[1 - \left(\frac{\phi}{\phi_{ij}^*}\right)^{-\frac{1}{2}}\right]^{-1}. \tag{1.23}$$

Using (1.23), the relative price of a variety across two markets becomes:

$$\frac{p_{ij}(\phi)}{p_{ik}(\phi)} = \frac{1 - [\epsilon_{ik}(\phi)]^{-1}}{1 - [\epsilon_{ij}(\phi)]^{-1}} \frac{\tau_{ij}}{\tau_{ik}}.$$

Thus, prices reflect trade barriers and price elasticities of demand in this model. More-over, in the absence of trade barriers, price equalization across markets does not occur. Since productivity thresholds fall with per-capita incomes of destinations, so do the price elasticities of demand as seen from (1.23). Thus, consumers in rich countries find their demand for an identical good less responsive to price changes than those in poor ones. Firms exploit this opportunity and charge a high mark-up in the more affluent market.

1.4 Quantitative Analysis

In this section, I calibrate the non-homothetic and CES models and proceed to study the resulting price levels of tradables for two sets of countries.

1.4.1   Calibration

In this subsection, I discuss the choice of parameters used to study the quantitative predictions of the models. To begin the exposition, it is useful to analyze the gravity equation suggested by the two models.

I define λ_{ij} to be the share of goods originating from country i in the total expenditure on final goods by consumers in country j, or simply j's import share of i-goods:

$$\lambda_{ij} \qquad = \frac{T_{ij}}{\sum_v T_{vj}} \tag{1.24}$$

$$= \frac{L_i A_i^\theta (\tau_{ij} w_i)^{-\theta}}{\sum_v L_v A_v^\theta (\tau_{vj} w_v)^{-\theta}}. \tag{1.25}$$

Recall that T_{ij} corresponds to total sales of firms from country i in market j, which are in turn the product of the number of firms and their average sales there, $T_{ij} = N_{ij} t_{ij}$. The average sales of firms are given by:

$$t_{ij} \quad = \int_{\phi_{ij}^*}^{\infty} r_{ij}(\phi)\mu_{ij}(\phi)d\phi \tag{1.26}$$

$$= \frac{(w_j + P_j)L_j}{2N_j(\theta+0.5)}. \tag{1.27}$$

Notice that average sales of firms in destination j are entirely determined by local market conditions. Thus, bilateral trade shares solely reflect the number of firms serving particular destinations. Using (1.26), I arrive at (1.24), which defines the trade share components that constitute a standard gravity equation of trade.

Following the methodology of Eaton and Kortum (2002), and letting $\tau_{jj} = 1$, the gravity equation is[32]:

$$\log\left(\frac{\lambda_{ij}}{\lambda_{jj}}\right) = S_j - S_i - \theta \log \tau_{ij}, \qquad (1.28)$$

where S_j and S_i represent importer-j and exporter-i fixed effects, with $S_j = \theta \log(w_j) - \log(L_j) - \theta \log(A_j)(\forall j)$. I assume the following functional form for trade barriers:

$$\log \tau_{ij} = d_k + b + e_h + x_i + \delta_{ij}, \qquad (1.29)$$

where the dummy variable associated with each effect has been suppressed for notational simplicity. In the above expression, d_k, $k = 1, ..., 6$, quantifies the effect of the distance between i and j lying in the k-th interval, b captures the importance of sharing a border and e_h is the effect of i and j both belonging to the European Union (in 2004) and the NAFTA (North American Free Trade Agreement), respectively[33]. Finally, following Waugh (2007), I let x_i capture additional hurdles exporters face in order to place their products abroad[34].

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[32]Import shares, λ_{ij}'s, are straightforward to compute from the bilateral trade flows data reported by UN Comtrade. I take bilateral trade flows that correspond to ISIC manufacturing categories only, using the concordance proposed by Muendler (2009) and UN Comtrade data at the SITC 4-digit level. Thus, my data excludes agricultural goods. I compute the domestic share of total expenditure, λ_{jj}, as the residual of gross output that is not imported, where I approximate gross output to be 5 times the manufacturing value added in 2004 as found in WDI.

[33]I obtain distance and border data from Nicita and Olarreaga (2006), better known as World Bank's Trade, Production and Protection Database.

[34]In Appendix O.1 available on my website www.econ.umn.edu/~ina, I repeat the analysis with trade barriers estimated according to Eaton and Kortum (2002), namely using importer-specific fixed effects. I report all summary statistics and reproduce figure 1.1 using prices generated from the CES and non-homothetic models. Since trade barriers are systematically lower in richer destinations, they diminish

As discussed in appendix A.1, with the help of two assumptions about the CES model, its gravity equation collapses to (1.28). First, I assume that the amount of labor necessary to cover the fixed cost of selling domestically and abroad is equivalent, an assumption used by Arkolakis (2008) when calibrating a similar model. Second, I assume that fixed costs are incurred in destination-specific wages. This assumption can be rationalized if one takes fixed costs to represent the costs of establishing a retail network in the destination country.

A quick glance at the gravity equation indicates that a value for the Pareto shape parameter θ is necessary in order to calibrate the trade barriers in the model. I take a value of 8 for θ, a parameter choice used by Eaton and Kortum (2002) in their study of OECD economies, and retain the value for the larger sample of countries [35].

In order to derive the technology parameters of each country, A_i, I solve the model using the calibrated trade barriers and Pareto shape parameter, together with per-capita income and population data for 2004[36]. The technology parameters thus satisfy all equilibrium conditions of the model[37].

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the effect low price elasticities of demand have on the price level of tradables. But, the reader can verify that, while estimated elasticities are lower, the nature of the results remains unaltered.

[35] Eaton and Kortum (2002) choose a value of θ so that their model matches price dispersion in OECD countries. I use this value in order to compare the results in the present paper to the existing quantitative literature. Simonovska and Waugh (2009) propose an alternative estimation of the parameter for the present and other models using detailed 2005 price data.

[36] Per-capita and population data are obtained from WDI.

[37] In appendix A.3.3, I show that all equilibrium objects can be expressed as functions of wage rates of all the countries. Since the CES and the non-homothetic models deliver identical gravity equations, the system of equations that characterizes the unique vector of wages that solves the two models is also identical. Hence, technology parameters, calibrated to generate per-capita incomes observed in the data, are equivalent in the two models.

Finally, for the purpose of price-comparisons across countries, the fixed cost of market entry f_e, the non-homotheticity parameter $\bar{q}$, the lower bound on productivity b, the fixed cost of selling to a market f, and the constant elasticity of substitution σ, (where the last two parameters are found in the CES model only) need not be calibrated. This is because they are country-invariant and cancel out in relative-price comparisons[38]. I set b to ensure that $b \leq \min_{k=nh,ces} \min_i \min_j \phi_{ij}^{k*}$. f_e simply rescales the measure of operating firms in both models, so I normalize it to unity. In this simple non-homothetic model, $\bar{q}$ simply rescales the quantities sold by each firm. This is not the case in the non-limiting model explored in section 1.4.4, due to the presence of non-linearities. I employ a value of $5,000$ (in units of f_e), which is calibrated to firm-level data using the generalized utility function in section 1.4.4. This way, quantitative results throughout the paper are comparable. Finally, I normalize the fixed cost of serving a destination in the CES model, f, to unity.

1.4.2 Income Differences and Prices of Tradables

In this section, I evaluate the ability of the two models to explain the observed differences in prices of tradable goods across countries. As discussed in section 3.1, tradable goods are systematically more expensive in richer (per-capita) countries. For the OECD[39]

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[38]Since both models are limiting cases of the general utility function introduced earlier, there is an apparent discontinuity in both models. For values of $\bar{q} = 0$ and $\sigma = 1$, both models collapse into a simple framework in which products are perfect substitutes. This case is of no interest because exporter behavior is trivial. An interesting case is the general one, in which both utility parameters are chosen to match observed features of firms. I explore this in section 1.4.4.

[39]The sample of OECD countries contains 29 price and income observations. I compute a weighted average of the price observations for Belgium and Luxembourg, using GDP as weights, because bilateral trade flows data are meaningful only for the two countries together.

member countries, the estimated elasticity of the price level of tradables with respect to per-capita income is 0.2442 (0.0360), while for a sample of 119 countries, the same statistic is 0.1116 (0.0117). In order to evaluate the ability of the two models to reconcile these observations, I solve the calibrated models and calculate the price levels of tradable goods[40].
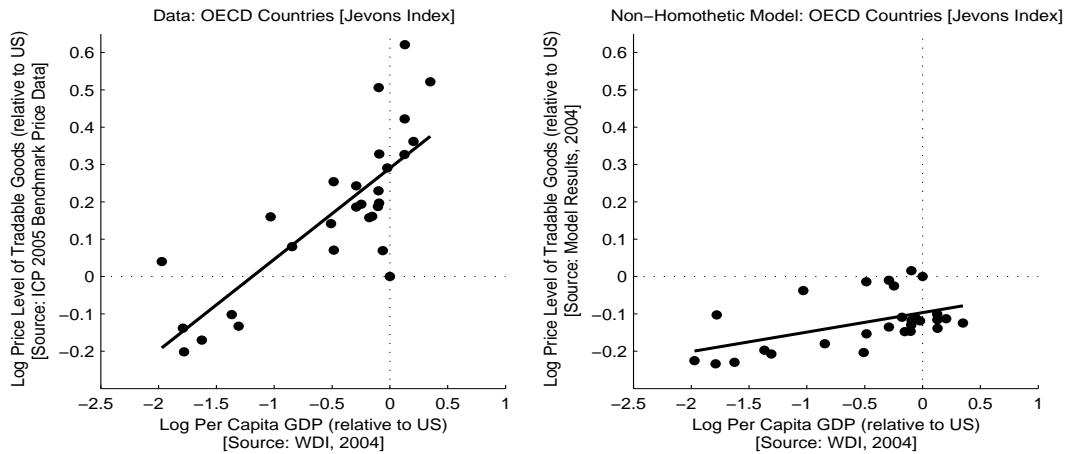
FIGURE 1.2: Price Level of Tradable Goods and Per-Capita GDP for OECD Countries

Figure 1.2 plots the price-income relationship for OECD countries resulting from the data and the non-homothetic model whose parameters have been calibrated to match 2004[41] bilateral trade flows of OECD countries. Figure A.3 in appendix A.4 plots the relationship between prices of tradables and per-capita incomes for OECD countries

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[40]I take the price data from the 2005 ICP Benchmark Studies. I use data at the basic-heading level, the lowest level of aggregation possible, and combine it to calculate price indices according to the Jevons method. I repeat the procedure for the two models. Appendix A.2 describes the accounting procedure for the data and the two models in detail.

[41]I combine 2005-price data with 2004 data on all other income- and trade-related statistics purely due to availability limitations. Moreover, since the ICP round was carried out during the 2003-2005 period, prices likely reflect 2004-levels. An exception is Zimbabwe, which experienced extreme hyperinflation during this period, which is why I exclude it from my analysis.

in the non-homothetic and CES models. This is a natural comparison, since it gives a quantitative measure of the importance variable mark-ups play in capturing cross-country price differences.

While the models match OECD bilateral trade shares well, they depart in their predictions regarding price levels. The CES model is unable to produce a relationship between the price level of tradables and per-capita income for OECD countries. The model's estimated elasticity of the price level of tradables with respect to per-capita income is -0.0078, which is not statistically different from 0, as the t-statistic is -0.2813. The non-homothetic model, on the other hand, not only qualitatively predicts a positive relationship between the two variables, but can also explain over a fifth of the price differentials since its estimated elasticity is 0.0523, with standard error 0.0171.
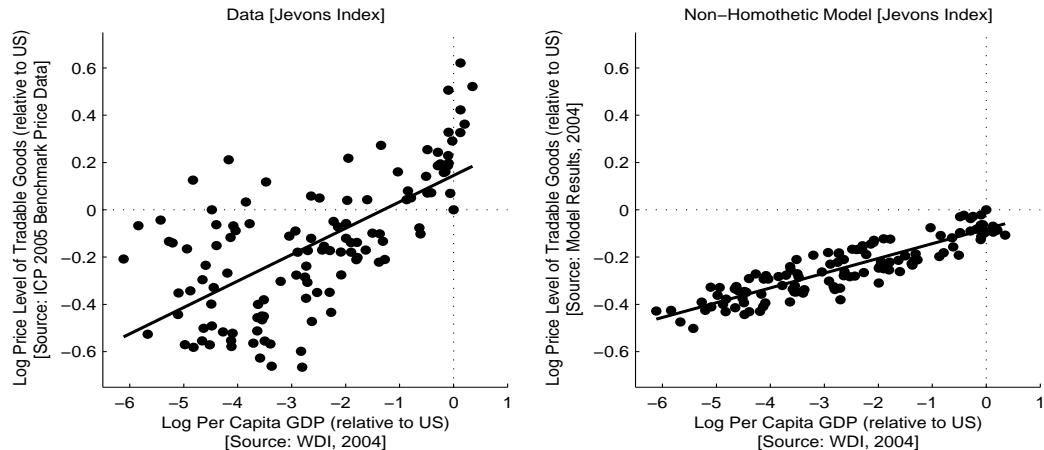

FIGURE 1.3: Price Level of Tradable Goods and Per-Capita GDP for 119 Countries

Figure 1.3 plots the price-income relationship for 119 countries resulting from the data and the non-homothetic model whose parameters have been re-calibrated to match

2004 bilateral trade flows of these countries. Figure A.4 in appendix A.4 plots the relationship between prices of tradables and per-capita incomes for these countries in the non-homothetic and CES models. While the non-homothetic model predicts a positive correlation between prices of tradables and per-capita income levels, the CES model obtains a counterfactual prediction. Indeed, the estimated price elasticity of tradables with respect to per capita income implied by the CES model is -0.0088 (0.0034), while that generated by the non-homothetic model is 0.0624 (0.0029). Thus, the non-homothetic model can explain over a half of the observed cross-country price differences for a large sample of countries.

To understand the CES model's different predictions regarding the two samples of countries, it suffices to examine the optimal pricing rule of any firm with productivity ϕ, originating in country i and selling to country j, $p_{ij} = \sigma/(\sigma - 1)\tau_{ij}w_i/\phi$. The price of a tradable good captures the productivity of the exporting firm, reflected in its marginal cost of production, trade barriers and a constant mark-up. Moreover, the relative price of a good that is actually exported to two different destinations departs from unity only to the extent that its producer faces country-specific trade barriers. Should trade barriers be uncorrelated with per-capita income, no relationship between prices and incomes is to be expected. Indeed, this is the case for OECD economies. These countries have bilateral trade flows that are characterized by virtually no zero-entries, suggesting low trade barriers. Hence, for these economies, the CES model predicts no statistically significant relationship between prices of tradables and income levels.

Once the sample is extended to 119 countries, the per-capita income heterogeneity rises dramatically. However, in this case, trade barriers also diverge in order to deliver the many zero bilateral trade observations found in the data. These are in turn more prominent among poor countries. In fact, rich countries are both more productive and trade more among themselves. Their high productivity levels in turn imply low marginal costs of production. Hence, the varieties they produce and trade with each other are cheaper. From the point of view of a poor economy, it only benefits from low prices if its trade barriers are low enough. Otherwise, the low levels of productivity, which result in high marginal costs of production for its domestic producers, not only prevent it from placing its products internationally, but also hurt its consumers by raising the price of domestically produced goods. Thus, a negative relationship between prices of tradable goods and per-capita income levels arises.

The non-homothetic model, on the other hand, introduces a pricing-to-market channel in addition to the trade barrier effect outlined above. While trade barriers are an important determinant of the price of imports, so is the responsiveness of consumers to price changes. The pricing rule a firm ϕ follows is $p_{ij}(\phi) = \tau_{ij}/(1 - [\epsilon_{ij}(\phi)]^{-1})$, which reflects trade barriers and the price elasticity of demand. High income levels result in low price elasticity of demand, allowing firms to extract high mark-ups in more affluent markets. Although domestically-produced varieties are relatively cheap in rich markets due to the countries' high productivity levels, imports are not. To the extent that rich economies enjoy lower trade barriers, their import-penetration ratios are higher, and so

are their price levels of tradable goods.

1.4.3 Firms Size and Market Entry

This section explores how the predictions of the non-homothetic model regarding the size

distribution of firms and their decision to enter different markets relate to the behavior

of French exporters in 1986, as reported by Eaton, Kortum, and Kramarz (2004) and

Eaton, Kortum, and Kramarz (2008)[42].

Letting $m_{ij}(\phi)$ represent the mark-up a firm from country i with productivity ϕ

selling to destination j charges, the sales this firm realizes in market j, relative to the

average firm sales in market j, are given by:

$$s_{ij}(\phi) \equiv \frac{r_{ij}(\phi)}{t_{ij}} = \begin{cases} (1+2\theta)\left(1 - \frac{1}{m_{ij}(\phi)}\right) & \text{if } \phi \geq \phi_{ij}^* \\ 0 & otherwise, \end{cases}$$

where $t_{ij} = T_{ij}/N_{ij}$ represents average sales of firms from country i in destination j.

Notice that a firm with productivity equivalent to the threshold, ϕ_{ij}^*, sets a mark-

up of unity and realizes zero sales. When looking at the optimal pricing rule, a more

productive firm sells its variety at a lower price. This naturally raises its sales. However,

notice that the price of a variety contains two components: the firm's marginal cost and

its mark-up. While a more productive firm faces lower marginal cost, it is also able to

charge a higher mark-up. Thus, a more productive firm enjoys higher mark-ups and

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[42]I refer the reader to Eaton, Kortum, and Kramarz (2008) for a detailed discussion of the CES model's predictions regarding firms' sales and their distribution.

higher sales. However, while the mark-up increases with firm productivity, it does so in a concave fashion. This translates into firm sales that are also concave in firm productivity. Figure A.2 in appendix A.4 graphically summarizes the relationship between firms sales' and their productivities.

Since the marginal firm in a market realizes zero sales, and sales are increasing in firms' productivities, this model generates a distribution of firms' sales that is qualitatively in line with the findings for French exporters reported by Eaton, Kortum, and Kramarz (2008)[43].

Appendix A.3.4 derives the following distribution of firms' sales, relative to average sales in a market, predicted by the model:

$$F_{ij}(s) = 1 - \left[1 - \frac{s}{2\theta + 1}\right]^{2\theta}.$$

It also shows that the above distribution exhibits Pareto tails. Arkolakis (2008), in turn, finds that the distribution of French exporters' sales in Portugal in 1986 has the same feature. Finally, recall that, in this model, richer countries consume a larger pool of varieties. Since each variety is produced by a single firm, the relationship between the number of firms that serve each destination and the destination's per-capita income is a positive one. The opposite is true with respect to the size of the

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[43]Eaton, Kortum, and Kramarz (2008) identify the failure of the CES model to deliver small sales of exporters, if they face fixed costs of reaching a market. Arkolakis (2008) proposes a model in which exporters sell tiny amounts because they optimally reach only a portion of a destination's population. His model explains the behavior of exporters qualitatively as well as quantitatively, but it relies on CES preferences, thus delivering predictions regarding prices of tradables that are in contrast with the data.

market. However, since the elasticity of the number of firms with respect to per-capita income of a market is much larger than that with respect to the market's size (see equation (1.22)), more firms serve markets characterized by higher total income. Thus, the non-homothetic model's qualitative predictions regarding firms' sales are in line with the behavior of French exporters reported in Eaton, Kortum, and Kramarz (2004) and Eaton, Kortum, and Kramarz (2008).

While the model qualitatively captures the behavior of exporters reported in the French data, it doesn't do so quantitatively. To see this, notice first that the model predicts a strong hierarchy in the markets firms sell to. Since richer markets are more easily accessible, all firms that sell to destination A necessarily serve all richer destinations $B, C, D, ...$ Hence, we can order the markets in terms of the productivity cutoffs that are necessary in order to reach each destination. Let $\phi_{FF}^{(k)}$ represent the minimum productivity a French firm needs in order to sell to France and to k additional markets, where $k = 0, 1, 2, ...I - 1$. Then, the model delivers the following equation:

$$\frac{T_{FF}^{(k)}}{t_{FF}^{(0)}} = N_{FF}^{(0)} \left[(2\theta + 1)\frac{N_{FF}^{(k)}}{N_{FF}^{(0)}} - \frac{\theta(2\theta + 1)}{\theta + 0.5} \left(\frac{N_{FF}^{(k)}}{N_{FF}^{(0)}} \right)^{\frac{\theta+0.5}{\theta}} \right],$$

which relates the domestic sales of French firms that serve at least k destinations (normalized by average domestic sales) to their corresponding measure (normalized by the measure of operating French firms).

Notice that this relationship is entirely pinned down by the parameter θ, which also

governs bilateral trade flows through a standard gravity equation. When $\theta = 8$, the model matches bilateral trade flows very well, but the elasticity of sales with respect to the number of exporters above is 0.61, which is well above the value of 0.35 for French exporters reported by Eaton, Kortum, and Kramarz (2008). The reason why the model over-predicts the size of firms is the relatively low substitutability across varieties implied by the log-utility function. This hints toward the need of higher elasticities of substitution in the utility function.

Next, recall that the total sales of firms from country i in destination j are composed of the number of firms originating from i and serving market j and their average sales there, $T_{ij} = N_{ij}t_{ij}$. In addition, these sales represent the fraction of j-consumers' total expenditure devoted to these goods, $T_{ij} = \lambda_{ij}w_jL_j$. These two expressions allow me to relate the number of firms serving a destination normalized by their market share there, N_{ij}/λ_{ij}, to the destination's income, w_jL_j:

$$\log\left(\frac{N_{ij}}{\lambda_{ij}}\right) = \alpha + \beta \log(w_jL_j) + \epsilon, \tag{1.30}$$

where α, β can be estimated using a simple linear regression.

Eaton, Kortum, and Kramarz (2008) estimate this relationship for French exporters in 1986 using 113 destinations and find β to be 0.65. I repeat their analysis using the equilibrium number of French firms resulting from the non-homothetic model, calibrated to match bilateral trade flows of OECD countries. I find that the corresponding elasticity

is above unity, which suggests that the model over-predicts firm entry[44]. This finding

hints to a necessary adjustment on the extensive margin, namely, entry needs to be less

responsive to destination's income. In the non-homothetic model, the extensive margin

is influenced, among other variables, by the non-homotheticity parameter $\bar{q}$. Since firms

do not pay fixed costs of market entry, the boundedness in marginal utilities limits the

group of firms that serve each market. While in the limiting non-homothetic model

$\bar{q}$ simply rescales the number of firms in each market, that is no longer the case once

elasticities of substitution depart from unity. Hence, the elasticity of substitution σ

and the non-homotheticity parameter $\bar{q}$ can be chosen to match the above firm-level

statistics in a calibrated model. The next section does just that.

1.4.4 Quantitative Predictions of the General Model

In this section, I analyze the quantitative predictions of the model in which consumer

preferences take on the following form:

$$U^g = \left(\int_{\omega \in \Omega} (q^c(\omega) + \bar{q})^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} ,$$

where $\sigma \geq 1$ and $\bar{q} \geq 0$. The model nests both the CES and the simple non-homothetic

model analyzed in previous sections.

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[44]The model calibrated to match moments of the 119 countries gives elasticity estimates slightly below unity. While this sample is more comparable to the study of Eaton, Kortum, and Kramarz (2008), I restrict the analysis to the OECD sample to make it comparable to the calibration of the generalized non-homothetic model outlined below. While a sample of 119 countries is more interesting, the computational requirements for the general model for such sample are too large.

For as long as $\bar{q} > 0$, the qualitative predictions of this general model are in line with the limiting log-case studied throughout the paper. However, closed form solutions no longer exist. To see this, the optimal price a firm with productivity ϕ from country i charges to destination j solves the following implicit equation:

$$(1-\sigma)p_{ij}^{-\sigma}L_j\frac{w_j+\bar{q}P_j}{P_{j\sigma}^{1-\sigma}} - L_j\bar{q} + \sigma\frac{\tau_{ij}w_i}{A_i\phi}p_{ij}^{-\sigma-1}L_j\frac{w_j+\bar{q}P_j}{P_{j\sigma}^{1-\sigma}} = 0, \qquad (1.31)$$

where:

$$P_j = \sum_{v=1}^{I}\int_{\phi_{vj}^*}^{\infty}p_{vj}(\phi)\frac{\theta J_v b^\theta}{\phi^{\theta+1}}d\phi, \quad P_{\sigma i}^{1-\sigma} = \sum_{v=1}^{I}\int_{\phi_{vj}^*}^{\infty}(p_{vj}(\phi))^{1-\sigma}\frac{\theta J_v b^\theta}{\phi^{\theta+1}}d\phi. \qquad (1.32)$$

(1.31) suggests that integer values of σ are necessary in order to obtain numerical solutions to the firm's problem. Moreover, what makes the model computationally difficult is the numerical integration required in order to characterize all equilibrium objects which contain the price indices in (1.32).

In an online appendix, I characterize the solution to this model and outline the numerical algorithm used in order to deliver the results reported below. Before proceeding to study the quantitative predictions regarding prices, I summarize the parameters used in the calibration as well as the targeted moments.

As mentioned earlier, the non-homotheticity parameter is expressed in units of the fixed cost of entry, which is normalized for convenience. The latter parameter can be calibrated to deliver the average sales of French firms instead, which would result in

TABLE 1.1: Parameters of General Model

Parameter	Fact	Source
$I=29$	# countries in sample	–
L	country population ('04)	WDI
A	country per-capita income ('04)	WDI & model's solution
τ_{ij}	–	log-utility NH model
$\theta=8$	–	Eaton and Kortum (2002)
$f_e = 1$	normalization	–
$b = 0.01$	$b \leq \min_i \min_j \phi_{ij}^*$	model's solution
$\sigma = 6$	French firm size dist. (35%)	Eaton, Kortum, and Kramarz (2008) & solution
$\bar{q} = 5000$	French firm entry (65%)	Eaton, Kortum, and Kramarz (2008) & solution

a considerably lower value for $\bar{q}$. Furthermore, it is important to note that the trade barriers are no longer calibrated to match observed bilateral trade flows. This is due to the fact that the model no longer yields the simple gravity equation of trade outlined earlier. So, while the model's predicted trade flows are not as close to observed trade flows as before, the differences are not substantial, which justifies the use of these trade barriers as a first possibility[45]. Finally, the elasticity parameter needed to match the size distribution of firms is in line with that reported by Arkolakis (2008).

Figure (1.4) plots the prices of tradable goods arising from the two non-homothetic models. The general model is not as successful at capturing the price-income relationship as the simple non-homothetic model analyzed above. First, trade barriers are no longer calibrated to deliver observed bilateral trade flows. Second, once the elasticity of substitution takes on the value of 6, goods become significantly more substitutable than in the log-utility case. This necessarily gives each monopolistically-competitive firm a

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[45]I provide summary statistics and a discussion of alternative calibration procedures online.
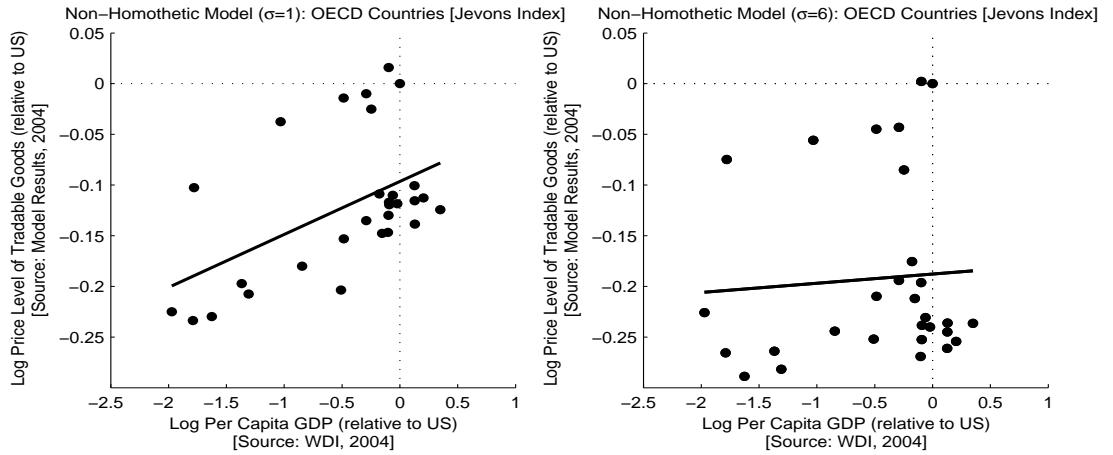
FIGURE 1.4: Price Level of Tradable Goods and Per-Capita GDP for OECD Countries

lower market share and therefore less of an ability to price-discriminate across markets. Nonetheless, the model is still able to generate a positive and statistically significant price-income relationship. Thus, given its ability to capture both firm-level and aggregate observations, the model performs very well both qualitatively and quantitatively.

1.5 Conclusion

This paper builds on the success of the existing trade literature that aims to explain the behavior of exporters and bilateral trade flows. It further contributes to the literature by capturing the observed positive relationship between prices of tradable goods and income. It does so by introducing non-homothetic preferences in a model of trade with product differentiation and heterogeneity in firm productivity. In an analytically tractable framework, the model predicts that not only are exporters in the minority, but that they also sell tiny amounts per market. Moreover, these exporters exploit low

price elasticities of demand in rich countries by charging high mark-ups for identical products relative to poor destinations.

The pricing-to-market channel is not only key for qualitatively matching the relationship between prices of tradables and countries' incomes, but it also appears to be quantitatively important. In particular, variable mark-ups can account for more than a half of price differences across a large sample of countries. Alternative parametrizations of the model enable it to also capture a variety of cross-sectional facts at the firm-level, however, at the expense of lowering its degree of quantitative success along the price-income dimension.

Finally, since a simple model of non-homothetic preferences appears to both qualitatively and quantitatively match trade flows and price levels across countries, it may be reasonable to build on such framework in future studies. Given the model's desirable features and tractability, it can be easily extended to a dynamic framework in which real exchange rate fluctuations can be explored.

Chapter 2

Elasticity of Trade for Developing Nations: Estimates and Evidence

2.1 Introduction

Quantitative results from standard models of international trade depend critically on a single parameter governing the elasticity of trade with respect to trade frictions.[1] We provide an estimate of this elasticity consistent with heterogenous firm models of international trade for 129 countries representing 98 percent of World GDP for the year 2004 using new disaggregate price and trade flow data.

To illustrate how important this parameter is, consider two examples (of many) in

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[1]By standard models of international trade, we mean those of Krugman (1980), Anderson and van Wincoop (2003), Eaton and Kortum (2002), and Melitz (2003) as articulated in Chaney (2008), which all generate log-linear relationships between bilateral trade flows and trade frictions.

the empirical trade literature: Anderson and van Wincoop (2003) find the estimated tariff equivalent of the U.S.-Canada border varies between 48 and 19 percent depending upon the assumed elasticity of trade with respect to trade frictions. Yi (2003) points out that observed reductions in tariffs can explain almost all or none of the growth in world trade depending upon this elasticity. Thus depending upon this elasticity, the cost of the border and the growth in world trade are puzzles seeking explanations or not.

Despite its importance, evidence regarding this parameter is scarce and often comes from small samples of developed countries.[2] Estimating this parameter is difficult because standard trade models can rationalize small trade flows with either large trade frictions and small elasticities or small trade frictions and large elasticities. Thus one needs satisfactory measures of trade frictions *independent* of trade flows to estimate this elasticity. Because of the extreme data requirements, estimates of this parameter are from limited samples of developed countries. For this reason, these estimates may be appropriate for studying trade between the U.S. and Canada, but may be inappropriate for broader questions and specifically those related to developing countries which are responsible for a rising portion of world trade.

Our contribution is to provide an estimate of this elasticity for 129 countries representing 98 percent of World GDP using new disaggregate price and trade flow data.

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[2]See for example Head and Ries (2001) for the U.S. and Canada, Baier and Bergstrand (2001) and Eaton and Kortum (2002) for OECD countries, or the survey of these and several other studies in Anderson and van Wincoop (2004).

The key piece of data allowing us to estimate this elasticity is disaggregate price data from the most recent results from the International Comparison Programme. This data provides comparable prices for 129 good categories for all countries in our sample. With this data we use the maximum price difference across goods between countries as a proxy for trade frictions similar in spirit to the approach of the Eaton and Kortum (2002) study of 19 OECD countries. The maximum price difference between two countries is meaningful as it is bounded by the trade friction between the two countries via simple no arbitrage arguments. Using these proxies for trade costs from disaggregate price data and data on bilateral trade shares, we are able to identify and estimate the elasticity of trade with respect to trade frictions for a large cross-section of countries.

Our (preliminary) benchmark estimate for all countries is approximately 7.5 with a standard error of about 0.60. Prior research has suggested that this elasticity lies in the range between 4 and 9; see Anderson and van Wincoop (2004) survey.[3] Our estimate provides the most comprehensive evidence regarding this parameter with it lying near the middle the range as suggested in the literature.

We also explore if this elasticity varies with level of development. When the sample is restricted to only high income countries, we find the estimate is only slightly lower than 7.5. When the estimate is restricted to low income countries, it is only slightly lower than 7.5. In both cases the standard errors increase to near one. Thus we provide

[3]We currently follow simple approaches to estimating this parameter as suggested in Eaton and Kortum (2002). We hope to provide monte carlo evidence regarding this approach and possibly alternative estimation approaches in future versions of this paper.

evidence supporting models with common elasticities of trade with respect to trade frictions across all countries.

Because our estimation approach relies heavily upon the retail prices of goods across countries, we address several important questions regarding our analysis. First, we show how our method is robust to unobserved quality differences and distribution costs within standard trade models. Second, we also estimate this elasticity in the context of a model of variable markups and non-homothetic preferences as in Simonovska (2009). Third, we provide Monte Carlo evidence that our approach can reliably recover this estimate in the presence of measurement error.

2.2   A Prototype Trade Model

In this section, we outline a model of trade that incorporates the monopolistic competition structure proposed by Melitz (2003) and derive a relationship mapping trade flows to trade frictions with elasticity θ—which is the key parameter of interest. Though we focus on this particular framework, we discuss how alternative frameworks such as Eaton and Kortum (2002) and Anderson and van Wincoop (2003) all generate the same exact relationship. Thus the parameter that we ultimately estimate is not unique to one particular framework, but applicable for a broad class of models.

2.2.1 Consumers

Each country n has measure L_n of consumers. The maximization problem of a consumer with a unit labor supplied inelastically on the domestic labor market in country n buying varieties from (potentially) all countries $v = 1, ..., I$ is:

$$\max_{\{q_{nv}\}_{v=1}^{I} \geq 0} \left(\sum_{v=1}^{I} \int_{\Omega_{nv}} (q_{nv}(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} \quad s.t. \quad \sum_{v=1}^{I} \int_{\Omega_{nv}} p_{nv}(\omega) q_{nv}(\omega) d\omega \leq w_n. \quad (2.1)$$

$q_{nv}(\omega)$ is the quantity purchased in country n from county v of variety ω. σ governs the elasticity of substitution across varieties ω and w_n is the wage in country n. Ω_{nv} denotes the set of varieties available to consumers in country n from country v.

Each variety is produced by a single firm, where firms are differentiated by their productivity, ϕ, and country of origin, i. Any two firms originating from country i and producing with productivity level ϕ choose identical optimal pricing rules. This implies that we can index each variety by the productivity of its producer which we will do through out.

The demand for variety of type ϕ originating from country i consumed in a positive amount in country n, populated by L_n identical consumers, is given by:

$$q_{ni}(\phi) = w_n L_n \frac{p_{ni}(\phi)^{-\sigma}}{(P_n)^{1-\sigma}}, \quad (2.2)$$

where P_n is the ideal price index in this CES-based model:

$$(P_n)^{1-\sigma} = \sum_{v=1}^{I} N_{nv} \int_{\phi_{nv}^*}^{\infty} p_{nv}(\phi)^{1-\sigma} \mu_{nv}(\phi) d\phi. \tag{2.3}$$

Equations (2.2) and (2.3) characterize the equilibrium behavior from the consumers perspective.

2.2.2 Firms

In every country i, there exists a pool of potential entrants who pay a fixed cost, $f_e > 0$, and subsequently draw a productivity from a Pareto distribution, $T_i \phi^{-\theta}$, with support $[T_i^{1/\theta}, \infty)$. Only a measure J_i of them produce in equilibrium. Firm entry and exit drives average profits to zero. In addition, only a subset of producers, N_{ni}, with productivity draws $\phi \geq \phi_{ni}^*$, sell to a particular market n. Hence, $N_{ni} = J_i T_i / (\phi_{ni}^*)^\theta$ is the measure of goods of i-origin consumed in n. Finally, we denote the density of firms originating from i conditional on selling to n by $\mu_{ni}(\phi) = \theta(\phi_{ni}^*)^\theta / \phi^{\theta+1}$.

Assuming firms incur a fixed cost f_n, expensed in destination wages, in order to serve a market n, the profit maximization problem of a firm with productivity draw ϕ originating in country i and considering to sell to country n is then:

$$\pi_{ni}(\phi) = \max_{p_{ni} \geq 0} \quad p_{ni} w_n L_n \frac{p_{ni}^{-\sigma}}{(P_n)^{1-\sigma}} - \frac{\tau_{ni} w_i}{\phi} w_n L_n \frac{p_{ni}^{-\sigma}}{(P_n)^{1-\sigma}} - w_n f_n. \tag{2.4}$$

The optimal pricing rule of a firm with productivity draw $\phi \geq \phi_{ni}^*$ is given by:

$$p_{ni}(\phi) = \frac{\sigma}{\sigma - 1} \frac{\tau_{ni} w_i}{\phi}. \tag{2.5}$$

Using (2.5) we can derive a zero-profit condition, which determines the productivity threshold ϕ_{ni}^*:

$$\pi_{ni}(\phi_{ni}^*) = 0 \iff \phi_{ni}^* = \frac{\tau_{ni} w_i}{P_n} \left(\frac{(\sigma - 1)^{1-\sigma} \sigma^\sigma f_n}{L_n} \right)^{\frac{1}{\sigma-1}} \tag{2.6}$$

Assuming $\theta > \sigma - 1$, define the total sales to country n by firms originating in country i as:

$$X_{ni} = N_{ni} \int_{\phi_{ni}^*}^{\infty} p_{ni}(\phi) q_{ni}(\phi) \mu_{ni}(\phi) d\phi. \tag{2.7}$$

In addition, the ex-ante average profits of firms originating from country i are:

$$\pi_i = \sum_{v=1}^{I} \frac{T_i}{(\phi_{vi}^*)^\theta} \int_{\phi_{vi}^*}^{\infty} \pi_{vi}(\phi) \mu_{vi}(\phi) d\phi, \tag{2.8}$$

where potential profits from destination v are weighted by the probability that they are realized. The average profit, in turn, barely covers the fixed cost of entry:

$$w_i f_e = \sum_{v=1}^{I} \frac{T_i}{(\phi_{vi}^*)^\theta} \int_{\phi_{vi}^*}^{\infty} \pi_{vi}(\phi) \mu_{vi}(\phi) d\phi. \tag{2.9}$$

Finally, the income of consumers from country i, spent on final goods produced domestically and abroad, becomes:

$$w_i L_i = \sum_{v=1}^{I} X_{vi}. \tag{2.10}$$

Using (2.6), (2.9) and (2.10) yield the measure of entrants in each country i:

$$J_i = \frac{L_i}{f_e} \frac{\sigma - 1}{\sigma \theta}. \tag{2.11}$$

2.2.3   Trade

Given these previous results, we now proceed to derive bilateral trade shares between countries. For concreteness, a bilateral trade share is defined to be X_{ni}/X_n where X_{ni} is the total value that country n imports from country i and X_n is the total value of consumption of all goods (either imported or domestically produced) in country n.

One can show that bilateral trade shares relative to the domestic share of consumption (or home trade share) is given by:

$$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \frac{\sum_{v=1}^{I} \frac{L_v T_v}{(\tau_{iv} w_v)^\theta}}{\sum_{v=1}^{I} \frac{L_v T_v}{(\tau_{nv} w_v)^\theta}} \tau_{ni}^{-\theta} \tag{2.12}$$

Substituting (2.5) into (2.3) and using the free entry condition defined by (2.6) yields

the price index in country n:

$$(P_n)^{-\theta} = \sum_{v=1}^{I} \frac{J_v T_v}{(\tau_{nv} w_v)^\theta} \left(\frac{f_n}{L_n}\right)^{\frac{-\theta-1+\sigma}{\sigma-1}} \theta \sigma^{\frac{\sigma\theta+\sigma+1}{1-\sigma}} \frac{(\sigma-1)^\theta}{\theta-\sigma+1} \qquad (2.13)$$

Using the measure of entrants in each country i given in equation (2.11) and substituting it into equation (2.13), the relative price indices become:

$$\left(\frac{P_i}{P_n}\right)^{-\theta} = \frac{\sum_{v=1}^{I} \frac{L_v T_v}{(\tau_{iv} w_v)^\theta} \left(\frac{f_i}{L_i}\right)^{\frac{-\theta-1+\sigma}{\sigma-1}}}{\sum_{v=1}^{I} \frac{L_v T_v}{(\tau_{nv} w_v)^\theta} \left(\frac{f_n}{L_n}\right)^{\frac{-\theta-1+\sigma}{\sigma-1}}}. \qquad (2.14)$$

Finally, we make the assumption that the fixed costs of market access are proportionate to the size of the market, $f_i = AL_i$ and the degree of proportionality constant across countries.[4] This assumption simplifies equation (2.14):

$$\left(\frac{P_i}{P_n}\right)^{-\theta} = \frac{\sum_{v=1}^{I} \frac{L_v T_v}{(\tau_{iv} w_v)^\theta}}{\sum_{v=1}^{I} \frac{L_v T_v}{(\tau_{nv} w_v)^\theta}}. \qquad (2.15)$$

Examining equation (2.12) relative to equation (2.15), one can derive a simple expression relating trade shares to variable trade costs and aggregate relative prices.

$$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \tau_{ni}^{-\theta} \times \left(\frac{P_i}{P_n}\right)^{-\theta}, \qquad (2.16)$$

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[4]One can make alternative assumptions on fixed costs and arrive at a similar expression that we desire. Furthermore, can think of this fixed cost as a distribution/retailing cost to access a market of size L. Thus, distribution costs do not affect the estimates of θ.

2.2.4 Discussion

Equation (2.16) is the key equation of this paper and the parameter of interest is θ which governs the elasticity of trade flows with respect to trade costs.

Equation (2.16) is basically an arbitrage condition. If $P_n > P_i$, then country n has incentives to purchase relatively more goods from country i because they are cheaper. Or if trade costs between country n and i are large, then country n has less incentives to purchase a good from country i. Given this intuition, it should not be surprising that alternative models of international trade generate this same relationship. Below we discuss Eaton and Kortum (2002) and Anderson and van Wincoop (2003).

Relationship to Eaton and Kortum (2002)

Equation (2.16) is exactly equivalent to equation (12) derived in Eaton and Kortum (2002) which they used to estimate their elasticity. Although the two models are based on very different market structures, they turn out to deliver equivalent structural equations of θ. Mechanically, this is due to the fact θ governs the variability in the distribution of productivities in both Ricardian and monopolistic competition frameworks that employ the Fréchet and Pareto distributions, respectively. To see this, let agents consume varieties indexed by ω, where each variety is produced with efficiency $\phi \in [0, J]$. Let the measure of varieties produced with efficiency of at least ϕ be given by:

$$f(\phi; J) = J \left\{ 1 - \exp\left[-\frac{T}{J}\phi^{-\theta} \right] \right\} \tag{2.17}$$

If $J = 1$, equation (2.17) collapses to the Fréchet distribution used in Ricardian models. If on the other hand $J \to \infty$, (2.17) becomes the Pareto distribution with shape parameter θ, used in monopolistic competition models. To see this, rewrite (2.17) and apply the L'Hôpital rule as follows:

$$\lim_{J \to \infty} J \left\{ 1 - \exp \left[-\frac{T}{J} \phi^{-\theta} \right] \right\} = \lim_{J \to \infty} \left\{ \exp \left[-\frac{T}{J} \phi^{-\theta} \right] \right\} \phi^{-\theta} T = \phi^{-\theta} T \qquad (2.18)$$

Relationship to Anderson and van Wincoop (2003)

In principal there is nothing unique about equation (2.16) to the heterogenous firm models of Melitz (2003) and Eaton and Kortum (2002). The model of Anderson and van Wincoop (2003) generates equation (2.16) as well. To do so, assume that each country has constant returns technologies with competitive firms producing a good which is defined by its country of origin, i.e., the Armington assumption. These assumptions imply the unit cost (and price) to deliver a country j good to country i is $p_{ij} = \tau_{ij} T_j^{\frac{1}{1-\sigma}} c_j$. Here c_j is the cost of inputs to produce one unit of the country j good and $T_j^{\frac{1}{\sigma-1}}$ is total factor productivity in country j.

Preferences are equally simple. Each country has symmetric constant elasticity preferences over all the (country specific) goods with common elasticity of substitution

σ. The key result from this simple model are the expenditure shares

$$X_{ij} = \frac{T_j(\tau_{ij}c_j)^{1-\sigma}}{\displaystyle\sum_{\ell=1}^{N} T_j(\tau_{ij}c_j)^{1-\sigma}}. \tag{2.19}$$

The right-hand side is country i's imports from country j divided by country i expenditure on all traded goods. The left-hand side relates the trade cost country i faces to import a good from country j and country j's unit cost of production relative to the sum of the prices paid for imported goods.[5]

Given preferences, each country faces the following price of tradable goods for each country i

$$P_i = \Upsilon \left[\sum_{\ell=1}^{N} T_\ell \left(c_\ell \tau_{i\ell} \right)^{1-\sigma} \right]^{\frac{1}{\sigma-1}}. \tag{2.20}$$

Divide equation (2.19) with the analogous equation for country j's expenditure on country j goods and noting the relationship between the denominator of equation (2.19) and the price index in equation 2.19 results in the following relationship

$$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \tau_{ni}^{1-\sigma} \times \left(\frac{P_i}{P_n} \right)^{1-\sigma}. \tag{2.21}$$

Noticing that redefining terms in equation (2.21) such that $\theta = \sigma - 1$, this is the same

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[5]Anderson and van Wincoop (2003) call the term P_i inward multilateral resistance because it is a summary measure of the difficulty for country i to import.

expression as in (2.16) relating the bilateral trade shares to trade costs and the relative aggregate price of tradables.

2.3 Estimating θ

2.3.1 Estimation Approach

Given equation (2.16), our approach is to construct measures of trade shares, aggregate prices, and trade costs from data and then use equation (2.16) to estimate θ. Below we talk about how each was constructed. The key to our approach is how we identify trade costs from observable data *independent* of trade flows. As noted in the introduction, the difficulty in estimating θ is that τ is generally unobserved as well. Hence small trade shares can be rationalized by small trade costs and a large θ or large trade costs and small θ. The key to our approach is the utilization of a new data set of disaggregate price data that will provide a proxy for trade costs.

2.3.2 Data

Our sample contains 129 countries. We use trade flows and production data for the year 2004 and price data that was collected over the 2003-2005 time period to construct trade shares, aggregate prices, and proxies for trade cots.

Trade Shares

To construct trade shares, we used bilateral trade flows and production data in the following way:

$$\frac{X_{ni}}{X_n} = \frac{\text{Imports}_{ij}}{\text{Gross Mfg. Production}_i - \text{Total Exports}_i + \text{Imports}_i},$$

$$\frac{X_{nn}}{X_n} = 1 - \sum_{i \neq n}^{N} \frac{X_{ni}}{X_n}.$$

To construct $\frac{X_{ni}}{X_n}$, the numerator is the aggregate value of manufactured goods that country n imports from country i. Bilateral trade flow data is from UN Comtrade for the year 2004. We obtain all bilateral trade flows for our sample of 129 countries at the 4-digit SITC level. We then used concordance tables between 4-digit SITC and 3-digit ISIC codes provided by the UN and further modified by Muendler (2009).[6] We restrict our analysis to manufacturing bilateral trade flows only, namely those that correspond with manufactures as defined in ISIC Rev.2. In the denominator is gross manufacturing production minus total manufactured exports (for the whole world) plus manufactured imports (for only the sample). Put all together, this is simply computing an expenditure share by dividing the value of inputs country n imported from country i divided by the total value of inputs in country n. Gross manufacturing production data is the most

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[6]The trade data we obtain often reports bilateral trade flows from two sources. For example, the exports of country A to country B can can appear in the UN Comtrade data as exports reported by country A or as imports reported by country B. In this case, we take the report of bilateral trade flows between countries A and B that yields higher total volume of trade across the sum of all SITC-4-digit categories.

serious data constraint we faced. We obtain manufacturing production data for 2004 from UNIDO for a large sub-sample of countries. We then used various methods to impute gross manufacturing production for countries for which data are unavailable.[7]

The home trade share $\frac{X_{nn}}{X_n}$ is simply constructed as the residual from one minus the sum of all bilateral expenditure shares.

Aggregate Price of Tradables

The starting point to constructing the aggregate price of tradables uses data from the 2005 round of the International Comparison Program (ICP) at the basic heading level provided by the World Bank. According to the ICP Handbook[8], unit price data on goods with identical characteristics was collected across retail locations in the participating countries during the 2003-2005 period. The lowest level of aggregation is the basic heading (BH), which represents a narrowly-defined group of goods for which expenditure data are available. There are a total of 129 BHs in the data set. Each BH contains a certain number of products. Hence, the reported price of a BH is aggregated over a narrowly-defined group of goods. An example of a basic heading is "1101111 Rice" which is made up of prices of different types of rice contained in specific packages.

To construct the aggregate price of tradables p_i, we took the geometric average across all basic heading categories for which we defined as tradable. In the Appendix we outline which goods are defined as tradable. We have 62 tradable categories and are

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[7]Our Data Appendix explains the approach that we used.
[8]The ICP Handbook prepared by the World Bank is available at http://go.worldbank.org/VMCB80AB40.

currently exploring the robustness of alternative categorizations.

Using Disaggregate Price Data to Proxy Trade Costs

To proxy trade costs τ_{ni} we exploit *disaggregate* prices at the basic heading level across countries in the following way. To illustrate our approach consider the following example. Suppose there are two countries (home and foreign) and two goods: TV and DVD players. Suppose the price of a TV and DVD player in the home country is 100 each, and the price of the TV and DVD player in the foreign country is 150 and 125, respectively. Trade in TV and DVD players implies the trade cost $\tau_{f,h}$ must be at least 1.50 because otherwise there would be an arbitrage opportunity.

In general, it must be the case that for a given good ℓ, $\frac{p_n(\ell)}{p_i(\ell)} \leq \tau_{ni}$, otherwise there would be an arbitrage opportunity. This implies an estimate of τ_{ni} is the maximum of relative prices over goods ℓ. To summarize, our proxy for τ_{ni}, in logs, is:

$$\log \hat{\tau}_{ni} = \max_{\ell} \left\{ \log \left(p_n(\ell) \right) - \log \left(p_i(\ell) \right) \right\}, \tag{2.22}$$

where the max operator is over all ℓ goods. Table 2.1 reports some summary statistics for the trade costs.

There are several points to notice. First the median trade cost for all countries corresponds with a 170 percent tariff rate equivalent. When only high income countries are considered the median trade cost declines by to only 100 percent. Anderson and van Wincoop (2004) survey the literature and report that for a representative developed country, trade

Table 2.1: Trade Cost Summary Statistics

Median	2.73	Correlation with Distance	0.16^{***}
Median High Income	2.00	Correlation with $\frac{X_{ni}/X_n}{X_{ii}/X_i}$	-0.30^{***}
		Correlation with $\frac{y_n}{y_i}$	0.49^{***}

$***$ indicates statistical difference from 0 at the 1 percent level. Correlations are with both variables expressed in logs. Number of Observations = 10513.

barriers fall in a range between 40 and 90 percent depending on the study and elasticities of substitution. Hence the levels found here are not implausible relative to alternative approaches in the literature.

Second, the recovered trade costs correlate both with distance and the normalized trade shares $\frac{X_{ni}/X_n}{X_{ii}/X_i}$. Because the trade costs positively correlate with distance, this suggests that these costs partially reflect a known impediment to trade. Furthermore, because they correlate negatively with normalized trade shares (and stronger than distance alone) this suggests they are reflecting costs that are impeding trade.

Third, the recovered trade costs correlate strongly with relative level of development. This results is shown by correlating the trade costs with income per worker of the importer relative to the exporter. Because the correlation is positive, this implies that the cost for a country to export is increasing the poorer the country is. Though some care should be taken with this result, it is consistent the the arguments of Waugh (2007). Furthermore, this is consistent with evidence from reduced form gravity regressions that find income per worker is an important determinant of trade flows.

2.4 Estimates of θ

With proxy's for τ_{ni} from equation (2.22) we then use equation (2.16), bilateral trade data, and aggregate price data to estimate θ.

Table 2.2: Estimates of θ

	Number of Obvs. = 10513	
Approach	Est. θ	S.E.
Least Squares	7.34	0.59
Least Absolute Deviation	7.28	0.59
Method of Moments	7.74	0.62

Note: Heteroskedasticity-robust standard errors reported.

Table 2.2 presents the results under a variety of estimation techniques with no intercept term as the theory predicts.[9] The first two columns present estimates and standard errors of θ when all countries are considered. Least squares and least absolute deviation all produce a similar estimate around 7.34.[10] Method of moments generates similar but slightly higher estimate.

Figure 2.1 plots log normalized trade shares and the log trade cost multiplied by the relative price.[11] Also in this plot is the best fit line from running the appropriate regression to estimate θ, hence the slope of the best fit line is our estimate of θ. The

[9]Imposing no intercept term also helps mitigate the errors in variables problem that we face. We hope to explore alternative approaches such as instrumental variables to alleviate this problem.

[10]Large deviations between least squares and least absolute deviation would suggest the estimation technique is sensitive to outliers. This does not appear to be the case, however.

[11]Because of the large amount of data, only a 20 percent random sample of the data is plotted.
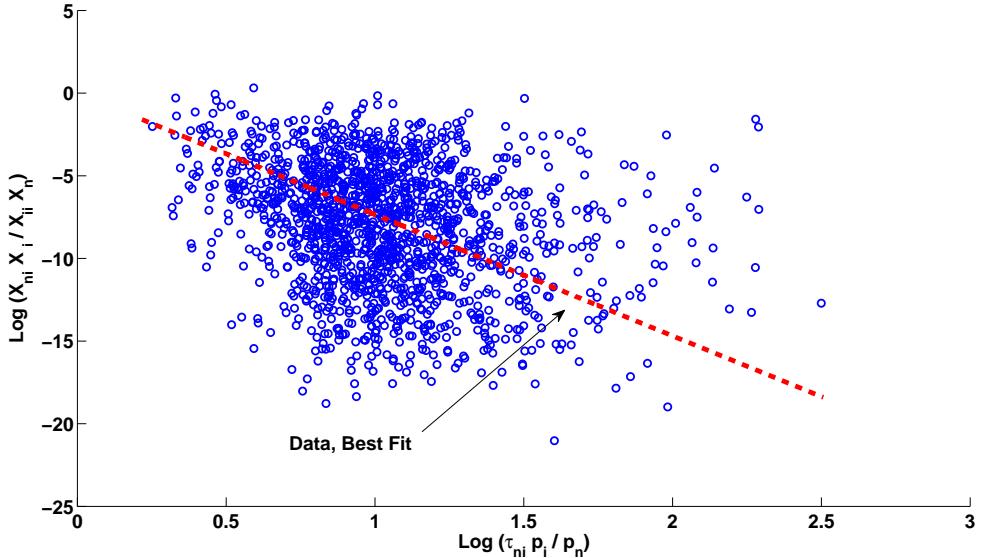
FIGURE 2.1: Plot of Log $\frac{X_{ni}/X_n}{X_{ii}/X_i}$ and Log $\tau_{ni} \times \left(\frac{p_i}{p_n}\right)$. Slope is estimate of θ.

two things to notice are that the data does exhibit a negative relationship between normalized trade shares and trade impediments. However, there is substantial noise in the data. Hence estimates from a regression without imposing a zero intercept term result in estimates of θ that are biased downwards. This is symptomatic of the errors in variables problem that we face and Figure 2.1 suggests this.

2.4.1 θ's Among Rich and Poor Nations

A key contribution of our analysis relies on the fact that we have observations on both rich and poor countries. In this section, we examine estimates of θ when only studying trade between countries of similar income level. Table 2.3 presents the results when the sample is restricted to only "High Income" countries and all "Non-High Income"

Countries. The category "High Income" is defined by the World Bank as those countries which meet a specified level of income per capita.

Table 2.3: Estimates of θ Among Rich and Poor Nations

	High Income, Obvs. = 1073		Non-High Income, Obvs. = 5538	
Approach	Est. θ	S.E.	Est. θ	S.E.
Least Squares	6.78	0.92	7.93	1.17
Least Absolute Deviation	6.52	0.93	8.02	1.18
Method of Moments	7.11	0.95	8.49	1.27

Note: Heteroskedasticity-robust standard errors reported.

The key result from this exercise is that the estimates with rich countries or with poor countries are similar and not dramatically different. The θ with only rich countries is estimated be 6.78 with a standard error of about one and the the estimate for poor countries is 7.98 with a standard error slightly larger than one. While the point estimates are different, given the large standard errors, our results suggest that there are not dramatic differences in the θ's for rich countries relative to poor countries. Furthermore, these results do not appear to be sensitive relative to alternative definitions of Non-High Income countries.

2.4.2 Results with Second Order Statistic

Eaton and Kortum (2002) use the second order statistic rater than the maximum price difference we used to proxy trade costs. In this section, we explore this alternative approach.

Their argument for using the second order statistic comes from the observation that in their price data the estimates of the trade costs were more closely correlated with normalized trade shares than the maximum. In our data set both give qualitatively similar answers, but the trade costs using maximum delivers the highest correlation with normalized trade shares and distance. The key difference that using the second order statistic does deliver is that the level of trade costs are substantially lower. For example, the median trade costs decreases to 2.24 from 2.73 when the second order statistic is used relative to the maximum.

Table 2.4: Estimates of θ with 2nd Order Statistic

	Est. θ	S.E.
All	9.23	0.69
High Income, Obvs. = 1073	8.54	1.15
Non-High Income, Obvs. = 5538	10.28	1.17

Note: Least Squares with no intercept used. Heteroskedasticity-robust standard errors reported.

Lower estimated trade costs results in larger estimated elasticities since normalized trade shares are kept constant. This is illustrated in Table 2.4 which reports the least squares estimate of θ and the standard error being 9.23 and the standard error increases to 0.69 as well. Table 2.4 also presents results when only sub-samples of high and low income countries are considered. Similar to the results in the prior section, the estimates for rich nations decline slightly relative to the whole sample and the estimates for poor

countries increases slightly relative to those from the whole sample. However, in both cases standard errors increase substantially. Finally, notice that our estimate of θ for high income countries using the second order statistic is very close to Eaton and Kortum (2002) estimate of 8.28 from data on OECD countries.

2.5 Robustness

2.5.1 Models With Distribution Costs

The price data we use is collected at the retail level and thus partially reflects distribution/advertising costs. In the previous section, we showed that assuming these costs are proportional to the size of the market, they do not affect the estimates of the elasticity of trade parameter. In this section, we study a model featuring per-unit distribution costs and claim they do not affect our results at all.

Suppose firms incur a per-unit market-specific cost τ_n in order to place their product in market n. Then, the production function of a firm with productivity draw ϕ originating in country i and selling to market n is $x^d(\phi) = \phi l^d/(\tau_{ni}\tau_n)$, where τ_{ni} represents the trade barriers between the country pair as in previous sections, and l^d is labor[12]. This scenario results in price indices that reflect distribution costs, while trade shares remain unchanged from the previous section. To see this, notice that the optimal price

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[12]If distribution costs are exporter- and importer-specific, they would be thought of as being discriminatory, in which case they can be interpreted as trade barriers.

a firm with productivity draw ϕ from country i will charge in destination n becomes:

$$p_{ni}^d(\phi) = \frac{\sigma}{\sigma - 1} \frac{\tau_{ni} \tau_n w_i}{\phi}. \tag{2.23}$$

The zero-profit condition, which determines the productivity threshold ϕ_{ni}^d, now becomes:

$$\pi_{ni}^d(\phi_{ni}^d) = 0 \iff \phi_{ni}^d = \frac{\tau_{ni} \tau_n w_i}{P_n^d} \left(\frac{(\sigma - 1)^{1-\sigma} \sigma^\sigma f_n}{L_n} \right)^{\frac{1}{\sigma-1}}, \tag{2.24}$$

where P_n^d is the associated ideal price index.

The measure of entrants is still given by (2.11) since preceding steps remain unchanged. Moreover, the relative import ratios in (2.12) also remain unchanged since all firms serving a particular market n are assumed to incur identical per-unit distribution costs. However, the price indices now account for these distribution costs. Specifically, we can show that the aggregate price index in the model with per-unit distribution costs are has the following relationship with the price index in the model with no per-unit distribution costs: $P_n^d = \tau_n P_n$.

To arrive at an equation similar to (2.16) used to estimate θ in the benchmark case, combine (2.12) and $P_n^d = \tau_n P_n$ and then using the assumption that fixed costs are proportional to market size we obtain:

$$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \tau_{ni}^{-\theta} \left(\frac{P_i^d/\tau_i}{P_n^d/\tau_n} \right)^{-\theta} \tag{2.25}$$

Now notice that when we estimate τ_{ni} we want to take the maximal price difference across goods *net* the distribution cost. This value in logs equals

$$
\begin{aligned}
\log \hat{\tau}_{ni} &= \max_{\ell} \left\{ \log \left(p_n^d(\ell)/\tau_n \right) - \log \left(p_i^d(\ell)/\tau_i \right) \right\} \\
&= \max_{\ell} \left\{ \log \left(p_n^d(\ell) \right) - \log \left(p_i^d(\ell) \right) \right\} - \log \tau_n + \log \tau_i \quad (2.26)
\end{aligned}
$$

where d superscripts denotes a world with per-unit distribution costs.

Combining equation (2.25) and equation (2.26) in logs we arrive at the following relationship:

$$
\log \left(\frac{X_{ni}/X_n}{X_{ii}/X_i} \right) = -\theta \left(\max_{\ell} \left\{ \log \left(p_n^d(\ell) \right) - \log \left(p_i^d(\ell) \right) \right\} + \log P_i^d - \log P_n^d \right) \quad (2.27)
$$

which is the same equation as (2.16) but with the observable data now indicating distributional costs are included. The key implication is that under the structure of the model, distribution costs cancel out and they do not affect our results.

2.6   Conclusion

In this paper, we provide an estimate of the elasticity of trade with respect to trade costs consistent with heterogenous firm models of international trade for 129 countries representing 98 percent of World GDP for the year 2004 using new disaggregate price and trade flow data. Estimating this parameter is difficult because standard trade models

can rationalize small trade flows with either large trade frictions and small elasticities or small trade frictions and large elasticities. Thus one needs satisfactory measures of trade frictions *independent* of trade flows to estimate this elasticity. Because of the extreme data requirements, estimates of this parameter are from limited samples of developed countries. For this reason, these estimates may be appropriate for studying trade between the U.S. and Canada, but may be inappropriate for broader questions and specifically those related to developing countries which are responsible for a rising portion of world trade.

Our contribution is to provide an estimate of this elasticity for 129 countries representing 98 percent of World GDP using new disaggregate price and trade flow data. The key piece of data allowing us to estimate this elasticity is disaggregate price data from the most recent results from the International Comparison Programme. This data provides comparable prices for 129 good categories for all countries in our sample. With this data we use the maximum price difference across goods between countries as a proxy for trade frictions similar in spirit to the approach of the Eaton and Kortum (2002) study of 19 OECD countries. The maximum price difference between two countries is meaningful as it is bounded by the trade friction between the two countries via simple no arbitrage arguments. Using these proxies for trade costs from disaggregate price data and data on bilateral trade shares, we are able to identify and estimate the elasticity of trade with respect to trade frictions for a large cross-section of countries.

Our (preliminary) benchmark estimate for all countries is approximately 7.5 with a

standard error of about 0.60. Prior research has suggested that this elasticity lies in the range between 4 and 9; see Anderson and van Wincoop (2004) survey. Our estimate provides the most comprehensive evidence regarding this parameter with it lying near the middle the range as suggested in the literature.

We also explore if this elasticity varies with level of development. When the sample is restricted to only high income countries, we find the estimate is only slightly lower than 7.5. When the estimate is restricted to low income countries, it is only slightly lower than 7.5. In both cases the standard errors increase to near one. Thus we provide evidence supporting models with common elasticities of trade with respect to trade frictions across all countries.

Chapter 3

Business Cycle Accounting for Chile

3.1 Introduction

Chile has enjoyed an impressive economic performance over the past decade and a half. The country has been at the forefront among emerging markets in achieving macroeconomic stability and reducing economic vulnerabilities. Moreover, due to strong growth and pro-poor policies, per-capita income has tripled in U.S. dollar terms since 1990 and the poverty rate has been cut by two-thirds. A major challenge going forward is to maintain, or improve, this record. In this context, while Chile's growth potential remains high, it has no doubt declined in recent years. Indeed, average real GDP growth fell from well over 6 percent in the 1990s to just over 4 percent since. There

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are a number of plausible explanations for this slowdown. For example, by now Chile has strengthened its macroeconomic policy framework to a point where the marginal impact of further improvement may have declined. It is also probable that Chile has already harvested most of the "low hanging fruit" in terms of structural reforms.

Looking forward, Chile's economy needs to be adaptable to global competition and changing global economic circumstances, in order to weather both short-term shocks and longer-term trend changes. For example, there are questions regarding the flexibility of the labor market; hiring and firing costs are high by international standards, and labor participation relatively low, especially among women. In addition, the quality of human capital appears to lag countries at similar level of development, complicating skills-matching and retraining of the labor force. By contrast, Chile's financial system is generally well-developed, providing ample access to financing for households and large corporations. However, embryonic venture and risk capital markets limit financing for new and smaller firms, thereby hampering innovation and entrepreneurship. Other kinds of rigidities may also affect the efficiency of the Chilean economy, and its capacity to cope with shocks.

This study attempts to quantify the relative importance of the type of rigidities or shocks mentioned above for the cyclical behavior of Chile's economy during the 1998-2007 period. The analysis is based on the Business Cycle Accounting (BCA) approach developed by Chari, Kehoe, and McGrattan (2006b). Specifically, we introduce time-varying wedges to a standard neo-classical growth model, representing frictions in the

labor and capital markets, and shocks to productivity and government spending or net exports. The purpose of this exercise is twofold: (i) focus the policy discussion on the most important wedges in the economy; and (ii) identify which broad class of models would present fruitful avenues for further research.

3.2 Analytical Framework

Business Cycle Accounting, developed by Chari, Kehoe, and McGrattan (2006b), is a simple framework for analyzing the sources of business cycle fluctuations. This methodology is useful for identifying, within a unified framework, the dominating frictions or shocks within the economy. The underlying model is a standard neoclassical growth model, in which a number of time-varying wedges (each representing different types of distortions or shocks) are introduced. The wedges are a labor wedge, an investment wedge, an efficiency wedge, and an income accounting wedge, capturing government spending and net exports (referred to as government wedge in Chari, Kehoe, and McGrattan (2006b)).

To see how these wedges work, consider a standard neoclassical growth model, with a representative consumer optimizing lifetime utility, derived from consumption and leisure. She maximizes her discounted lifetime utility subject to her budget constraint, law of motion of capital, and non-negativity constraints:

$$\max_{c_t, x_t, l_t} E \sum_{t=0}^{\infty} \beta^t \quad U(c_t, 1 - l_t) N_t \qquad s.t.$$

$$c_t + (1 + \tau_{xt})x_t \quad = r_t k_t + (1 - \tau_{lt})w_t l_t$$

$$N_{t+1}k_{t+1} \quad = [(1 - \delta)k_t + x_t]N_t$$

$$c_t, x_t \quad \geq 0 \qquad in \quad all \quad states$$

where c_t denotes consumption, l_t labor, x_t investment, k_t capital, r_t rental rate of capital, w_t wage rate, and N_t working-age population[1]. In the above equation, τ_{lt} can be compared to a time-varying tax on labor income, which interferes in the choice between consumption and leisure. All else equal, an increase in this implicit tax leads to a decrease in labor input. Similarly, τ_{xt} can be compared to a tax on investment, which interferes in the representative agents intertemporal choice between consumption and investment. For purely presentational purposes, we will define $(1 - \tau_{lt})$ as the labor wedge and $1/(1 + \tau_{xt})$ as the investment wedge. This definition facilitates visual inspection of the wedges, with an increase in either wedge benefiting growth, just like an increase in the productivity level would. A more extensive discussion on the interpretation of the wedges is presented below.

The representative firm maximizes its profits from sales of final goods:

$$\max_{K_t, L_t} F(K_t, L_t) - r_t K_t - w_t L_t$$

---

[1] In this paper, all lowercase-letter variables represent aggregate (uppercase-letter) variables per working-age person (population aged 15-64) rather than per capita. Bergoeing, Kehoe, Kehoe, and Soto (2001) argue that this is an appropriate choice since Chile experienced demographic transitions during the 1960-2000 period as population growth rates fell sharply and the percentage of working-age persons in the total population changed. This way, we ensure that no demographic changes are captured in the wedges of the model. In addition, all variables are divided by a labor endowment of 1250 hours per quarter.

where Z_t represents the efficiency wedge modeled as labor-augmenting technical progress.

Finally, equilibrium requires that the total amount of consumption, investment, and government goods is produced by the representative firm, as well as that capital and labor inputs used by the firm are supplied by the representative consumer, namely:

$$N_t(c_t + x_t) + G_t \; = F(K_t, Z_t L_t)$$

$$N_t k_t \qquad = K_t$$

$$N_t l_t \qquad = L_t$$

where G_t is the income accounting wedge, which captures government expenditures and net exports. We assume the following functional forms for the production function

$$F(K, ZL) = K^\theta (ZL)^{1-\theta} \tag{3.1}$$

and the utility function

$$U(c, 1 - l) = \log(c) + \psi \log(1 - l) \tag{3.2}$$

where ψ is the relative weight of leisure in the utility function.

Hence, the first order conditions are as follows (for details on derivations, see

Chari, Kehoe, and McGrattan (2006a)):

$$\hat{c}_t + \hat{g}_t + (1 + g_z)(1 + g_n)\hat{k}_{t+1} - (1 - \delta)\hat{k}_t = \hat{y}_t$$

$$\hat{y}_t = \hat{k}_t^\theta (z_t l_t)^{1-\theta}$$

$$\frac{\psi \hat{c}_t}{1 - l_t} = (1 - \tau_{lt})(1 - \theta)\frac{\hat{y}_t}{l_t}$$

$$\frac{(1 + \tau_{xt})}{\hat{c}_t} = \hat{\beta}E_t\frac{1}{\hat{c}_{t+1}}\left[\theta\frac{\hat{y}_{t+1}}{\hat{k}_{t+1}} + (1 - \delta)(1 + \tau_{xt+1})\right]$$

where g_z is trend growth in labor efficiency (Z) and g_n is working-age population growth,

and:

$$\hat{x}_t = \frac{X_t}{N_t z_0 (1 + g_z)^t} \tag{3.3}$$

The actual wedges are derived from the model and the data. The income account-

ing wedge $\hat{g}_t$ is taken directly from the data on government expenditure and net ex-

ports. The efficiency wedge z_t is computed from the production function. The labor

wedge $(1 - \tau_{lt})$ is calculated from the consumption-leisure condition and the investment

wedge $1/(1 + \tau_{xt})$ is calculated from the intertemporal consumption condition. Note

that all wedges except the investment wedge can be derived directly from the data

and static first-order conditions. The investment wedge needs to be estimated, as it

depends not only on observable data but also on expectations. To do so, we follow

Chari, Kehoe, and McGrattan (2006b) and assume that expectations follow an AR(1)

process, in which next periods expected wedges can be fully determined by current pe-

riod data and wedges. In particular, we loglinearize equations (1)-(4) around the steady

state of the model and then use Maximum Likelihood Estimation in order to obtain the parameters that govern the processes of the four wedges above[2].

All variables are expressed in per-capita (actually per-labor force) terms and all (except labor) are detrended by a labor productivity trend g_z. Hence, the productivity wedge shows the progress in productivity relative to this trend.

While the interpretation of the income accounting wedge is straightforward, it is important to keep in mind that the model cannot identify the precise nature of the other wedges. In fact, Chari, Kehoe, and McGrattan (2006b) demonstrate that a wide range of models including different types of frictions would produce the same first order conditions as our prototype model. Notably, the labor and investment wedges should not literally be interpreted as taxes. For example, the labor wedge could capture unionization or sticky wages and monetary shocks.

Moreover, the presence of credit restrictions or taxes/subsidies on consumption or capital income would all have similar effects on the investment wedge. Furthermore, if one introduces a consumption tax into the model it would be indistinguishable from the investment wedge. Hence, the latter should be thought of as capturing frictions on investment spending relative to consumption. This is important to keep in mind in the case of Chile, because consumer lending has developed significantly in recent years, not least in the form of department store credit cards, which have become available even to

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[2]Throughout this exercise, we use the solution method and estimation suggested by Chari, Kehoe, and McGrattan (2006a). In fact, we modify the original code generously provided by Ellen R. McGrattan in order to apply it to our study of Chile. We refer the reader to Chari, Kehoe, and McGrattan (2006a) and Chari, Kehoe, and McGrattan (2006b) for a detailed explanation of the accounting procedure.

the lower-income population. Meanwhile, access to corporate credit remains relatively limited for smaller and less well-established companies.

Furthermore, the efficiency wedge captures the level of total factor productivity as well as any input-financing frictions. Hence, a degree of caution is warranted when interpreting the results. The point of the analysis is to determine which broad class of distortions have played the greatest role for variations in growth, employment, investment, and consumption. The results can also serve as guidance for the appropriate direction of a more detailed analysis.

In order to assess the importance of each wedge for the overall economy, the wedges are fed into the model one by one, and in combinations. Accordingly, to measure the effect of, say, the labor wedge, the model is run with all other wedges fixed at their first-period (Q1 1998) values. Thus, we can identify which one(s) of the four wedges best explains the observed economic fluctuations in Chile during the 1998-2007 period. Note that this is an accounting exercise; by definition, if all wedges are included simultaneously, the model returns the actual data.

3.2.1 Calibration

In order to solve the model, we first calibrate its parameters to match certain observed facts about Chile. The parameters we use in our benchmark calculations are summarized in Table ?? below. As can be seen from Table ??, we follow Bergoeing, Kehoe, Kehoe, and Soto (2001) in the use of the share of capital in the production function, θ, and the quarterly

depreciation rate, δ. In fact, the authors find that, during the 1980s, the share of labor income in production for Chile is 0.53 (which corresponds to $\theta = 0.47$). However, they argue that the measured labor compensation in Chile fails to account for the income of most self-employed and family workers, who amount to a large portion of the total labor force. Moreover, as they point out, Gollin (2002) shows that, for countries for which there is sufficient data to adjust for this mismeasurement, θ tends to be close to the US estimate of 0.3. In Appendix **??**, we present results with $\theta = 0.47$, but the qualitative nature of our findings remains unchanged.

Furthermore, Chari, Kehoe, and McGrattan (2006b) calibrate the annual depreciation parameter for Chile to 0.08 during the 80s and the 90s. However, they opt to use $\delta = 0.05$ (which corresponds to a quarterly depreciation rate of 0.0125) in their calculations because higher values yield an implausibly low capital-output ratio in Chile during the relevant period. In Appendix **??**, we simulate the model using $\delta = 0.02$ (which corresponds to an annual depreciation rate of 0.08 as calibrated by Bergoeing, Kehoe, Kehoe, and Soto (2001)) and we find no qualitative difference in the results.

Notice that, in order to calibrate the model, we assume that our first-period observations, namely those corresponding to the first quarter of 1998, represent the steady state of the economy. Then, using the parameters suggested by Bergoeing, Kehoe, Kehoe, and Soto (2001), together with our data observations, we calibrate the discount factor and the

weight of leisure in the utility function as well as the first-period capital stock and efficiency level, in order to satisfy equations (1)-(4) above. In doing so, we normalize the first-period labor and investment wedges to unity. We construct the capital stock according to the law of motion of capital, using actual investment data.

In addition, we take gn to be the quarterly equivalent of the observed average annual growth rate of the working-age population during the studied period. Finally, we detrend all per-capita variables by the calibrated first-period efficiency level and a 2%-annual TFP growth rate, corresponding roughly to trend productivity growth in Chile during the studied period.

3.3   Results

Using the calibrated model and quarterly aggregate variable data on Chile for the 1998-2007 period, we first compute the four wedges described in equations (1)-(4). Figure 1 below plots these wedges.

Figure 3.1 plots the efficiency (z_t), labor $(1 - \tau_{lt})$ and investment $(1/(1 + \tau_{xt}))$ wedges normalized to their first-period realizations. The lower figure plots the government wedge $(\hat{g}_t)$ as a fraction of total detrended per-capita output. Since the income accounting wedge is much more volatile than the remaining three wedges, we show it on a separate graph.

Notice that during the 1998-1999 crisis in Chile, both the efficiency and the labor wedge fell. Since 2001, however, the labor wedge kept improving and it especially
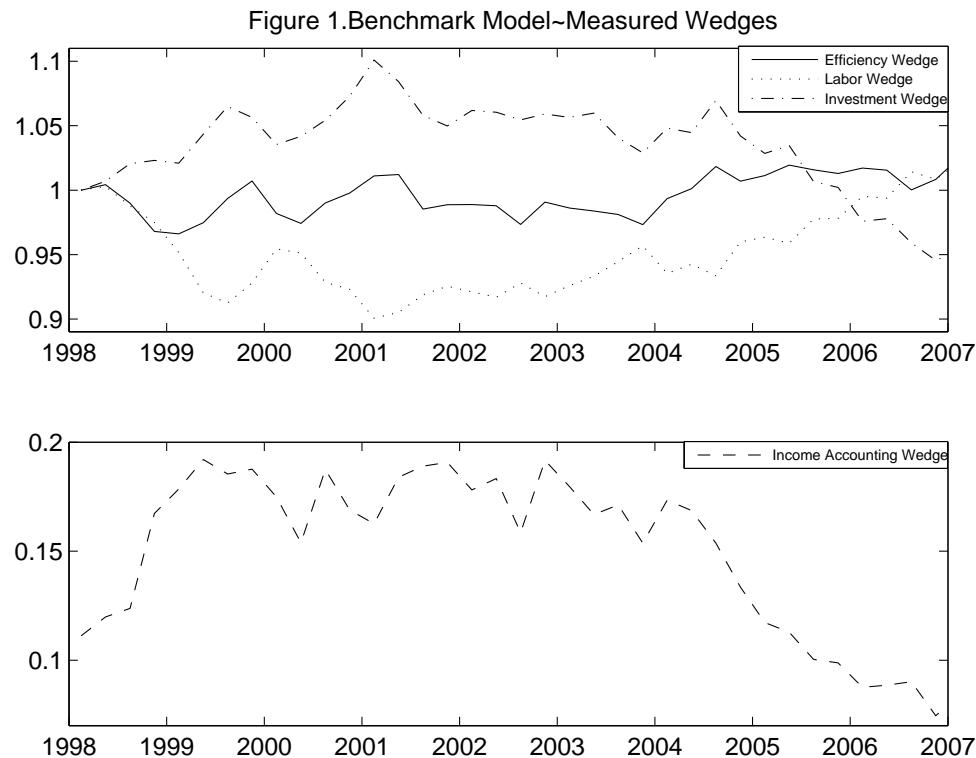
FIGURE 3.1: Benchmark Model - Measured Wedges

picked up starting in 2005. The latter is consistent with the surge in employment in Chile, and may capture recent structural improvements in the functioning of the labor market. As mentioned earlier, however, a more detailed model focusing on labor market imperfections would be required to gain insights into the precise nature of such structural improvements. Beginning in 2004, the efficiency wedge started to increase and surpassed its 1998 levels. Throughout most of the decade, however, both the efficiency and labor wedges remained below their 1998 levels indicating the presence of frictions in the labor or other input markets.

The income accounting wedge has been highly volatile throughout the period. Government consumption has increased in a relatively steady fashion from roughly 13% to 15% of output during the period. Thus, most of the volatility is due to changes in net exports. In particular, the sharp drop of the income accounting wedge beginning in 2004 is mostly due to the sharp increase in imports, which has been matched by increases in consumption and investment.

Finally, the investment wedge also appears to have been rising throughout most of the decade. However, beginning in mid-2004, it exhibits a sharp decline, consistent with the improved access to household credit in Chile mentioned earlier[3]. Notice, however, that the investment wedge exhibits strong negative correlation with the labor wedge, especially in years in which the labor wedge experiences spikes. A plausible explanation for this unexpected behavior of the investment wedge is that it is, in a sense, a residual. It is the only wedge that is estimated rather than taken directly from the data. Moreover, since the total effect of all wedges should by construction replicate the data, the investment wedge absorbs any estimation or calibration errors or exaggerated spikes in the data.

Figure 3.2 below shows the predictions of the model, simulated with each of the four wedges at a time, for total detrended per-capita output during the 1998-2007 period. In all four subplots, the solid line represents the actual data plotted relative to the first-period observation; other lines correspond to output simulations using one particular

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[3]Recall that one interpretation of the investment wedge is the relative ease of financing of investment versus consumption.

wedge.
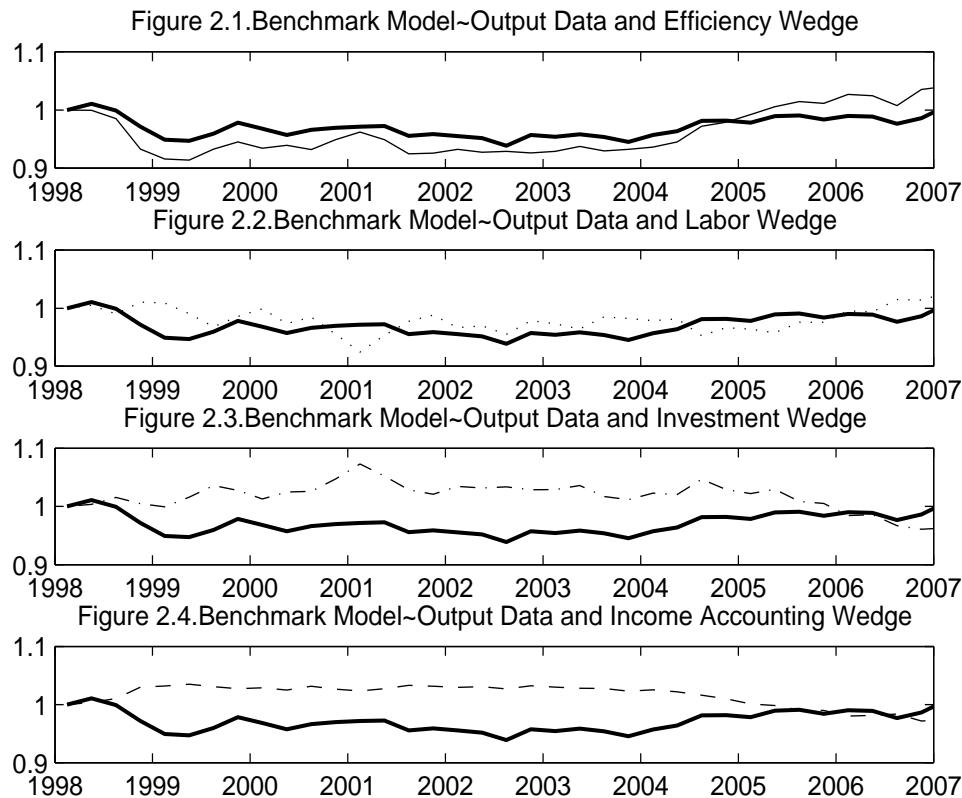
FIGURE 3.2: Benchmark Model - Output Data and Efficiency Wedge

In 1998, Chile experienced a crisis and thus a drop in output. However, (detrended per-capita) output remained below its 1998 level throughout most of the decade. It began to recover in 2004 and reached its 1998 level in 2007.

Overall, the efficiency wedge does the best job predicting the movement in output in Chile during the 1998-2007 period. Although it tracks the direction of movement of actual output very well, the efficiency wedge overpredicts the fall in output until 2005

and also overpredicts its recovery since.

At the beginning of the 1998-1999 crisis, the labor wedge predicts a fall in output. However, overall, it does a poor job explaining the remainder of the crisis. It appears to explain the movement in output during the 2002-2003 period well and it predicts a recovery beginning in mid-2004 as well.

The investment wedge does not predict the observed movements in output particularly well, while the income accounting wedge predicts counterfactual movements in output. The latter is consistent with the findings of Chari, Kehoe, and McGrattan (2005) for the Mexican crisis in the mid-1990s. The authors argue that when a sudden stop occurs, the fall in the capital account must be balanced out by an increase in the current account, namely an increase in net exports due to a fall in imports. In and by itself, this would stimulate output, but this impact is obviously superseded by other manifestations of the sudden stop. Nevertheless, this explains why the income accounting wedge counterfactually predicts that, during the crisis, output should increase rather than decrease. Similarly, the income accounting wedge predicts a fall in output rather than a recovery beginning in 2004.

Our results are consistent with similar studies on other Latin American countries. Graminho (2004) uses the BCA approach and finds that the efficiency wedge plays a central role in explaining the fluctuations of the major aggregates in the Brazilian economy during the 1980-2000 period. Applying a slightly modified BCA model, Lama (2005) finds that business cycle fluctuations in the 1990s were mostly explained by the

labor wedge in Argentina, and by efficiency fluctuations in Brazil and Mexico. Using a standard growth accounting methodology, Bergoeing, Kehoe, Kehoe, and Soto (2001), Bergoeing, Kehoe, Kehoe, and Soto (2002a), and Bergoeing, Kehoe, Kehoe, and Soto (2002b) find that total factor productivity fluctuations play a central role in explaining the behavior of output in Chile and Mexico during the 1980s and 1990s.

We have also simulated the impact of each wedge on hours worked, investment, and consumption (see Appendix C.2). Overall, the efficiency wedge plays a central role in explaining the movement in investment and hours, while the income accounting wedge predicts the observed fall in consumption.

3.4   Alternative Specification:

Adjusting for Copper Investment

Chile is the biggest copper producer in the world, and while mining as a percentage of total GDP is in the single digits, copper exports and copper-related investment can be quite substantial and volatile. Under the plausible assumption that resource extraction behaves differently than the rest of the economy, it would be of interest to replicate the BCA exercise on the non-mining sector of the Chilean economy. Unfortunately, available data do not permit isolating the mining sectors share in consumption, investment, and imports. Moreover, apart from mining revenues to the government, no data are available on flows between the mining and non-mining sectors. The latter may be of less concern,

since the copper sector can be looked at as an enclave, with only limited links to the rest of the economy.

We do, however, have annual data on mining FDI. As a sensitivity check, we make a rough attempt to correct the investment wedge for mining investment. For this purpose, we are forced to make a number of simplifying assumptions. First, we approximate mining investment by mining FDI. On one hand, this ignores the fact that a part of FDI is for purposes other than investment, and on the other it neglects investment by CODELCO, the Chilean state-owned copper company. Secondly, because we have sectoral FDI data only at an annual frequency, we assume the mining sectors share of FDI constant throughout the year. We then subtract mining FDI from the quarterly investment observations and move it to the income accounting wedge. Clearly this is just a partial solution, in that we cannot adjust for mining on the supply side, as long as we do not have full information on the sectors demand components. However, this should not be a major shortcoming, since mining is a relatively small and stable share of total GDP.

We replicate the calibration procedure to the benchmark model using the modified data series. The results are reported in Table 3.1 below. We consider this our preferred model, and as such, we also present more detailed results on hours worked, investment, and consumption. The results are similar to those from the benchmark model above. In the calibration, only the parameter β changes, since we only modified the definition of investment.

TABLE 3.1: Parameter Estimates for Alternative Economy

Parameter	Value	Source (Assume Chile is in SS in 1998Q1)
θ	0.3000	Bergoeing, Kehoe, Kehoe, and Soto (2001)
δ	0.0125	Bergoeing, Kehoe, Kehoe, and Soto (2001)
β	0.9915	Calibration
ψ	3.3631	Calibration
g_n	0.400%	Match 1.6% annual growth rate of population
g_z	0.500%	Assume 2% annual TFP growth rate

Figure 3.3 below plots the four wedges of the alternative model.

Notice that, in contrast to Figure 3.1, the investment wedge no longer shows a strong negative correlation with the labor wedge. In addition, the investment wedge falls below trend in certain periods and shows a strong decline starting in 2005 as in Figure 3.1. The income accounting wedge, which now incorporates mining investment, is slightly more volatile than before, but maintains its downward trend in recent years consistent with Figure 3.1. As expected, the labor wedge remains unchanged, since it is computed directly from the aggregate data series. The efficiency wedge differs only slightly from the previous exercise.

Figure 3.4 below shows the predictions of the model adjusted for mining FDI, simulated with each of the four wedges at a time, for total detrended per-capita output during the 1998-2007 period.

Notice that the efficiency wedge still tracks the direction of the movement of output best. However, in late 1999 and early 2001, it predicts that output should be slightly above its 1998 realization, which is in contrast with the data. Also, the recovery the efficiency wedge predicts in this case is much stronger than in the benchmark model.
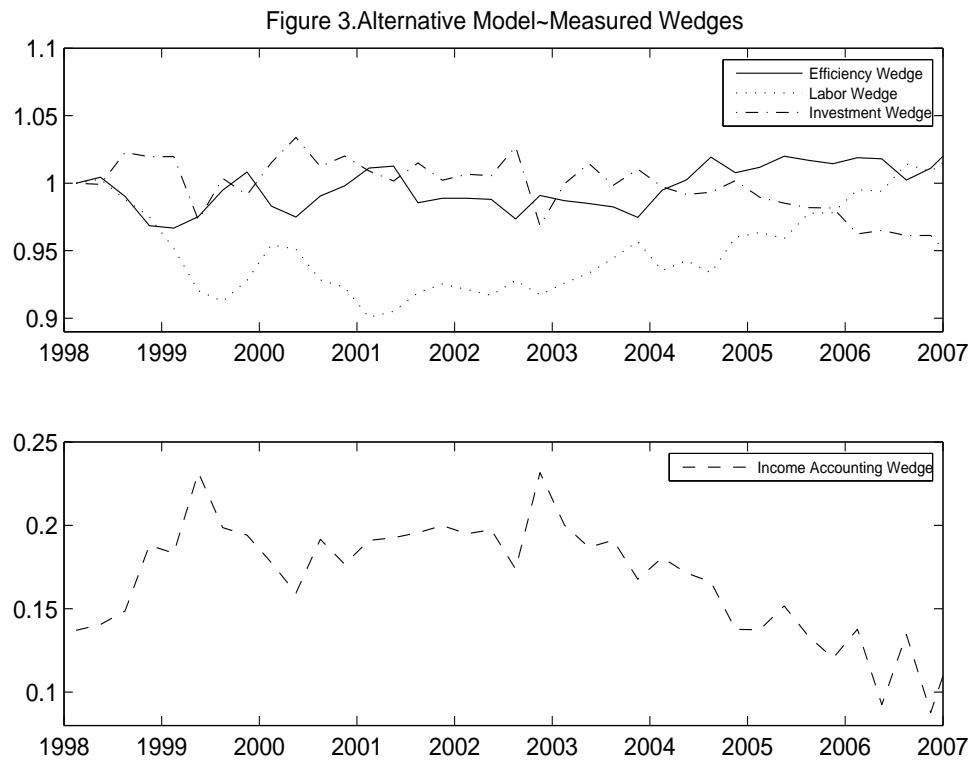
FIGURE 3.3: Alternative Model - Measured Wedges

Although the labor wedge still portrays some counterfactual movements in output, it explains the behavior of output in the latter part of the crisis until mid-2000, and also from mid-2001 until mid-2002, which are precisely the periods in which the efficiency wedge predicts that output would be too high.

The investment wedge still does not explain the movements in output very well, while the income accounting wedge gives contrary predictions as discussed earlier.

Figure 3.5 plots predicted and actual investment. Although the efficiency wedge generally tracks the actual movements of investment, the income accounting wedge

Figure 4.1.Alternative Model~Output Data and Efficiency Wedge

Figure 4.2.Alternative Model~Output Data and Labor Wedge

Figure 4.3.Alternative Model~Output Data and Investment Wedge

Figure 4.4.Alternative Model~Output Data and Income Accounting Wedge
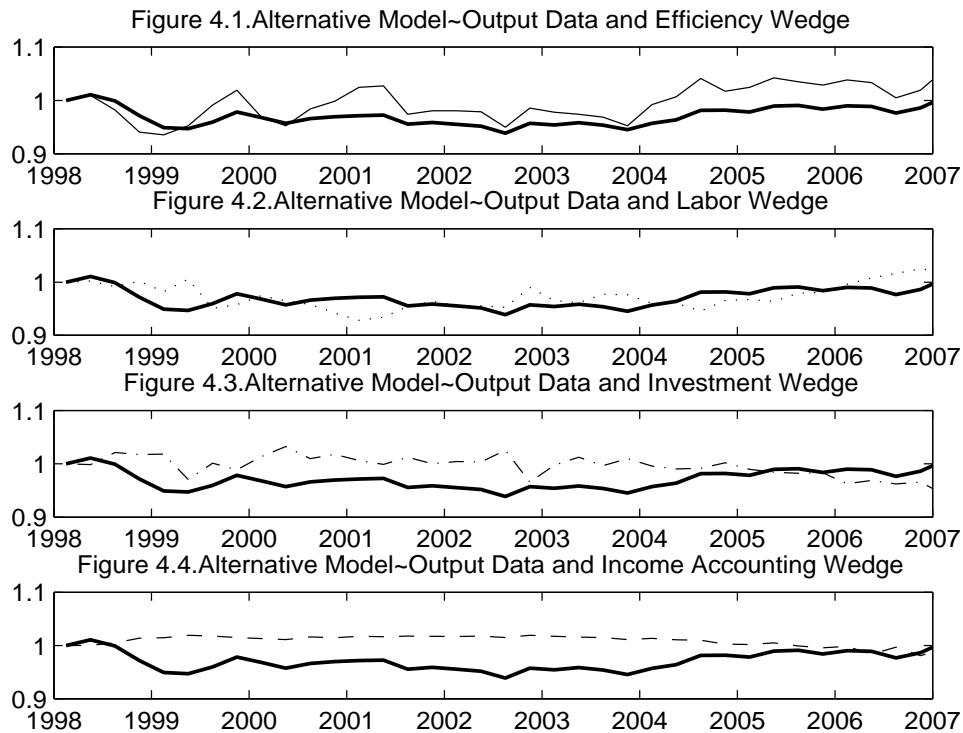
FIGURE 3.4: Alternative Model - Output Data and Efficiency Wedge

does a much better job at explaining investment. This may at first come across as puzzling since the investment series no longer contain the mining FDI component, while the income accounting wedge does. However, since the income accounting wedge is largely driven by changes in net exports, it is not surprising that it does a fair job at explaining investment movements as investment goods in Chile are predominantly imported. Finally, although the investment wedge does not generate enough of a fall in investment throughout the period, it does track the direction of investment movements very well for a large part of the decade. Beginning in 2005, it does however predict a

Figure 5.1.Alternative Model~Investment Data and Efficiency Wedge
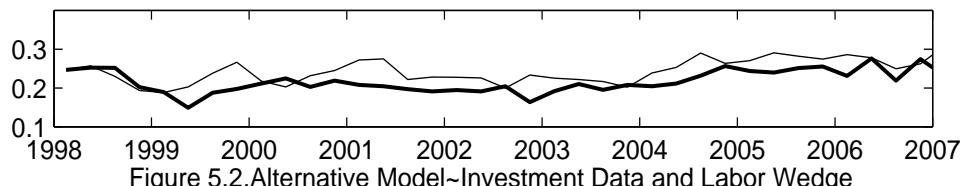
Figure 5.2.Alternative Model~Investment Data and Labor Wedge
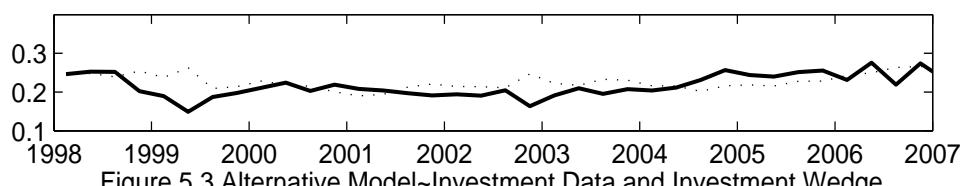
Figure 5.3.Alternative Model~Investment Data and Investment Wedge
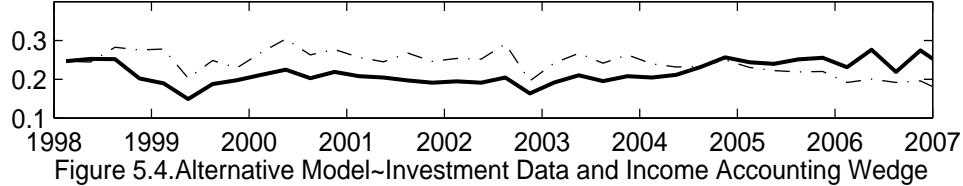
Figure 5.4.Alternative Model~Investment Data and Income Accounting Wedge
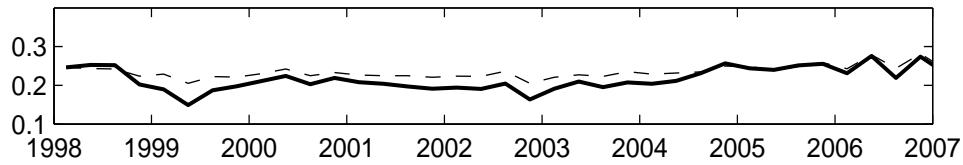
FIGURE 3.5: Alternative Model - Investment Data and Efficiency Wedge

much larger fall in investment as it captures the increase in consumer credit discussed earlier.

The movements in total hours worked do not seem to be explained very well by any particular wedge (Figure 3.6), although the efficiency and labor wedges do explain the general behavior of these series during certain sub-periods. Both wedges, however, predict a much higher volatility in hours than suggested by the data. Total hours worked are calculated as the product of total quarterly employment, average weekly

Figure 6.1.Alternative Model~Hours Data and Efficiency Wedge

Figure 6.2.Alternative Model~Hours Data and Labor Wedge

Figure 6.3.Alternative Model~Hours Data and Investment Wedge

Figure 6.4.Alternative Model~Hours Data and Income Accounting Wedge
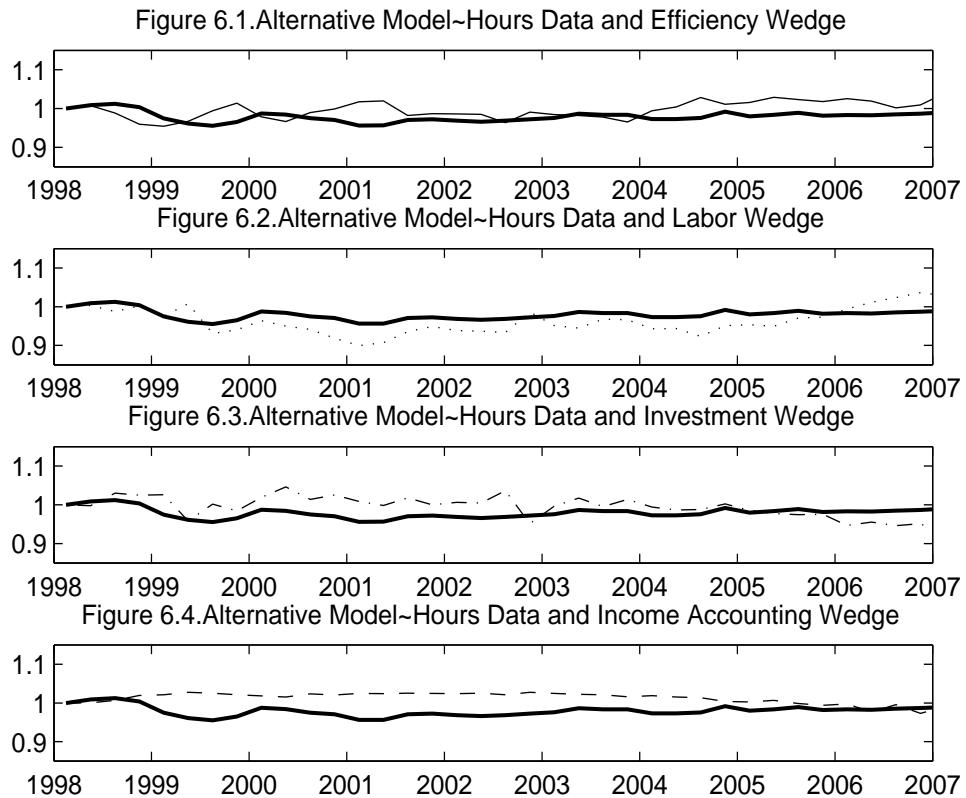
FIGURE 3.6: Alternative Model - Hours Data and Efficiency Wedge

hours worked per person, and the number of weeks in a quarter. Since average weekly hours worked per person were only available at an annual basis (see Appendix C.1 for details), this may be contributing toward the smoothness of the series.

It is interesting to note that actual hours worked did not fall immediately as the 1998-1999 crisis took place, but rather seem to show a downward trend with a lag. As expected, the efficiency wedge predicts a fall in hours and a recovery consistent with the movements in output shown in Figure 3.6. The labor wedge predicts a much larger

fall in hours throughout most of the period as well as a much stronger recovery than actually observed, which may in part be due to data issues (see Appendix C.1). Finally, the income accounting wedge predicts a rise in hours throughout the period, which is consistent with its "sudden-stops" predictions for output discussed earlier.

Figure 7.1.Alternative Model~Consumption Data and Efficiency Wedge

Figure 7.2.Alternative Model~Consumption Data and Labor Wedge

Figure 7.3.Alternative Model~Consumption Data and Investment Wedge

Figure 7.4.Alternative Model~Consumption Data and Income Accounting Wedge
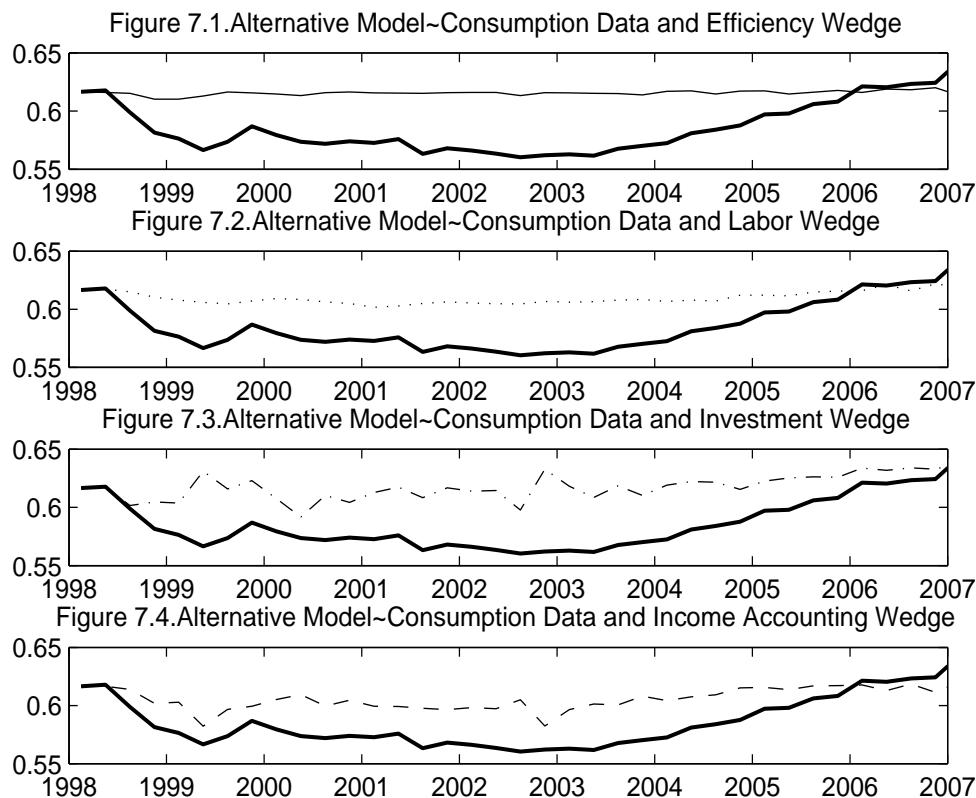
FIGURE 3.7: Alternative Model - Consumption Data and Efficiency Wedge

The efficiency and labor wedges are poor predictors of movements in consumption (Figure 3.7). In general, the benchmark model produces rather smooth consumption series due to the assumption of rational expectations and the representative consumers

consumption-smoothing preferences. However, the income accounting wedge does predict a drop in consumption, especially during the crisis. Again, as in the case of investment, this may be driven by the changes in net exports as consumption goods to a large degree are imported. Finally, notice that the investment wedge correctly predicts an increase in consumption in recent years, consistent with the consumer credit increase discussed earlier.

3.5   Conclusions and Policy Recommendations

In summary, our business cycle accounting exercise suggests that productivity and labor market considerations best explain the behavior of aggregate economic variables in Chile throughout the 1998-2007 period. The investment wedge does not appear to play a major role in explaining the observed patterns of aggregate data, except in recent years, when it correctly predicts an increase in consumption relative to investment. The latter is consistent with the increased access to credit on the part of the consumers. Finally, the income accounting wedge generates counterfactual predictions for output when the economy experiences a sudden stop, but it does explain the observed movements in investment and consumption rather well.

The predictive power of the efficiency and labor wedges suggests that labor market rigidities should be a focus for policy. In addition, the results from the model with an investment wedge suggest that policy should also focus on improving access to corporate credit along the lines of the consumer credit market improvements already observed in

Chile. However, specific policy recommendations would require a closer look at a more detailed model that incorporates frictions that manifest themselves as efficiency and/or labor wedges.

Conclusion

The three chapters in this thesis have explored three very important topics in the international economics literature. The first chapter addressed the observed positive relationship between prices of tradable goods and the per-capita income of a country. The second chapter provided new estimates of one of the most important parameters in the recent quantitative literature of international trade, namely the elasticity of trade. Finally, the third chapter explored the reasons behind the business cycle fluctuations in a very important trading economy, that of Chile. The results found in this thesis are likely to be further used in future studies in the international economics field and have made an important contribution toward the understanding of real-life phenomena within very simple and intuitive economic modeling frameworks.

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Appendix A

Appendices for Income

Differences and Prices of

Tradables

A.1 CES Model

Throughout this paper, I compare the predictions of the model with non-homothetic preferences to those arising from one with symmetric CES preferences. This is a variant of the model proposed by Melitz (2003) and extended by Chaney (2008)[1].

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[1] It can also be seen as the limiting case of the general utility function outlined earlier, where $\bar{q} \to 0$.

The maximization problem of a consumer in country j buying goods from (potentially) all countries $v = 1, ..., I$ is:

$$\max_{\{q_{vj}^c\}_{v=1}^{I} \geq 0} \left(\sum_{v=1}^{I} \int_{\Omega_{vj}} (q_{vj}^c(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}$$

$$s.t. \quad \sum_{v=1}^{I} \int_{\Omega_{vj}} p_{vj}(\omega) q_{vj}^c(\omega) d\omega \leq w_j.$$

I assume that the market structure is identical to that of the model with non-homothetic preferences. Then, the demand for variety of type ϕ originating from country i consumed in a positive amount in country j, $q_{ij}(\phi) > 0$, is given by[2]:

$$q_{ij}(\phi) = w_j L_j \frac{p_{ij}(\phi)^{-\sigma}}{P_j^{1-\sigma}}, \tag{A.1}$$

where

$$P_j^{1-\sigma} = \sum_{v=1}^{I} N_{vj} \int_{\phi_{vj}^*}^{\infty} p_{vj}(\phi)^{1-\sigma} \mu_{vj}(\phi) d\phi, \qquad \sigma > 1. \tag{A.2}$$

From (A.1), notice that the productivity threshold in this economy cannot be determined using the demand for the cutoff variety. Instead, it is necessary to introduce fixed costs at the firm level to bound the number of firms that serve each market.

Using (A.1), the profit maximization problem of a firm with productivity draw ϕ

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[2]I refer the reader to Melitz (2003) for detailed derivations of optimal rules in this economy. Arkolakis (2008) describes a procedure for computing equilibrium objects in this economy. The procedure is virtually identical to the one I apply to the non-homothetic model, so I refrain from the details in this paper.

originating in country i and considering to sell to country j is:

$$\max_{p_{ij} \geq 0} \quad p_{ij} w_j L_j \frac{p_{ij}^{-\sigma}}{P_j^{1-\sigma}} - \frac{\tau_{ij} w_i}{A_i \phi} w_j L_j \frac{p_{ij}^{-\sigma}}{P_j^{1-\sigma}} - w_j f.$$

In the above problem, I assume that each firm incurs a fixed cost, $f > 0$, in order to sell to a particular market. Moreover, the fixed cost is paid in terms of labor units of the destination country[3].

The optimal pricing rule of a firm with productivity draw $\phi \geq \phi_{ij}^*$ is given by:

$$p_{ij} \quad (\phi) = \frac{\sigma}{\sigma-1} \frac{\tau_{ij} w_i}{A_i \phi}. \tag{A.3}$$

A.2 Computing Price Levels of Tradables

In this section, I describe the procedure used to derive the price levels of tradable goods in the data and the two models.

To begin, I use data from the 2005 round of the International Comparison Program (ICP) at the basic heading level provided by the World Bank. According to the ICP Handbook[4], unit price data on identical goods is collected across retail locations in the participating countries. The lowest level of aggregation is the basic heading (BH), which

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[3]These two assumptions do not change the predictions of the model with respect to price levels, however, they result in a gravity equation for the model that is equivalent to the one with non-homothetic preferences. This allows me to use the same parameter estimates for the two models in the quantitative analysis of price levels.

[4]The ICP Handbook prepared by the World Bank is available at
$http://go.worldbank.org/VMCB80AB40$.

represents a narrowly-defined group of goods for which expenditure data are available. There are a total of 129 BHs in the data set. Each BH contains a certain number of products. Hence, the reported price of a BH is an aggregate price. An example of a basic heading is "1101111 Rice" which is made up of prices of different types of rice contained in specific packages.

In order to derive the price of a BH, the ICP uses a Jevons index[5]. For all N countries and I products within the basic heading, the ICP collects unit prices. The goal is to find the equivalent product in every country, thus washing away any quality differences. If an identical product is not found, the price entry is either left blank, resulting in missing observations, or a comparable product is found, ensuring that its specifications are carefully recorded so that quality adjustments can be made to the price entry.

A numeraire country is chosen, USA, and prices are expressed in 2005 US dollars. The Jevons index at the BH-level is a geometric average of relative prices of goods available in the US and another country. However, not all goods are found in all countries, resulting in price indices that are not transitive. Consequently, geometric averages are taken for every pair of countries in the sample and then prices relative to the US are computed using cross prices. The procedure, which yields transitive price indices, can be summarized as follows:

Step 1: Relative price of BH between countries j and k based on goods available in j and

k is:

$$P_{jk}^{j,k} = \left(\prod_{i=1}^{R_{jk}} \frac{p_{ij}}{p_{ik}} \right)^{\frac{1}{R_{jk}}},$$

where R_{jk} denotes the number of goods available in countries j and k.

Step 2: The transitive Jevons index of BH between countries j and k becomes:

$$P_{jk} = \left[\left(P_{jk}^{j,k} \right)^2 \prod_{l \neq j,k} \frac{P_{lk}^{l,k}}{P_{lj}^{l,j}} \right]^{\frac{1}{N}},$$

where N denotes the number of countries actually used in the relative price comparison. Notice that if a pair of countries does not have any goods in common, the relative price observation is missing and cannot be used to compute cross prices. Hence N is reduced accordingly.

I use prices at the BH-level to arrive at the price level of tradable goods by computing geometric averages across goods that correspond to tradable categories for 121 countries. Since there are no zero observations across these categories for the sample of countries I study, the price levels are transitive.

I now describe the Jevons index as it applies to the two models studied in this paper. The procedure is equivalent for the two models, but the price entries differ, since the optimal pricing rules of firms in the two models are different.

In the models, a good is differentiated by the productivity of the firm producing it

as well as the source country of the firm. First, I compute Jevons indices across goods

originating from a particular source and then I proceed to compute a Jevons index across

all source countries. Consider two destinations, j and k, and a common source country

υ. If $\phi^*_{\upsilon j} \neq \phi^*_{\upsilon k}$, then not all firms from country υ serve both destinations. Hence, only

prices of firms with productivity draws $\phi \geq \max[\phi^*_{\upsilon j}, \phi^*_{\upsilon k}]$ are relevant in my comparison.

In order to arrive at a geometric average of relative prices for a continuum of firms, the

geometric mean formula

$$\bar{x}_g = \left(\prod_K x_k \right)^{\frac{1}{K}}$$

becomes

$$\bar{x}_g = \exp \left(\int_K \log[x(k)] f(k) dk \right),$$

where $f(k)$ is the appropriate pdf of firm productivities.

The relative price of goods from country υ sold in destinations j and k is:

$$P^{j,k}_{\upsilon j k} = \exp \left\{ \int_{\max(\phi^*_{\upsilon j}, \phi^*_{\upsilon k})}^{\infty} \log \left[\frac{p_{\upsilon j}(\phi)}{p_{\upsilon k}(\phi)} \right] \frac{\theta[\max(\phi^*_{\upsilon j}, \phi^*_{\upsilon k})]^\theta}{\phi^{\theta+1}} d\phi \right\}. \tag{A.4}$$

However, the relative price a given firm charges in two destinations is independent of its

productivity and depends only on relative trade barriers in the CES model, and on trade

barriers, per-capita incomes and populations of the destinations in the non-homothetic

model. Thus, (A.4) for the CES and non-homothetic model, respectively, becomes:

$$CES: \qquad P_{vjk}^{j,k} = \exp\left\{\log\left[\frac{\tau_{vj}}{\tau_{vk}}\right]\right\}$$

$$NH: \qquad P_{vjk}^{j,k} = \exp\left\{\log\left[\frac{\tau_{vj}}{\tau_{vk}}\left(\frac{\phi_{vk}^*}{\phi_{vj}^*}\right)^{\frac{1}{2}}\right]\right\}.$$

Using these expressions in step 2 allows me to compute the Jevons index between countries j and k for goods originating from source country v. Finally, in order to arrive at price levels of tradable goods in the models, I repeat steps 1 and 2 treating each source country v as a BH. This is necessary since there are a number of zero price observations corresponding to the zeros in the bilateral trade matrix, which implies that geometric averages across source countries would not yield transitive Jevons indices.

A.3 Algebraic Derivations

A.3.1 Deriving Consumer's Demand

The maximization problem of a consumer in country j buying goods from (potentially) all countries $v = 1, ..., I$ is:

$$\max_{\{q_{vj}^c\}_{v=1}^I \geq 0} \sum_{v=1}^I \int_{\Omega_{vj}} \log(q_{vj}^c(\omega) + \bar{q})d\omega$$

$$s.t. \quad \lambda_j \left[\sum_{v=1}^I \int_{\Omega_{vj}} p_{vj}(\omega)q_{vj}^c(\omega)d\omega \leq w_j\right],$$

where λ_j is the Lagrange multiplier.

The FOCs of the above problem yield $(\forall q_{ij}^c(\omega) > 0)$:

$$\lambda_j p_{ij}(\omega) = \frac{1}{q_{ij}^c(\omega) + \bar{q}}. \qquad (A.5)$$

Let $\Omega_j^* \equiv \sum_{v=1}^{I} \Omega_{vj}^*$ be the set of all consumed varieties in country j. Letting N_{vj} be the measure of set Ω_{vj}^*, the measure of Ω_j^*, N_j, is given by $N_j = \sum_{v=1}^{I} N_{vj}$.

For any pair of goods $\omega_{ij}, \omega'_{vj} \in \Omega_j^*$, (A.5) gives:

$$p_{ij}(\omega)(q_{ij}^c(\omega) + \bar{q}) = p_{vj}(\omega') q_{vj}^c(\omega') + p_{vj}(\omega') \bar{q}. \qquad (A.6)$$

Integrating over all $\omega'_{vj} \in \Omega_j^*$, keeping in mind that the measure of Ω_{vj}^* is N_{vj}, yields the consumer's demand for any variety $\omega_{ij} \in \Omega_j^*$:

$$\int_{\Omega_j^*} \left[p_{ij}(\omega)(q_{ij}^c(\omega) + \bar{q}) \right] d\omega' = \int_{\Omega_j^*} \left[p_{vj}(\omega') q_{vj}^c(\omega') + p_{vj}(\omega') \bar{q} \right] d\omega' \quad (A.7)$$

$$\Rightarrow \sum_{v=1}^{I} \int_{\Omega_{vj}^*} \left[p_{ij}(\omega)(q_{ij}^c(\omega) + \bar{q}) \right] d\omega' = \sum_{v=1}^{I} \int_{\Omega_{vj}^*} \left[p_{vj}(\omega') q_{vj}^c(\omega') + p_{vj}(\omega') \bar{q} \right] d\omega' \quad (A.8)$$

$$\Rightarrow \left[p_{ij}(\omega)(q_{ij}^c(\omega) + \bar{q}) \right] \sum_{v=1}^{I} \int_{\Omega_{vj}^*} 1 d\omega' = \sum_{v=1}^{I} \int_{\Omega_{vj}^*} \left[p_{vj}(\omega') q_{vj}^c(\omega') + p_{vj}(\omega') \bar{q} \right] d\omega' \quad (A.9)$$

$$\Rightarrow \left[p_{ij}(\omega)(q_{ij}^c(\omega) + \bar{q}) \right] \sum_{v=1}^{I} N_{vj} = w_j + \sum_{v=1}^{I} \int_{\Omega_{vj}^*} p_{vj}(\omega') \bar{q} d\omega' \quad (A.10)$$

$$\Rightarrow \left[p_{ij}(\omega)(q_{ij}^c(\omega) + \bar{q}) \right] N_j = w_j + P_j \quad (A.11)$$

$$\Rightarrow q_{ij}^c(\omega) = \frac{w_j + P_j}{N_j p_{ij}(\omega)} - \bar{q} \quad (A.12)$$

where $P_j \equiv \bar{q} \sum_{v=1}^{I} \int_{\Omega_{vj}^*} p_{vj}(\omega') d\omega'$ is an aggregate price statistic and $N_j = \sum_{v=1}^{I} N_{vj}$

is the number of varieties consumed.

The total demand for variety ω originating from country i by consumers in country j then becomes:

$$q_{ij}(\omega) = L_j \left[\frac{w_j + P_j}{N_j p_{ij}(\omega)} - \bar{q} \right].$$

A.3.2 Solving the Firm's Problem

Recall (1.7), which gives the profit maximization problem of a firm with productivity draw ϕ originating in country i and considering to sell to country j:

$$\max_{p_{ij} \geq 0} \quad p_{ij} L_j \left[\frac{w_j + P_j}{N_j p_{ij}} - \bar{q} \right] - \frac{\tau_{ij} w_i}{A_i \phi} L_j \left[\frac{w_j + P_j}{N_j p_{ij}} - \bar{q} \right]$$

Since there is a continuum of firms, an individual monopolistic competitor does not view the aggregate variables, P_j and N_j, as choice variables. Hence, the FOCs of the firm's problem are given by

$$-L_j \bar{q} + \frac{\tau_{ij} w_i}{A_i \phi} L_j \frac{w_j + P_j}{N_j (p_{ij})^2} = 0,$$

which results in the optimal price of:

$$p_{ij}(\phi) = \left(\frac{\tau_{ij} w_i}{A_i \phi} \frac{w_j + P_j}{N_j \bar{q}} \right)^{\frac{1}{2}}.$$

A.3.3 Solving for Equilibrium Objects

In this section, I characterize the equilibrium objects of the model. I express all objects in terms of wage rates and I derive a set of equations that solve for the wage rates of all countries simultaneously. In the next section, I explore the properties of the system of equations and prove that a unique solution exists.

Straightforward algebraic manipulations allow to obtain the aggregate price statistic P_j, the number of firms serving each destination N_{ij}, and the productivity thresholds ϕ_{ij}^*, in terms of wage rates and number of entrants for each country.

As described in section 1.3.4, to solve the model, it is necessary to jointly determine wage rates, w_i, and the number of entrants, J_i, $\forall i$. These are in turn found using the free entry condition, (2.9), and the income/spending equality, (2.10).

Free entry requires that average profits cover the fixed cost of entry:

$$w_i f_e = \pi_i \tag{A.13}$$

$$\Rightarrow w_i f_e = \sum_v \left(\frac{b}{\phi_{iv}^*}\right)^\theta \frac{\bar{q}\tau_{iv} w_i L_v}{2A_i \phi_{iv}^*(\theta+1)(\theta+0.5)} \tag{A.14}$$

The income/spending identity requires that country i's consumers spend their entire income on imported and domestically-produced final goods:

$$L_i w_i = \sum_v J_i \frac{b^\theta}{\phi_{iv}^{*\ \theta}} \frac{\bar{q}\tau_{iv} w_i L_v}{2A_i \phi_{iv}^*(\theta+0.5)} \tag{A.15}$$

Expressions (A.13) and (A.15) yield:

$$J_i \quad = \quad \frac{L_i}{(\theta+1)f_e} \tag{A.16}$$

In order to characterize wages, I follow the approach of Arkolakis (2008) and

Arkolakis, Demidova, Klenow, and Rodríguez-Clare (2008). This amounts to using

import shares λ_{ij}, and the trade balance $\sum_j T_{ij} = \sum_j T_{ji}$, to arrive at:

$$\frac{w_i^{\theta+1}}{A_i^\theta} \quad = \quad \sum_j \left(\frac{L_j w_j}{\tau_{ij}{}^\theta \sum_v L_v A_v^\theta (\tau_{vj} w_v)^{-\theta}} \right) \tag{A.17}$$

This equation implicitly solves for the wage rate w_i for each country i, where $w_1 = 1$

can be taken to be the numeraire country.

A.3.4 Distribution of Firms' Sales

Section (1.4.3) derives the sales of a firm with productivity ϕ from source country i in

destination j, relative to average sales there:

$$s_{ij}(\phi) \equiv \frac{r_{ij}(\phi)}{t_{ij}} = \begin{cases} (1+2\theta) \left(1 - \left[\frac{\phi_{ij}^*}{\phi} \right]^{\frac{1}{2}} \right) & \text{if } \phi \geq \phi_{ij}^* \\ \\ 0 & \text{otherwise.} \end{cases} \tag{A.18}$$

Firm sales are increasing, strictly concave in firm productivity, and bounded above:

$$\lim_{\phi \to +\infty} s_{ij}(\phi) = 1 + 2\theta$$

Let $s_{ij}^{\min} = s_{ij}(\phi_{ij}^*)$ represent sales of a firm with productivity draw equivalent to the threshold, ϕ_{ij}^*. For the remainder of this subsection, I suppress all i, j-subscripts for ease of exposition. Then,

$$Pr[S \geq s | S \geq s^{\min}] = \frac{Pr[\Phi \geq \phi]}{Pr[\Phi \geq \phi^*]} = \left(\frac{\phi^*}{\phi}\right)^{\theta}$$

Let F represent the distribution of firms' sales, relative to average sales. This distribution satisfies:

$$Pr[S \geq s | S \geq s^{\min}] = 1 - Pr[S < s | R \geq s^{\min}] = 1 - F(s)$$

The above two expressions yield:

$$1 - F(s) = \left(\frac{\phi^*}{\phi}\right)^{\theta} \tag{A.19}$$

Using (A.18) and (A.19), the cdf F, and its corresponding pdf f, become:

$$F(s) = 1 - \left[1 - \frac{s}{2\theta + 1}\right]^{2\theta} \qquad f(s) = \frac{2\theta}{2\theta + 1}\left[1 - \frac{s}{2\theta + 1}\right]^{2\theta - 1}.$$

I now follow Saez (2001) to argue that the distribution of firms' sales is Pareto in the tail.

Let $\bar{s}^m$ be the mean of s, conditional on $s \geq s^m$, for $1 + 2\theta \geq s^m \geq s^{\min}$, where

$1 + 2\theta$ is the upper bound on firm sales as shown above. It suffices to show that $\bar{s}^m/s^m$

is constant. Clearly,

$$
\begin{aligned}
\frac{\bar{s}^m}{s^m} &= \frac{1}{s^m} \int_{s^m}^{2\theta+1} s \frac{\frac{2\theta}{2\theta+1}\left[1-\frac{s}{2\theta+1}\right]^{2\theta-1}}{\left[1-\frac{s^m}{2\theta+1}\right]^{2\theta}} ds \\
&= \frac{\left(1-\frac{s^m}{2\theta+1}\right)^{2\theta}(2\theta(s^m+1)+1)}{s^m(2\theta+1)}
\end{aligned}
$$

is constant, which allows to conclude that the distribution of firms' sales is Pareto in

the tail.

A.4 Tables and Figures

This section provides summary statistics from the Mango database. In addition to regressions (1.1) and (1.2), I check whether item prices are related to the size of the destination, measured by the 2006 population of each country. I estimate the following regression:

$$\log p_{ij} = \alpha_i + \beta_y \log y_j + \beta_\tau \log \tau_j + \beta_L \log L_j + \epsilon_{ij}, \tag{A.20}$$

where L_j is country j's population.

All tables and figures related to the Mango database can be found below. Finally, the end of the section contains all figures.

TABLE A.1: List of Countries in Sample

Austria	Belgium	Canada
Cyprus (Southern area)	Denmark	Estonia
Finland	France	Germany
Greece	Hungary	Ireland
Italy	Luxembourg	Malta
Netherlands	Norway	Portugal
Slovakia	Slovenia	Spain (Peninsula and Balearic Islands)
Sweden	Switzerland	United Kingdom

TABLE A.2: Free Shipping Minimum and Per-Unit Shipping Cost, Ascending (In Euro)

Destination	Free Shipping From	Destination	Shipping Cost
Spain	EUR 20.00	Spain	EUR 6.50
United Kingdom	EUR 38.72	United Kingdom	EUR 7.74
Sweden	EUR 38.84	Luxembourg	EUR 8.50
Belgium	EUR 45.00	Portugal	EUR 8.50
Germany	EUR 45.00	Sweden	EUR 8.50
Ireland	EUR 45.00	Austria	EUR 8.60
Luxembourg	EUR 45.00	Denmark	EUR 8.60
Portugal	EUR 45.00	Finland	EUR 8.60
Denmark	EUR 45.63	Greece	EUR 8.60
France	EUR 48.00	France	EUR 8.70
Italy	EUR 48.00	Germany	EUR 8.70
Netherlands	EUR 48.00	Netherlands	EUR 8.70
Austria	EUR 50.00	Italy	EUR 8.75
Finland	EUR 50.00	Belgium	EUR 8.85
Greece	EUR 50.00	Ireland	EUR 8.95
Switzerland	EUR 54.14	Switzerland	EUR 12.74
Norway	EUR 81.64	Norway	EUR 14.93
Estonia	EUR 94.25	Hungary	EUR 15.05
Cyprus	EUR 95.00	Cyprus	EUR 15.50
Hungary	EUR 95.67	Malta	EUR 15.50
Canada	EUR 96.44	Slovenia	EUR 15.50
Slovakia	EUR 99.78	Estonia	EUR 15.52
Malta	EUR 165.00	Slovakia	EUR 16.16
Slovenia	EUR 165.00	Canada	EUR 19.29

TABLE A.3: Average Price of Items in Euro and PCGDP (PPP 2006), Relative to Spain

Destination	Relative Price	Destination	Relative PC GDP
Portugal	0.9587	Slovak Republic	0.6211
Spain	1.0000	Hungary	0.6343
Greece	1.0869	Estonia	0.6655
Denmark	1.1422	Portugal	0.7235
Hungary	1.1564	Slovenia	0.8679
France	1.1786	Greece	0.9500
Belgium	1.1870	Spain	1.0000
Slovenia	1.2086	Italy	1.0200
Italy	1.2121	France	1.1085
Malta	1.2327	Germany	1.1272
Estonia	1.2337	Finland	1.1420
Austria	1.2363	United Kingdom	1.1591
Finland	1.2406	Belgium	1.1711
Luxembourg	1.2489	Sweden	1.2118
Germany	1.2501	Denmark	1.2476
Cyprus	1.2568	Austria	1.2587
Netherlands	1.2627	Netherlands	1.2801
Slovak Republic	1.2828	Canada	1.2803
United Kingdom	1.2846	Switzerland	1.3527
Sweden	1.3326	Ireland	1.4135
Norway	1.3468	Cyprus	1.5338
Ireland	1.3625	Norway	1.7449
Canada	1.5125	Malta	1.7567
Switzerland	1.5129	Luxembourg	2.6204

TABLE A.4: Good Fixed-Effects Regression of Logged Prices

Included Variables ———— Coefficient (St. Error) t-stat	PCGDP(PPP)	PCGDP(PPP) Distance	PCGDP(PPP) Distance Population
Log PCGDP (PPP)	0.1185 (0.0052) *22.93	0.1221 (0.0051) *24.09	0.1254 (0.0051) *24.79
Log Distance from Barcelona (KM)		0.0331 (0.0008) *41.09	0.0343 (0.0010) *33.52
Log Population			0.0039 (0.0012) *3.30

All prices are converted to Euro using February 2008 average monthly exchange rates. The distance variable contains the distance from Barcelona to the capital city of the destination country. The distance coefficients were minimally altered when distance between Barcelona and the destination country's most populated city was used.

Data Sources: Price data obtained by author from March 2008 online catalogues of clothing manufacturer Mango. PPP-adjusted per-capita income and population data for 2006 was collected from WDI. Exchange rate data was obtained from the IFS. Distance data in kilometers was obtained from Mapcrow.

Table A.5: Good Fixed-Effects Regression of Logged Prices in Euro Zone

Included Variables ————— Coefficient (St. Error) t-stat	PCGDP(PPP)	PCGDP(PPP) Distance	PCGDP(PPP) Distance Population
Log PCGDP (PPP)	0.1808 (0.0088) *20.54	0.1565 (0.0086) *18.13	0.2076 (0.0112) *18.46
Log Distance from Barcelona (KM)		0.0245 (0.0005) *48.64	0.0281 (0.0005) *60.49
Log Population			0.0156 (0.0014) *11.12

These regressions use countries in the Euro zone as of January 1, 2008 only so no exchange rate data is necessary. The distance variable contains the distance from Barcelona to the capital city of the destination country. The distance coefficients were minimally altered when distance between Barcelona and the destination country's most populated city was used.

Data Sources: Price data obtained by author from March 2008 online catalogues of clothing manufacturer Mango. PPP-adjusted per-capita income and population data for 2006 was collected from WDI. Distance data in kilometers was obtained from Mapcrow.

The plot shows Log Average Price of Items (relative to Spain) [Source: Mango Summer Catalog, 2008] on the vertical axis versus Log Per Capita GDP (relative to Spain) [Source: WDI, 2006] on the horizontal axis. The fitted line equation reads:

$$\log(P^T) = 0.1225 \log(PCY) + 0.1929$$
$$*p = 0.05$$
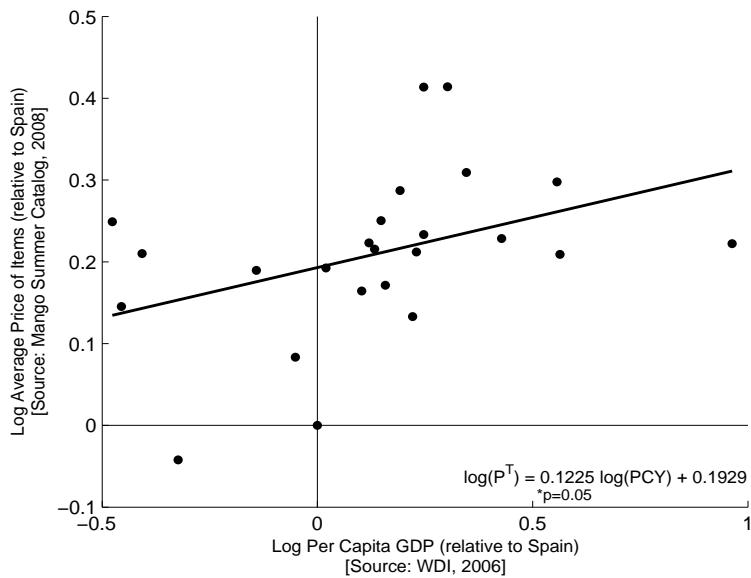
FIGURE A.1: Average Price of Identical Items and Per-Capita GDP for 24 Countries

The plot shows Firms' Sales as a function of Firm Productivity, ϕ, with a threshold at ϕ^*.
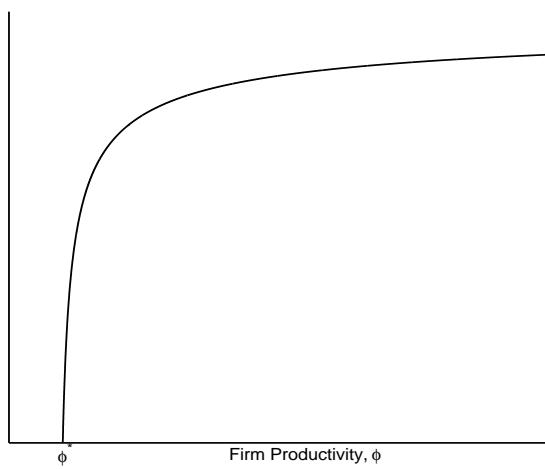
FIGURE A.2: Firms' Sales as Function of Firms' Productivities
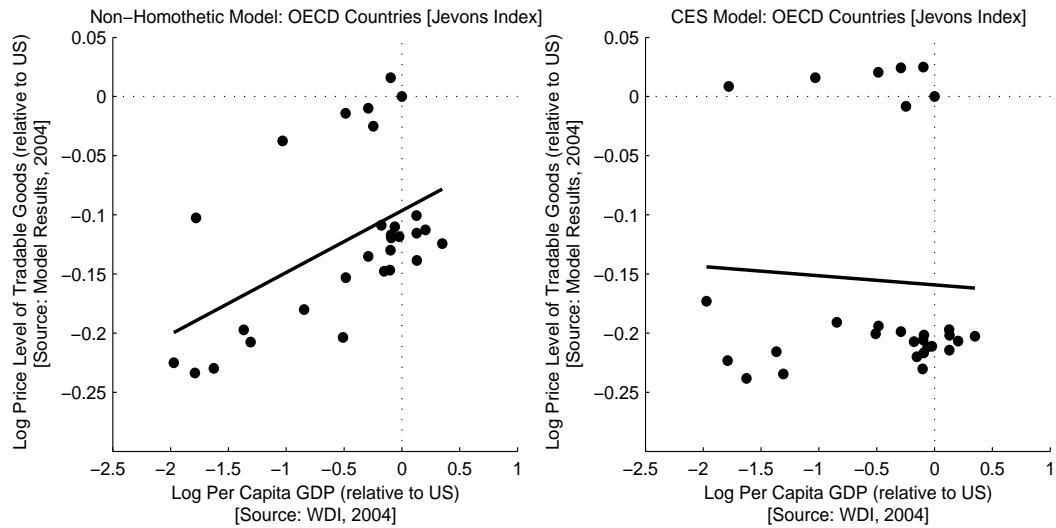
FIGURE A.3: Price Level of Tradable Goods and Per-Capita GDP for OECD Countries
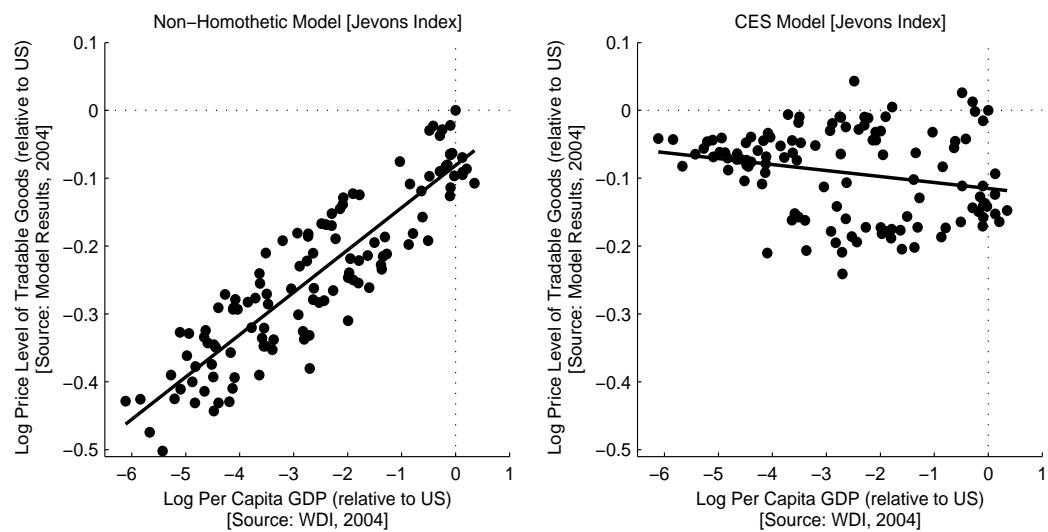
FIGURE A.4: Price Level of Tradable Goods and Per-Capita GDP for 119 Countries

Appendix B

Appendices for Estimates of the Elasticity of Trade

B.1 Alternative Models

B.1.1 Models With Sales Taxes and Mark-Ups

The price data we use, which is collected at the retail level, may also reflect sales taxes in countries that report the gross price of a good (for example a supermarket in the EU). In this section, we follow a similar argument to the previous section to show how sales taxes affect our estimates of the elasticity of trade parameter. All variables pertaining to this scenario contain the subscript t.

Suppose firms face production functions as in section 2.2, but consumers pay a net

sales tax in destination n, $t_n - 1^{12}$. For simplicity, we assume that tax proceeds are not rebated to consumers. Then, the consumer's problem in country n becomes:

$$\max_{\{q^{tc}_{nv}\}^I_{v=1} \geq 0} \quad \left(\sum_{v=1}^I \int_{\Omega_{nv}} (q^{tc}_{nv}(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} \tag{B.1}$$

$$s.t. \quad \sum_{v=1}^I \int_{\Omega_{nv}} t_n p^t_{nv}(\omega) q^{tc}_{nv}(\omega) d\omega \leq w_n. \tag{B.2}$$

Notice that t_n enters the budget constraint in a simple multiplicative manner. The demand for variety of type ϕ originating from country i consumed in a positive amount in country n, populated by L_n identical consumers, is given by:

$$q^t_{ni}(\phi) \;=\; \frac{w_n L_n}{t_n} \frac{p^t_{ni}(\phi)^{-\sigma}}{(P^t_n)^{1-\sigma}}, \tag{B.3}$$

where P^t_n is the ideal price index in country n with sales tax t_n. Using the demand function, the firm's problem becomes:

$$\pi^t_{ni}(\phi) = \max_{p^t_{ni} \geq 0} \quad p^t_{ni} \frac{w_n L_n}{t_n} \frac{(p^t_{ni})^{-\sigma}}{(P^t_n)^{1-\sigma}} - \frac{\tau_{ni} w_i}{\phi} \frac{w_n L_n}{t_n} \frac{(p^t_{ni})^{-\sigma}}{(P^t_n)^{1-\sigma}} - w_n f_n, \tag{B.4}$$

where it is clear that sales taxes do not affect the firm's optimal pricing rule, given by (2.5).

The zero-prodit condition, which determines the productivity threshold ϕ^t_{ni}, now

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[1]If taxes are exporter- and importer-specific, they become discriminatory, in which case they can be interpreted as trade barriers.

[2]If firms set exogenous country-specific mark-ups, the model is identical to the one described in this section. This is not the case however if mark-ups are firm- and country-specific. We study this scenario in the following section.

becomes:

$$\pi_{ni}^t(\phi_{ni}^t) = 0 \iff \phi_{ni}^t = \frac{\tau_{ni} w_i}{P_n^t} \left(\frac{(\sigma-1)^{1-\sigma} \sigma^\sigma f_n t_n}{L_n} \right)^{\frac{1}{\sigma-1}}. \tag{B.5}$$

The measure of entrants is still given by (2.11) since preceding steps remain unchanged. Moreover, the relative import ratios also remain unchanged since all varieties sold in a particular market n are subject to the same per-unit sales tax. However, the price indices now account for these taxes:

$$(P_n^t)^{1-\sigma} = \sum_v N_{nv}^t \int_{\phi_{nv}^t}^\infty \left(\frac{\sigma}{\sigma-1} \frac{\tau_{nv} w_v}{\phi} \right)^{1-\sigma} \mu_{nv}^t(\phi) d\phi \tag{B.6}$$

$$\Rightarrow \qquad (P_n^t)^{1-\sigma} = \sum_v J_v T_v (\tau_{nv} w_v)^{1-\sigma} (\phi_{nv}^t)^{-\theta-1+\sigma} \frac{\theta}{\theta-\sigma+1} \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \tag{B.7}$$

$$\Rightarrow \quad (P_n^t)^{1-\sigma} = \sum_v J_v T_v (\tau_{nv} w_v)^{1-\sigma} \left(\frac{\tau_{nv} w_v}{P_n^t} \left(\frac{(\sigma-1)^{1-\sigma} \sigma^\sigma f_n t_n}{L_n} \right)^{\frac{1}{\sigma-1}} \right)^{-\theta-1+\sigma} \frac{\theta}{\theta-\sigma+1} \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \tag{B.8}$$

$$\Rightarrow \qquad (P_n^t)^{-\theta} = \sum_{v=1}^I \frac{J_v T_v}{(\tau_{nv} w_v)^\theta} \left(\frac{f_n t_n}{L_n} \right)^{\frac{-\theta-1+\sigma}{\sigma-1}} \frac{\theta}{\theta-\sigma+1} \sigma^{\frac{\sigma\theta+\sigma+1}{1-\sigma}} (\sigma-1)^\theta \tag{B.9}$$

$$\Rightarrow \qquad (P_n^t)^{-\theta} = t_n^{\frac{-\theta-1+\sigma}{\sigma-1}} \sum_{v=1}^I \frac{J_v T_v}{(\tau_{nv} w_v)^\theta} \left(\frac{f_n}{L_n} \right)^{\frac{-\theta-1+\sigma}{\sigma-1}} \frac{\theta}{\theta-\sigma+1} \sigma^{\frac{\sigma\theta+\sigma+1}{1-\sigma}} (\sigma-1)^\theta \tag{B.10}$$

$$\Rightarrow \qquad (P_n^t)^{-\theta} = t_n^{\frac{-\theta-1+\sigma}{\sigma-1}} (P_n)^{-\theta} \tag{B.11}$$

$$\Rightarrow \qquad P_n^t = t_n^{\frac{-\theta-1+\sigma}{\theta(1-\sigma)}} P_n \tag{B.12}$$

To arrive at the structural relationship used to estimate θ, we combine the trade shares and (B.6) to obtain:

$$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \left(\frac{P_i^t / t_i^{\frac{-\theta-1+\sigma}{\theta(1-\sigma)}}}{P_n^t / t_n^{\frac{-\theta-1+\sigma}{\theta(1-\sigma)}}} \right)^{-\theta} \tau_{ni}^{-\theta} \left(\frac{f_n/L_n}{f_i/L_i} \right)^{\frac{-\theta-1+\sigma}{\sigma-1}} \tag{B.13}$$

$$\Rightarrow \qquad \frac{X_{ni}/X_n}{X_{ii}/X_i} = \left(\frac{P_i}{P_n}\right)^{-\theta} \tau_{ni}^{-\theta} \left(\frac{f_n/L_n}{f_i/L_i}\right)^{\frac{-\theta-1+\sigma}{\sigma-1}} \qquad (B.14)$$

The same assumptions as in the previous section yield estimating equations for θ.

B.1.2 Models with Endogenous Mark-Ups

The preceding section studied how country-specific mark-ups that are common across firms affect the estimates of the elasticity parameter. In this section, we study two monopolistic competition models in which mark-ups are endogenously determined by firms. Moreover, mark-ups are good- and destination-specific and arise in response to differing price elasticities of demand across countries.

We begin with the model introduced in Simonovska08. All variables pertaining to this model contain a superscript s.

The maximization problem of a consumer in country n buying goods from (potentially) all countries $v = 1, ..., I$ is:

$$C_n^s = \max_{\{q_{nv}^{sc}\}_{v=1}^I \geq 0} \quad \sum_{v=1}^I \int_{\Omega_{nv}} \log(q_{nv}^{sc}(\omega) + \bar{q})d\omega \qquad (B.15)$$

$$s.t. \quad \sum_{v=1}^I \int_{\Omega_{nv}} p_{nv}^s(\omega)q_{nv}^{sc}(\omega)d\omega \leq w_j, \qquad (B.16)$$

where $\bar{q} > 0$ and Ω_{vn} is compact.

The demand for variety of type ϕ originating from country i consumed in a positive

amount in country n, populated by L_n identical consumers, is given by:

$$q_{ni}^s(\phi) \;\; = L_n \left[\frac{w_n + P_n}{N_n p_{ni}^s(\phi)} - \bar{q} \right],$$
<div align="right">(B.17)</div>

where $P_n \;=\; \sum_{v=1}^{I} N_{nv} \int_{\phi_{nv}^s}^{\infty} p_{nv}^s(\phi) \mu_{nv}^s(\phi) d\phi$ is an aggregate price statistic in n (not to be mistaken with the ideal price index in this economy to be derived later), and $N_n = \sum_{v=1}^{I} N_{nv}$ is the measure of varieties consumed in n.

Using the demand function, the firm's problem becomes[3]:

$$\pi_{ni}^s(\phi) = \max_{p_{ni}^s \geq 0} \quad p_{ni}^s L_n \left[\frac{w_n + P_n}{N_n p_{ni}^s} - \bar{q} \right] - \frac{\tau_{ni} w_i}{\phi} L_n \left[\frac{w_n + P_n}{N_n p_{ni}^s} - \bar{q} \right].$$
<div align="right">(B.18)</div>

The optimal pricing rule of such firm is given by:

$$p_{ni}^s(\phi) = \frac{\tau_{ni} w_i}{(\phi \phi_{ni}^s)^{\frac{1}{2}}},$$
<div align="right">(B.19)</div>

where the productivity threshold ϕ_{ni}^s satisfies:

$$\phi_{ni}^s = \frac{\tau_{ni} w_i N_n \bar{q}}{w_n + P_n}.$$
<div align="right">(B.20)</div>

Following the steps outlined in section 2.2 yield the following measure of entrants in

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[3]In this model, the marginal utility of consuming each good is bounded at any level of consumption, thus limiting the measure of varieties that are sold in each destination. Hence, consumer demand imposes a limit on the measure of firms that serve each market, which allows to assume away the existence of market access fixed costs.

this model:

$$J_i^s = \frac{L_i}{(\theta + 1)f_e}. \tag{B.21}$$

Moreover, the relative import shares remain unchanged. So, in oder to arrive at a structural equation relating trade shares and prices, it is necessary to derive an ideal price index for the economy. Since consumer preferences are assumed to be non-homothetic, price elasticities of demand turn out to vary with the per-capita income and the (population) size of each destination. Consequently, so do mark-ups and prices firms set per destination. Since preferences are defined for an average consumer, we derive an ideal price index, P_n^s, that exhausts the consumer's budget, namely, $P_n^s C_n^s = w_n$, where C_n^s is given in (B.15). Using the solution to the firm problem yields the following C_n^{s}[4]:

$$C_n^s \qquad = \sum_{\upsilon=1}^{I} N_{n\upsilon} \int_{\phi_{n\upsilon}^s}^{\infty} \log(q_{n\upsilon}^{sc}(\phi) + \bar{q})\mu_{n\upsilon}(\phi)d\phi \tag{B.24}$$

$$= \sum_{\upsilon=1}^{I} J_\upsilon \frac{T_\upsilon}{(\phi_{n\upsilon}^s)^\theta} \int_{\phi_{n\upsilon}^s}^{\infty} \log\left(\bar{q}\left(\sqrt{\frac{\phi}{\phi_{n\upsilon}^s}} - 1\right) + \bar{q}\right) \frac{\theta(\phi_{n\upsilon}^s)^\theta}{\phi^{\theta+1}}d\phi \tag{B.25}$$

$$= \sum_{\upsilon=1}^{I} J_\upsilon \theta T_\upsilon \int_{\phi_{n\upsilon}^s}^{\infty} \log\left(\bar{q}\sqrt{\frac{\phi}{\phi_{n\upsilon}^s}}\right) \frac{1}{\phi^{\theta+1}}d\phi \tag{B.26}$$

$$= \sum_{\upsilon=1}^{I} J_\upsilon \theta T_\upsilon \int_{\phi_{n\upsilon}^s}^{\infty} \left[\log(\bar{q}) + \tfrac{1}{2}\log(\phi) - \tfrac{1}{2}\log(\phi_{n\upsilon}^s)\right] \frac{1}{\phi^{\theta+1}}d\phi \tag{B.27}$$

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[4]Deriving C_n requires to evaluate the following integral:

$$\int_{\phi_{n\upsilon}^s}^{\infty} \frac{\log(\phi)}{\phi^{\theta+1}}d\phi = \frac{\theta\log(\phi) + 1}{\theta^2(\phi)^\theta} \Big|_{\phi_{n\upsilon}^s}^{\infty}. \tag{B.22}$$

To ensure that the above integral is zero when evaluated at ∞, it is sufficient to assume that $\theta > 0$:

$$\lim_{\phi\to\infty} \frac{\theta\log(\phi) + 1}{\theta^2(\phi)^\theta} = \lim_{\phi\to\infty} \frac{\frac{\theta}{\phi}}{\theta^3(\phi)^{\theta-1}} = \lim_{\phi\to\infty} \frac{1}{\theta^2(\phi)^\theta} = 0, \tag{B.23}$$

where the L'Hopital rule has been used.

$$= \sum_{v=1}^{I} J_v \theta T_v \left\{ \left[\log(\bar{q}) - \tfrac{1}{2} \log(\phi_{nv}^s) \right] \frac{1}{\theta(\phi_{nv}^s)^\theta} + \tfrac{1}{2} \int_{\phi_{nv}^s}^{\infty} \frac{\log(\phi)}{\phi^{\theta+1}} d\phi \right\} \qquad (B.28)$$

$$= \sum_{v=1}^{I} J_v \theta T_v \left\{ \left[\log(\bar{q}) - \tfrac{1}{2} \log(\phi_{nv}^s) \right] \frac{1}{\theta(\phi_{nv}^s)^\theta} + \tfrac{1}{2} \frac{\theta \log(\phi_{nv}^s)+1}{\theta^2 (\phi_{nv}^s)^\theta} \right\} \qquad (B.29)$$

$$= \sum_{v=1}^{I} \frac{J_v T_v}{\phi_{nv}^s} \left\{ \log(\bar{q}) + \tfrac{1}{2\theta} \right\} \qquad (B.30)$$

$$= \left\{ \log(\bar{q}) + \tfrac{1}{2\theta} \right\} N_n \qquad (B.31)$$

Using the definitions of N_n and P_n as well the productivity cutoff in (B.20), the measure of firms N_n becomes:

$$N_n = \left[w_n^\theta \frac{(\theta+0.5)^\theta}{(\theta+1)f_e(\bar{q}(\theta+0.5)-\theta)^\theta} \sum_{v=1}^{I} \frac{L_v T_v}{(\tau_{nv} w_v)^\theta} \right]^{\frac{1}{\theta+1}} \qquad (B.32)$$

Substituting (B.32) into (B.24) yields the following ideal price index:

$$P_n^s = \frac{w_n}{C_n^s} \qquad (B.33)$$

$$= \frac{w_n}{\left\{ \log(\bar{q})+\tfrac{1}{2\theta} \right\} \left[w_n^\theta \frac{(\theta+0.5)^\theta}{(\theta+1)f_e(\bar{q}(\theta+0.5)-\theta)^\theta} \sum_{v=1}^{I} \frac{L_v T_v}{(\tau_{nv} w_v)^\theta} \right]^{\frac{1}{\theta+1}}} \qquad (B.34)$$

$$= \frac{1}{\left\{ \log(\bar{q})+\tfrac{1}{2\theta} \right\} \left[\frac{(\theta+0.5)^\theta}{(\theta+1)f_e(\bar{q}(\theta+0.5)-\theta)^\theta} \right]^{\frac{1}{\theta+1}}} \left[\frac{w_n}{\sum_{v=1}^{I} \frac{L_v T_v}{(\tau_{nv} w_v)^\theta}} \right]^{\frac{1}{\theta+1}} \qquad (B.35)$$

To arrive at the structural relationship used to estimate θ, we combine the trade shares and (B.33) to obtain:

$$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \left(\frac{P_i^s}{P_n^s} \right)^{-\theta} \tau_{ni}^{-\theta} \left(\frac{w_i/P_i}{w_n/P_n} \right) \qquad (B.36)$$

A few things stand out in the above equation. First, notice that (B.36) implies an augmented regression to estimate θ, where the term $\log\left(\frac{w_i/P_i}{w_n/P_n}\right)$ is the relative real-income ratio in the two countries and requires that a restriction be imposed in the regression to yield a coefficient on that term of exactly 1. However, the price indices are no longer proportionate to the CES ideal price index that appears in previous models. This is of course due to the non-homothetic nature of the preferences employed in this model. Moreover, one cannot expect that the price indices reported in the ICP data are computed according to this non-homothetic specification. In fact, Simonovska08 argues that the ICP price indices are computed using the Jevons method, discussed in Hill09. This method essentially combines prices of individual goods via a geometric average that is further linked across countries. So, we propose the following algorithm to estimate θ in this class of models:

(1) Make an initial guess $\theta = \theta_0$; (2) Compute the equilibrium outcomes in the calibrated models and obtain prices of individual tradable goods; (3) Aggregate goods' prices into Jevons price index; (4) Obtain an estimate $\hat{\theta}$ using the Jevons index in (B.36); (5) Repeat the procedure until the initial guess and the estimated value are equivalent. Finally, compare the resulting Jevons index and the price index in (B.33) at the newly estimated θ to see whether there are significant differences between the two.

Appendix C

Appendices for Business Cycle Accounting for Chile

C.1   Data Sources and Calculations

TABLE C.1: Quarterly Data for Chile, 1998-2007

Code	Description of Data	Unit	Source
O.1	Gross Domestic Product	(SA, Mil.2003.Ch Pesos)	Banco Central de Chile
O.2	Total Consumption	(SA, Mil.2003.Ch Pesos)	Banco Central de Chile
O.3	Gross Fixed Capital Formation	(SA, Mil.2003.Ch Pesos)	Banco Central de Chile
O.4	Change in Inventories	(SA, Mil.2003.Ch Pesos)	Banco Central de Chile
O.5	Government Consumption	(SA, Mil.2003.Ch Pesos)	Banco Central de Chile
O.6	Exports of Goods and Services	(SA, Mil.2003.Ch Pesos)	Banco Central de Chile
O.7	Imports of Goods and Services	(SA, Mil.2003.Ch Pesos)	Banco Central de Chile
O.8	Employment: Quarterly Moving Average Ended in Specified Month	(SA by Haver, Thousands)	Instituto Nacional de Estaditicas
O.9	Net VAT Revenue	(SA, Mil.2003.Ch Pesos)	Banco Central de Chile
O.10	Import Duties	(SA, Mil.2003.Ch Pesos)	Banco Central de Chile
O.I.1	Total FDI (Liabilities in Chile)	(NSA, Mil.USD)	Banco Central de Chile
O.I.2	Exchange Rate	(Ch/USD)	Banco Central de Chile
O.I.3	Gross Fixed Capital Formation	(SA, Mil.Ch Pesos)	Banco Central de Chile
O.I.4	Change in Inventories	(SA, Mil.Ch Pesos)	Banco Central de Chile

TABLE C.2: Annual Data for Chile, 1998-2007

Code	Description of Data	Unit	Source
O.11	Population ages 15-64[1]	(Thousands)	WDI
O.12	Hours actually worked, Men and Women (Weekly Average Hours)[2][3]	(Hours per Person)	ISIC-Rev.2
O.I.5	Mining Fraction of FDI	(NSA, Fraction of Total)	

C.2   Results from Benchmark Model

This sections reports the results for investment, hours worked, and consumption from the benchmark model. Figures A2.1-A2.3 summarize our findings.

Clearly, the efficiency wedge plays a central role in explaining the fluctuations of investment and hours worked in Chile throughout the 1998-2007 period. However, the income accounting wedge best explains the behavior of consumption.

TABLE C.3: Constructed Data for Chile, 1998-2007

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Code	Description of Variable
C.1=O.1-O.9-O.10	Y_t =GDP - Net VAT Revenue - Import Duties
C.2=O.2-O.5	C_t =Total Consumption - Gov't Consumption - VAT - Import Duties
C.3=O.3+O.4	X_t =Gross Fixed Capital Formation + Change in Inventories
C.4=O.5+O.6-O.7	G_t =Gov't Consumption + Exports - Imports
C.5=O.11 repeated quarterly	Population (Yearly Observation Repeated 4 Times)
C.6=% Changes in C.5	γ_n =Population Growth Rate
C.8=O.12 quarterly	Average Weekly Hours Actually Worked
C.9=C.8*O.8*52/4	L_t =Total Hours Worked Per Quarter

Figure A2.1.1.Benchmark Model~Investment Data and Efficiency Wedge
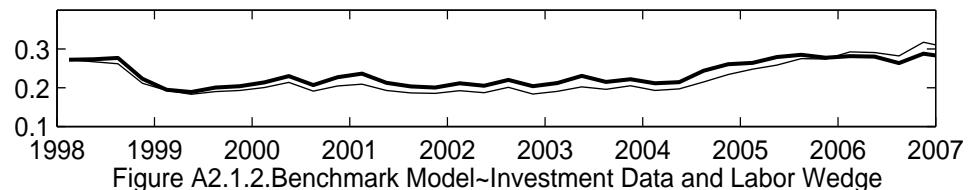
Figure A2.1.2.Benchmark Model~Investment Data and Labor Wedge
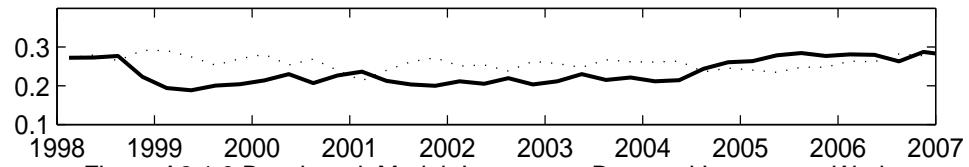
Figure A2.1.3.Benchmark Model~Investment Data and Investment Wedge
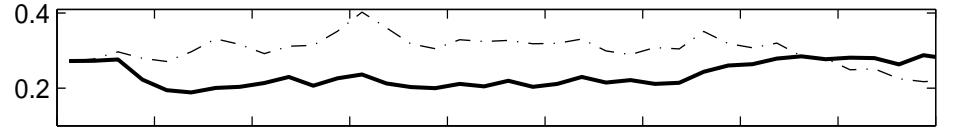
Figure A2.1.4.Benchmark Model~Investment Data and Income Accounting Wedge
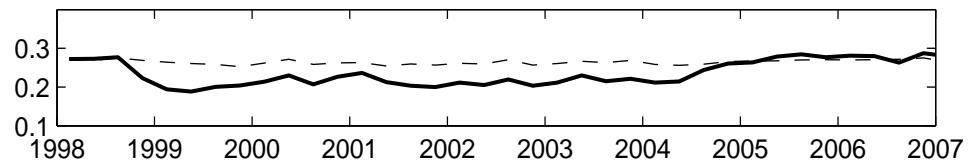
Figure A2.2.1.Benchmark Model~Hours Data and Efficiency Wedge
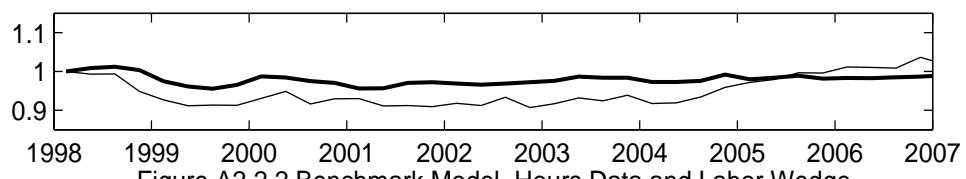

Figure A2.2.2.Benchmark Model~Hours Data and Labor Wedge
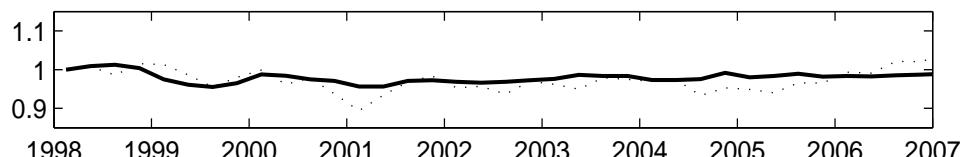
Figure A2.2.3.Benchmark Model~Hours Data and Investment Wedge
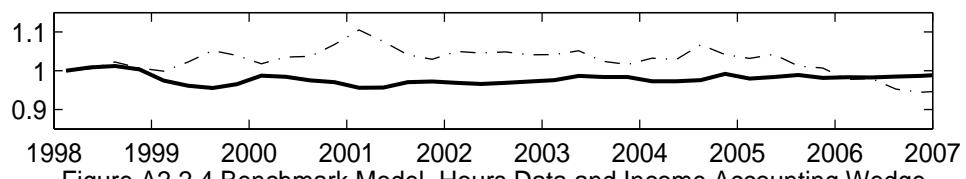
Figure A2.2.4.Benchmark Model~Hours Data and Income Accounting Wedge
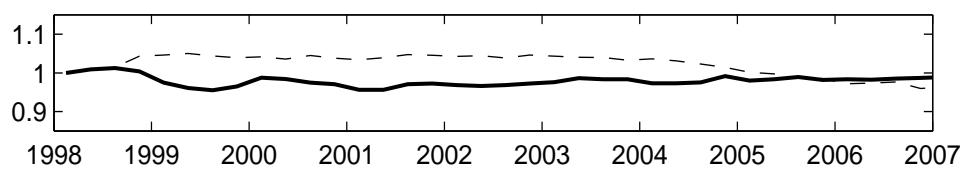
Figure A2.3.1.Benchmark Model~Consumption Data and Efficiency Wedge
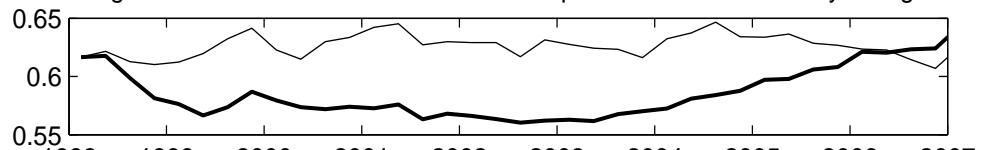
Figure A2.3.2.Benchmark Model~Consumption Data and Labor Wedge
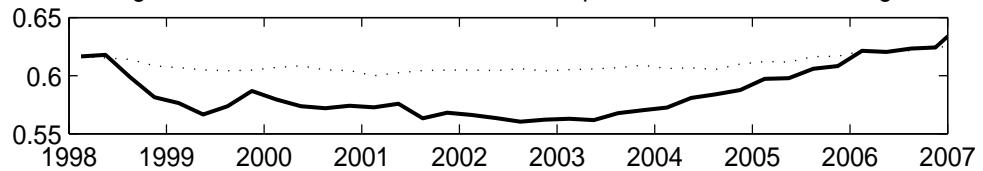
Figure A2.3.3.Benchmark Model~Consumption Data and Investment Wedge
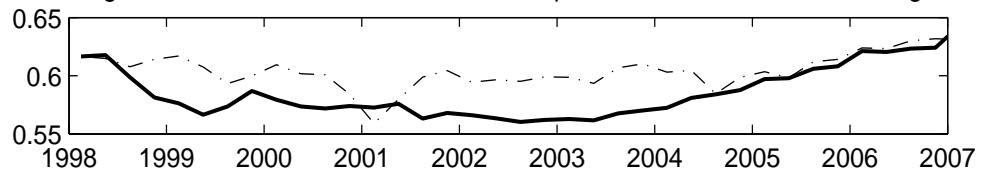
Figure A2.3.4.Benchmark Model~Consumption Data and Income Accounting Wedge