Essays on Giffen Behavior and International Trade

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Ramses Yusseff Armendariz

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Dedication

To those who have believed in me despite of my contant failures.

Abstract

This dissertation contains three independent papers. Each paper is a chapter in this thesis.

In chapter 1, I characterize a strictly increasing, quasi-concave, and continuous utility function that accounts for Jensen and Miller's (2008) empirical finding (i.e., downward sloping demands for food staples among the poorest and least poor of the poor, and upward sloping among the group in the middle) when the consumer maximizes it subject to a budget constraint.

According to this utility function, demands for food staples are upward sloping at low income levels because people highly dislike consuming a minimum amount of calories to subsist. Thus, this theory departs from the the standard models of subsistence caloric consumption that employ an exogenous "subsistence constraint" to predict upward sloping demands (Dooley, 1988; van Marrewijk and van Bergeijk, 1990; Gilley and Karels, 1991; Davies, 1994).

In chapter 2, I show that the total number of Tequila producers in Mexico exploded after the enactment of NAFTA; in particular, the increment in small Tequila distilleries was significantly larger than the increment in the number of larger distilleries. And many of this new small distilleries are specialized in producing expensive Tequila for exports.

By using the Melitz (2003) model as a benchmark, I discard the following three explanations for this change in distribution:

(1) A special section in NAFTA called "Regional Products" prohibits the production of Tequila outside Mexico. Consequently, there are no large American distilleries that can employ their economies of scale to sell cheap American Tequila in Mexico and drive small Mexican Tequila producers out of the market.

To introduce this environment in Melitz (2003), I assume that the United States does not produce a close substitute to Tequila.

(2) Consumers in the United States and Mexico enjoy drinking different varieties of similar spirits. And consumers in both sides of the border consider that Tequila, Bourbon, and Tennessee Whiskey are similar spirits, because the "Regional Products"

section in NAFTA protects them all in a similar way (i.e., NAFTA prohibits the production of Bourbon and Tennessee Whiskey outside the United States). Consequently, NAFTA induces trade of expensive Tequila from small Mexican distilleries for Bourbon and Tennessee Whiskey from the United States.

To introduce this environment in Melitz (2003), I assume that the United States produces a close substitute to Tequila.

(3) Average income on each side of the border is very different. Therefore, consumers in Mexico buy less varieties of spirits than American consumers. Moreover, American consumers buy more expensive varieties of Tequila, because they have a bigger mass of rich consumers. Therefore, the demand for more expensive varieties of spirits in the United States has driven the expansion of small Tequila distilleries that specialize in the production of expensive Tequila for exports.

To introduce this environment in Melitz (2003), I assume that "price independent generalized linearity" utility (Muellbauer, 1976) represent consumer preferences in both countries.

In Chapter 3, I provide a summary of the literature regarding Giffen behavior. To facilitate the exposition, I have chosen to divide the literature in four historical periods. Each period identifies a different set of dialectic debates regarding upward sloping demands.

The first period is the "Early Period". In this period, the theory of upward sloping demands was born. The second period is called the "Classical Period." In the Classical Period, economists became aware that the theory of utility is strong enough to explain Giffen behavior. However, they did not know how. The third period is called the "Empirical Period." In this period, economists noticed that they had no concrete evidence of Giffen behavior. Therefore, they focused on finding this evidence. The last period is called the "Synthesis Period." In this period, economists found empirical evidence of this phenomenon and constructed a utility-based model that can account for it.

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Chapter 1

Why the extreme poor show Giffen behavior for staples?

1.1 Introduction

Jensen and Miller (2008) develop a randomized experiment that shows the first empirical evidence of Giffen behavior (i.e., upward sloping demands). Their experiment studies consumers who live “below the World Bank’s extreme poverty line of 1 dollar per person per day” and “highly depend on a single staple food for the bulk of their [caloric] needs.” And the result of their experiment documents that the very poorest and the least poor consumers in their sample have downward sloping demands for their staple, while the group in the middle exhibits Giffen behavior.

To design their experiment, Jensen and Miller employ an indifference curve map (Figure 1 in their paper) to predict where Giffen behavior is most likely to be observed. This map corresponds to a strictly increasing and quasi-concave utility, and it predicts an upward sloping demand for the staple when the consumer maximizes it subject to a budget constraint. However, Jensen and Miller do not provide an explicit utility function that rationalizes those curves. Instead, they “[draw] connections between Marshall’s (1895) verbal argument [about upward sloping demands], two mathematical models of the situation, and the graphical analysis found in the microeconomics textbooks” to conjecture the shape of those curves.[1]

[1] In his Principles of Economics, Marshall (1895) says: “As Mr. Giffen has pointed out, a rise in

I presume that Jensen and Miller do not provide a utility function that rationalizes their indifference curve map because they do not have one available. In fact, as far as I am aware, standard models of subsistence caloric consumption that predict upward sloping demands employ two constraints: the budget constraint and a "subsistence constraint." Therefore, this type of models are not consistent with Jensen and Miller's Figure 1. Some examples of models that use a subsistence constraint are Dooley (1988), van Marrewijk and van Bergeijk (1990), Gilley and Karels (1991), and Davies (1994). In particular, the two mathematical models that Jensen and Miller use to "draw connections" belong to this type. This explains why Jensen and Miller conjecture that the poor are not only constrained by their budget, but also by "subsistence concerns."

However, there is one reason why Jensen and Miller creates their indifference curve map to predict where Giffen behavior is most likely to be observed. This map is consistent with the standard Consumer Theory, while the models based on subsistence constraints are not. In specific, in standard Consumer Theory, we know that a strictly increasing, quasi-concave, and continuous utility function can rationalize upward sloping demands.[2] Therefore, there must be a motivation to deviate from the standard approach other than just inducing upward sloping demands.[3]

In this paper, I fill this gap: I characterize a strictly increasing, quasi-concave, and continuous utility function that can account for Jensen and Miller's empirical finding when the consumer maximizes it subject to a budget constraint. In particular, this utility function rationalizes the indifference curves shown in Jensen and Miller's Figure 1.

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the price of bread makes so large a drain on the resources of the poorer labouring families and raises so much the marginal utility of money to them, that they are forced to curtail their consumption of meat and the more expensive farinaceous foods: and, bread being still the cheapest food which they can get and will take, they consume more, and not less of it."

Jensen and Miller present their two mathematical models in their appendix. However, these models cannot rationalize their Figure 1.

An example of the "graphical analysis found in the microeconomics textbooks" can be seen in Figure 1.19 (c) from Jehle and Reny (2011). Textbooks use this graphical analysis to show how upward sloping demands can arise. However, they do not provide a utility function that rationalizes those curves.

[2] Originally, this result was proved using a strictly increasing, strictly quasi-concave, and continuously differentiable utility function (Slutsky, 1915; Hicks and Allen, 1934). But, by using Afriat's (1976) result, we can extend this to a strictly increasing, continuous, and quasi-concave utility function.

[3] Preserving the standard approach in a consumer model is desirable to extend it into a broader set of environments. For instance, we know that a Competitive Equilibrium exists when the utility is strictly increasing, quasi-concave, and continuous. What's more, Sonnenschein (1972) shows that these conditions are sufficient to predict any possible economy in a General Equilibrium environment.

As I show later, my utility function departs from the "subsistence constraint" theory: it only employs the budget constraint to induce upward sloping demands. Instead of using a subsistence constraint, it assumes that the marginal utility of calories tends to infinity as the consumer approaches a subsistence level. Therefore, consumers always prefer eating more calories than the subsistence level. And Giffen behavior is a consequence of this assumption.

Models with subsistence constraints have one theoretical issue if they are employed to design experiments that account for Giffen behavior in the demand for food staples. They do not distinguish inferior goods from Giffen behavior, because these models predict that the staple becomes an inferior good and its demand shows Giffen behavior at exactly the same time: when the subsistence constraint holds with equality. However, standard Consumer Theory predicts that this may not be the case. Hence, experiments based on this type of models may predict Giffen behavior in environments where there is not. For example, I use the utility function that I characterize to correct an imprecision in Jensen and Miller's paper: Jensen and Miller mention "a set of conditions under which Giffen behavior is most likely to be observed" according to economic theory. And Jensen and Miller provide these conditions to replicate their experiment. In particular, their third condition says, "The basic good [the good that shows Giffen behavior] is the cheapest source of calories available, comprises a large part of the diet/budget, and has no ready substitute." However, I show that the basic good could become a normal good at very low prices, even when its demand shows Giffen behavior at higher prices. Therefore, theory predicts that it would be impossible to replicate Jensen and Miller's result if this were the case.

1.2 Consumer Preferences

The utility function I characterize is an application of Lancaster's (1966) Consumer Theory. In particular, my utility function represents a preference relation for bundles of two hedonic characteristics that food provide: "calorie surplus" and "flavor." Calorie surplus is total calories consumed minus a minimum amount of calories necessary to subsist. To ingest calories, the consumer must go to the markets to buy bread and meat. Bread and meat are perfect substitutes at the provision of calories; however, meat is the only food that provides flavor as well.

That is, mathematically, calorie surplus is defined as

$$c = \alpha_b b + \alpha_m m - \bar{c} \tag{1.1}$$

where c is calorie surplus, b is the quantity of bread consumed, α_b is the calories that each unit of bread provides, m is the quantity of meat consumed, α_m is the calories that each unit of meat provides, and $\bar{c}$ is the minimum amount of calories necessary to subsist.

And flavor is defined as δm, where δ is the amount of flavor that each unit of meat provides.

Figure 1 in Jensen and Miller (2008) has three types of indifference curves that they refer as: "standard zone", "subsistence zone", and "calorie-deprived zone." The former two types are strictly convex to the origin, while the latter is a straight line. Therefore, to replicate these two different shapes, the functional form of this utility is piece-wise (it contains two pieces). The first piece is strictly quasi-concave; this piece rationalizes the strictly convex indifference curves. While the second piece is weakly quasi-concave; this piece rationalizes the straight lines.

The piece that rationalizes the strictly convex curves represents a CES preference relation for bundles of calorie surplus and flavor. Therefore, the functional form of the utility is

$$u(b, m) = [(\alpha_b b + \alpha_m m - \bar{c})^\rho + (\delta m)^\rho]^{\frac{1}{\rho}} \tag{1.2}$$

where $\sigma = {}^1/_{(1-\rho)}$ is the elasticity of substitution between calorie surplus and flavor.

This piece is defined in the set of bundles that provide more than enough calories to subsist. That is, its domain is

$$\left\{(b, m) \in \Re^2_+ \mid \alpha_b b + \alpha_m m - \bar{c} > 0\right\} \tag{1.3}$$

This function is strictly increasing, strictly quasi-concave, and continuously differentiable on bread and meat. It satisfies Inada Conditions on meat, while the marginal utility of bread is finite when the consumption of bread is zero and tends to zero as the amount of bread grows unboundedly.

The other piece, the one that rationalizes the straight lines, is equal to the value of calorie surplus. That is,

$$\alpha_b b + \alpha_m m - \bar{c} \tag{1.4}$$

And this piece is defined in the rest of the first quadrant.

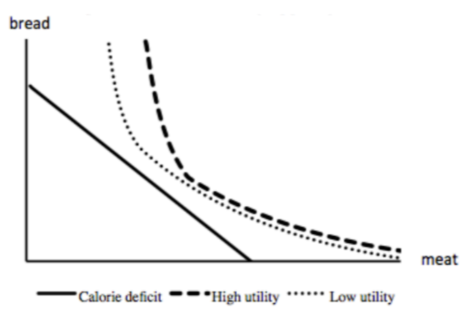
Therefore, the utility function is the following:

$$u(b,m) = \begin{cases} \left[(\alpha_b b + \alpha_m m - \bar{c})^{\rho} + (\delta m)^{\rho}\right]^{\frac{1}{\rho}} & if \quad \alpha_b b + \alpha_m m - \bar{c} > 0 \\ \alpha_b b + \alpha_m m - \bar{c} & if \quad \alpha_b b + \alpha_m m - \bar{c} \leq 0 \end{cases} \tag{1.5}$$

1.3 Replicating Figure 1 in Jensen and Miller

To check how this utility function can induce the indifference curve map drawn by Jensen and Miller, use the following set of parameters: $\alpha_m = 1.2$, $\alpha_c = 2$, $\bar{c} = 1.5$, $\delta = 0.1$, and $\rho = -5.25$.

Figure 1.1: Indifference Curve Map



This map contains two types of curves: strictly convex and straight lines. The first piece of the utility function, the CES-like piece, rationalizes the strictly convex curves. And the perfect substitutes piece rationalizes the straight lines. Later in section 1.5, I show that the strictly convex curves are the ones that rationalize Giffen behavior; the straight lines have nothing to do with upward sloping demands. In fact, the CES-like piece is not well-defined at bundles that assign the minimum amount of calories to subsist. Therefore, this utility function deviates from the "subsistence constraint" theory.

1.4 Demands for Bread and Meat

In this section, I solve the following Consumer Problem to obtain the demands for bread and meat:

$$\max_{\{b,m\}} u(b,m) \quad s.t.: \quad \begin{aligned} p_m m + p_b b &\leq i \\ m, b &\geq 0 \end{aligned} \tag{1.6}$$

The properties of the utility function imply that there are two types of solutions when the consumer maximizes this utility function subject to a budget constraint: either the solution is interior or the consumer spends all her income on one single commodity.

Clearly, when the consumer spends all her income on one single commodity, the demand for that commodity is downward sloping. Therefore, these cases are uninteresting as an explanation for Giffen behavior. Consequently, I proceed with describing the interior solution.[4]

Given the properties of the utility function, the following system of two equations characterize the demands for bread and meat when the solution is interior:

1. The budget constraint holding with equality

2. The marginal rate of substitution equalized to the ratio of prices

Then, by solving these system of equations, I obtain the demands for bread and meat in closed-form:

$$b = \frac{i\left(\delta - \mu\left(p_b, p_m\right)\alpha_m\right) + \mu\left(p_b, p_m\right)p_m\bar{c}}{p_b\left(\delta - \mu\left(p_b, p_m\right)\alpha_m\right) + \mu\left(p_b, p_m\right)p_m\alpha_b} \tag{1.7}$$

[4] The value of the utility is strictly positive when the bundle assigns more calories than the necessary to subsist, and it is not positive otherwise. Hence, the consumer will always buy a bundle that provides more calories than the subsistence level when her budget is enough to buy such a bundle. In this case, she will never specialize her consumption in bread due to Inada Conditions on meat. So, the only corner solution in this case is specializing on meat. However, when her budget is not enough to buy a bundle that provides enough calories to subsist, she will specialize her consumption on the cheapest source of calories.

$$m = \frac{\mu\left(p_b, p_m\right)\left(i\alpha_b - p_b\bar{c}\right)}{p_b\left(\delta - \mu\left(p_b, p_m\right)\alpha_m\right) + \mu\left(p_b, p_m\right)p_m\alpha_b} \tag{1.8}$$

where μ is the following function:

$$\mu\left(p_b, p_m\right) = \left(\frac{p_m\alpha_b - p_b\alpha_m}{p_b\delta}\right)^{\frac{1}{\rho-1}} \tag{1.9}$$

1.5 Giffen behavior in the demand for bread

In this section, I show that there is a range of prices of bread in which the demand for bread is upward sloping. I prove this in three steps. The first step constrains the parameters of the consumer problem. The second step shows that the consumer especializes her consumption on bread when the price of bread is equal to its upper bound allowed by the constraints from the first step. And the third step shows that the derivative of the demand for bread is upward sloping at that price. Then, by continuity of the derivative of the demand for bread, the demand is upward sloping at any price close enough to the upper bound.

1.5.1 Restrictions on the parameters of the consumer problem

Let the parameters of the consumer problem satisfy the following five inequalities:

$$\frac{\alpha_m}{p_m} < \frac{\alpha_b}{p_b} \tag{1.10}$$

$$\frac{p_m\bar{C}}{2\alpha_m} < i < \frac{p_m\bar{C}}{\alpha_m} \tag{1.11}$$

$$\frac{p_b\bar{C}}{\alpha_b} < i \tag{1.12}$$

$$\rho \leq 0 \tag{1.13}$$

$$\delta < \mu\left(p_b, p_m\right)\alpha_m \tag{1.14}$$

In economic terms, (1.10) says that bread is the cheapest source of calories. (1.11) says that the consumer cannot aford to buy enough meat to survive; however, her income is enough to buy over half the amount of calories necessary to survive. (1.12) says that the consumer is wealthy enough to avoid starvation. (1.13) says that calorie surplus and flavor are not substitutes. And (1.14) relates the amount of flavor with the amount of calories that meat provides.

1.5.2 Demands evaluated when bread is very expensive

Let the price of bread be equal to its upper bound allowed by (1.12). That is, let the price of bread be

$$p_b = \frac{\alpha_b i}{\bar{C}} \tag{1.15}$$

At this price, the consumer specializes her consumption on bread. That is,

$$b = \frac{\bar{C}}{p_b} \tag{1.16}$$

$$m = 0 \tag{1.17}$$

1.5.3 The demand for bread is upward sloping

This proof is straight forward: I show that the derivative of (1.7) evaluated at (1.15) is strictly positive. Then, by continuity, any price close enough to (1.15) makes the derivative be strictly positive.

The derivative of (1.7) is

$$\frac{\partial b}{\partial p_b} = \frac{\mu'(p_b)\left(p_m\bar{C} - \alpha_m i\right) - b(p_b)\left(\delta - \mu(p_b)\alpha_m - \mu'(p_b)p_b\alpha_m + \mu'(p_b)p_m\alpha_b\right)}{p_b\delta + \mu(p_b)\left(p_m\alpha_b - p_b\alpha_m\right)} \tag{1.18}$$

A quick inspection of (1.18) shows that its denominator is strictly positive, because (1.10) makes $\mu(p_b, p_m)$ be strictly positive. Hence, (1.18) is strictly positive as long as its numerator is strictly positive.

By plugging (1.15) and the restrictions of the parameters from section 1.5.1 in the numerator of (1.18), we find that its value becomes strictly positive.

Bread is an inferior good.

From the Slutsky Equation, we know that bread is an inferior good when its demand is upward sloping. Thus, we should expect to see that this utility function preserves this property. To verify that this is the case, it is sufficient to derive (1.7) with respect to income. Notice that, conditions (1.10) and (1.14) make this derivative be strictly positive.

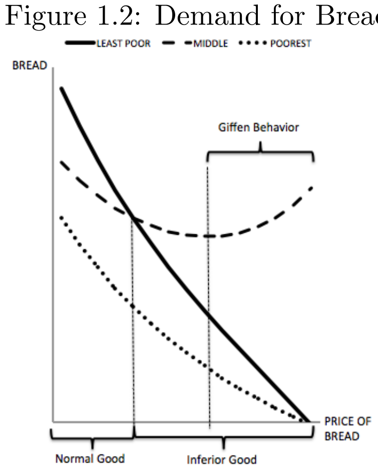
Alternatively, we can verify that bread is inferior by showing that the utility function is not supermodular (Quah, 2007).

1.6 The staple can be a normal good at very low prices

In this section, I show that the staple could be a normal good at very low prices even when it shows Giffen behavior at higher prices. To replicate this exercise, consider the following set of parameters: $\alpha_m = \bar{c} = p_m = 1$, $\delta = 0.1$, and $\rho = 0$.

This exercise contains three consumers with different income levels. The consumer labeled as "least poor" has an income of 1.1. The one labeled as "middle" has an income of 0.7. And the one labeled as "poorest" has an income of 0.4.

Figure 1.2: Demand for Bread



Notice that this graph shows how this model can account for Jensen and Miller's finding (i.e., downward sloping demands for food staples among the poorest and least poor of the poor, and Giffen behavior among the group in the middle). And yet, it also shows how the conditions they provide to replicate their experiment are not sufficient to predict Giffen behavior.

The demand labeled as "poorest" is the lowest demand when the good is inferior because this consumer is calorie deprived at that point, and his income is not enough to buy more bread.

1.7 Final Remarks

1.7.1 Davies meets Lancaster

The utility function I present in this paper unifies two opposing theories regarding upward sloping demands for food staples: Lancaster (1966) and Davies (1994). In particular, Davies has two criticisms for using Lancaster's theory to model caloric intake: "First, there is the basic difficulty of teasing from our commodities objectively measurable characteristics, other than nutritional variables, that are relevant sources of utility. Second, the utility conferred by the calorie characteristic is not something general to the consumption of commodities; it arises only in the particular context of subsistence consumption levels." Consequently, Davies proposes that it is more reasonable to model "its impact in commodity space, as an explicit and predictable influence on commodity substitution that arises when, and only when, the absolute level of commodity consumption falls to some critically low level." And he interprets this solution as modeling the subsistence constraint as the lowest possible indifference curve.

The utility function I propose in this paper, in fact, responds to these two criticisms in the following way.

First, call δm proteins instead of flavor. In this case, δ is the amount of protein that each unit of meat provides. And now, we have two perfectly measurable characteristics: calorie surplus and protein, where the subsistence level of calories is the minimum amount of calories necessary to live. And second, rewrite the utility function as follows:

$$u\left(b,m\right)=\begin{cases}\left[\left(\alpha_b b+\alpha_m m-\bar{c}\right)^{\rho}+\left(\delta m\right)^{\rho}\right]^{\frac{1}{\rho}} & if \quad \alpha_b b+\alpha_m m-\bar{c}>0\\ \alpha_b b+\alpha_m m-\bar{c} & if \quad \alpha_b b+\alpha_m m-\bar{c}=0\end{cases} \tag{1.19}$$

Notice that the lowest indifference curve possible according to this utility function is the set of bundles that assign the minimum amount of calories necessary to live.

This version of the utility function can account for upward sloping demands using both theories. In section 1.5, I show it can account for upward sloping demands using

Lancaster's theory. In this case, the consumer is running low on calories, but not quite consuming the minimum amount necessary to live. Therefore, she can afford the luxury to buy some protein. And to show how it can account for Giffen behavior using Davies theory is a simple exercise that involves using Figure 1 in his paper and apply it to my Figure A.1.

1.7.2 The strong Giffen problem

In the literature, there is a mathematical problem called the "strong Giffen problem" (Heijman and von Mouche, 2012c). In specific, the strong Giffen problem is to propose a "concrete utility function that is strictly increasing and quasi-concave [...] where the Giffen property can be shown by solving the equation of budget balancedness together with the equation saying that the price ratio equals marginal rate of substitution." Today, given the technical difficulty of this challenge, there is a very few number of economists that have completed (or partially completed) this task (e.g. Wold, 1948; Moffatt, 2002; Sorensen, 2007; Doi et al., 2012; Haagsma, 2012a; Biederman, 2015). Yet, none of these examples model calorie intake.

Notice that I prove that the CES-like utility function solves the strong Giffen problem as well in section 1.5.

Chapter 2

The Tequila Puzzle: the large surge of small exporting distilleries following NAFTA

2.1 Introduction

After the enactment of the North American Free Trade Agreement in 1994, the total number of Tequila producers in Mexico exploded. In particular, there was a large surge of small distilleries that produce expensive Tequila, most of it for exports.

The previews fact contradicts the prediction of the standard model of monopolistic competition and international trade (Melitz, 2003). According to this model, a tariff reduction drives the smallest producers out of business, while only large firms that produce low-priced products export.

This paper tests three different hypotheses using the Melitz (2003) model as a benchmark. Each of these hypothesis reflect a realistic and particular feature of the Tequila industry; nevertheless, this paper shows that none of these hypotheses can explain the evolution of the Tequila industry.

The first hypothesis assumes that the United States cannot produce a close substitute to Tequila. This hypothesis arises because NAFTA explicitly states that any product sold as Tequila in North America must be produced in Mexico. In other words, this hypothesis argues that the Denomination of Origin in the Tequila industry caused the drastic change in the size distribution of Tequila distilleries.

When the benchmark model incorporates the first hypothesis, it predicts that transportation costs (tariffs) have no impact on the size distribution of distilleries. Thus, the first hypothesis is discarded as a possible explanation.

The second hypothesis assumes that the United States produces a close substitute to Tequila. This hypothesis reflects that NAFTA explicitly protects Bourbon and Tennessee Whiskey producers in the US in a similar way it protects Tequila producers in Mexico: any product sold in North America as Bourbon or Tennessee Whiskey must be produce in the US.

After including this second hypothesis into the benchmark model, this paper shows that the model cannot account for an increase in the number of small distilleries that sell expensive Tequila while keeping the number of Bourbon producers unchanged when there is a reduction in transportation costs. The problem with this hypothesis is that, as section 2 shows, the number of total distilleries of Bourbon and Tennessee Whiskey remains mostly unchanged throughout the same period.

The third hypothesis assumes that preferences are non-homothetic and the United States does not produce a close substitute to Tequila. In this version, consumer preferences are represented by "price independent generalized linear utility" (Muellbauer, 1976). This assumption tests the impact of income distribution in the size distribution of firms.

In this third case, the benchmark model predicts that the size of the smallest firm increases after a reduction in transportation costs. Nevertheless, this is not what we observe on data: the number of small distilleries is what increases significantly, not the size of the smallest distillery. Thus, this third hypothesis is discarded as a possible explanation as well.

This paper proposes a puzzle in the literature of firm size heterogeneity and international trade. In this sub-field, Melitz (2003) and Bernard et al. (2000) are the standard theories. Neither approach can explain the evolution of the size distribution of Tequila producers.

Melitz (2003) extends the competitive model with heterogenous firms (Hopenhayn, 1992) to an environment with monopolistic competition (Dixit and Stiglitz, 1977) and international trade. Chaney (2008) shows that Melitz (2003) can overturn the predictions in Krugman (1980), a model of monopolistic competition and international trade with homogenous size firms. In both cases, Chaney (2008) and Krugman (1980), the number of firms within the industry is smaller after a reduction in tariffs, contrary to the experience in the Tequila sector.

Andrew Bernard et. al. (2003) extends the Ricardian environment in Dornbusch et al. (1977) to include heterogenous firms within industries. Their goal is to explain the evidence documented by Bernard et al. (1995) in the US: large plants within narrowly defined industries are more likely to be exporters than small plants, and firms only export a small fraction of their output. Thus, the evolution of the Tequila industry does not fit in this pattern.

Holmes and Stevens (2014) use a version of Bernard et. al. (2003) to argue that large plants produce a different type of goods than small plants even when Census data classify them in the same industry. In this case, smaller plants are less likely to export as well. Therefore, this story cannot account for the phenomenon in the Tequila industry either.

The rest of the paper proceeds as follows: section 2 describes the change in the size distribution of Tequila distilleries, shows that the number of Bourbon and Tennessee Whiskey producers remains mostly constant, and illustrates how NAFTA protects Tequila, Bourbon, and Tennessee Whiskey producers; section 3 displays the version of the model in which Tequila does not have a close substitute being produced in the US; section 4 describes the version of Melitz in which the US produces a close substitute to Tequila; section 5 exhibits the version of Melitz with “price independent generalized linearity” utility; and section 6 concludes the paper.

2.2 NAFTA and Tequila, Bourbon, and Tennessee Whiskey

This section shows three things: (1) the drastic change in the distribution of Tequila distilleries after NAFTA was implemented, (2) how the number of Bourbon and Tennessee Whiskey distilleries remained mostly unchanged, and (3) how NAFTA protects these three industries with a policy of Denomination of Origin.

2.2.1 Regional Products

NAFTA protects the Tequila, Bourbon, and Tennessee Whiskey industries in a special section called “Regional Products” (NAFTA, 2015). In particular for these three industries, this section protects them with the following two paragraphs:

> 1. Canada and Mexico shall recognize Bourbon Whiskey and Tennessee Whiskey, which is a straight Bourbon Whiskey authorized to be produced only in the State of Tennessee, as distinctive products of the United States. Accordingly, Canada and Mexico shall not permit the sale of any product as Bourbon Whiskey or Tennessee Whiskey, unless it has been manufactured in the United States in accordance with the laws and regulations of the United States governing the manufacture of Bourbon Whiskey and Tennessee Whiskey.
>
> 3. Canada and the United States shall recognize Tequila and Mescal as distinctive products of Mexico. Accordingly, Canada and the United States shall not permit the sale of any product as Tequila or Mescal, unless it has been manufactured in Mexico in accordance with the laws and regulations of Mexico governing the manufacture of Tequila and Mescal. This provision shall apply to Mescal, either on the date of entry into force of this Agreement, or 90 days after the date when the official standard for this product is made obligatory by the Government of Mexico, whichever is later.

2.2.2 Size distribution of distilleries in the Tequila industry

According to Mexican regulations, any Tequila distillery must be registered at the Consejo Regulador del Tequila (Tequila Regulation Council). Table 2.1 shows the number of distilleries officially registered to produce Tequila according to the size of their output for 1995 and 2012. In 1995, the first year for which there are clear records, the total number of distilleries registered to produce Tequila is 36. Previously, in the early 90’s before the enactment of NAFTA, the total number of distilleries was between 30 and 34. In 2012, the total number of distilleries reached 155. Notice that most of this increment comes from the birth of many “micro distilleries” (those that produce under 300,000 liters of Tequila yearly normalized at 40% alcohol content). The number of this type of distilleries went from 13 in 1995 to 116 in 2012. While the Tequila Council cannot provide exact numbers, they argue that most of these new micro distilleries were born as firms highly engaged in exports.

Table 2.1: Number of Tequila distilleries by output

TABLE 1: NUMBER OF TEQUILA DISTILERIES BY OUTPUT

YEAR	$X \leq 0.3$	$0.3 < X \leq 1$	$1 < X \leq 3$	$3 < X$
1995	13	9	9	5
2012	116	14	11	14

X: Millions of liters of Tequila produced at 40% alcohol content.
Data provided by the Consejo Regulador del Tequila.

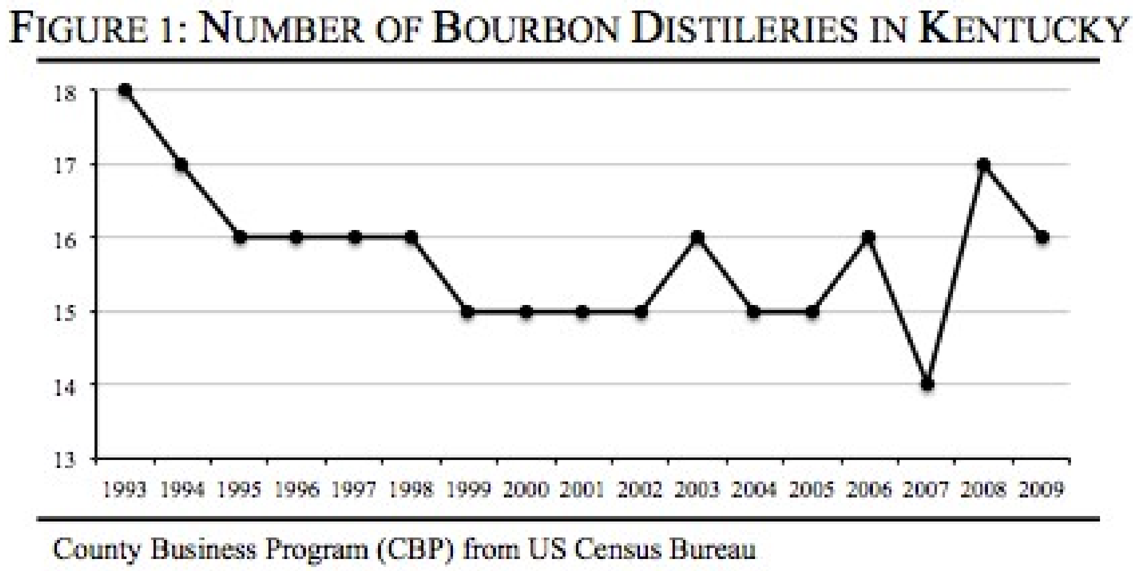
To show some examples of how these newly born distilleries were highly engaged in exports, the Consejo Regulador del Tequila provided the contact of some micro distilleries for the development of this project. One of these examples is Casa Maestri. This distillery was born after the enactment of NAFTA; 99% of its production is sold in the United States. In a personal interview, his CEO explained that most of his production is customized to satisfy the american market. Thus, they employ more expensive methods to distill and bottle their Tequila than large manufacturers, this makes their prices be higher than the average.

2.2.3 Size distribution of Bourbon and Tennessee Whiskey distilleries

The Tennessee Whiskey industry currently has 5 distilleries only. The two largest have been around since the 1870's: Jack Daniel's and George Dickel. The other three were born much recently and are significantly smaller that the former two: Benjamin Pichard's (born in 1997), Corsair Artisan (born in 2010), and Collier McKeel (born in 2010).

The Bourbon industry in Kentucky has remained mostly unchanged as well. As Figure 2.1 shows, the total number of registered Bourbon distilleries in the County Business Patterns (CBP) from the US Census Bureau fluctuates between 14 and 18 from 1993 to 2009. Most years, the number of distilleries were between 15 and 16 (Coomes and Kornstein, 2012).

Figure 2.1: Number of registered Bourbon distilleries in Kentucky



2.3 Hypothesis 1: The US cannot produce a close substitute for Tequila

This section presents a version of the Melitz model with two countries: Mexico and the US. In this version, only Mexico produces a good for which individuals have love-for-variety preferences. This paper thinks of Tequila being that good. On the other hand, both countries produce a homogenous, freely tradable good.

This section shows that a model of this type is unable to explain the explosion in the number of Tequila distilleries after a reduction in transportation costs, because the model predicts that transportation costs has no effect on the size distribution of Tequila distilleries.

2.3.1 Households

Assume that households in country j, $j \in \{mx, us\}$, have the following indirect utility function:

$$\log(w_j h) - (1-\gamma)\log p_0^j - \frac{\gamma}{1-\sigma}\log\left(\int_0^{n_{mx}^j} p_{mx}^j(i)^{1-\sigma}\,di\right) \tag{2.1}$$

Here, $w_j h$ is the wage income of a household in country j with efficiency units of labor h; p_0^j is the price of the numeraire good in country j; $p_{mx}^j(i)$ is the price of variety of Tequila i in country j; n_{mx}^j is the measure of varieties of Tequila consumed in country j; $\gamma \in (0,1)$ is the share of income spent on Tequila; and $\sigma > 1$ is the elasticity of substitution between varieties of liquor. Notice that this indirect utility function is dual to the (direct) utility function:

$$(1-\gamma)\log c_0^j + \frac{\gamma}{\rho}\log\left(\int_0^{n_{mx}^j} c_{mx}^j(i)^{\rho}\,di\right) \tag{2.2}$$

where $\rho = {}^{(\sigma-1)}/_{\sigma}$.

Using Roy's identity, we can calculate the demand functions:

$$c_0^j(h) = \frac{(1-\gamma)\,wh}{p_0^j} \tag{2.3}$$

$$c_{mx}^j(i) = \frac{\gamma wh}{p_{mx}^j(i)^{\frac{1}{1-\rho}}\,P_j^{\frac{-\rho}{1-\rho}}} \tag{2.4}$$

where

$$P_j = \left(\int_0^{n_{mx}^j} p_{mx}^j(i)^{\frac{-\rho}{1-\rho}}\,di\right)^{\frac{1-\rho}{-\rho}} \tag{2.5}$$

is the standard constant elasticity of substitution price index for Tequila in country j.

Further, assume that there is a mass of households m_{mx} in Mexico who have a distribution of effective labor units that follows a Pareto distribution $h : 1 - \underline{h}_{mx}^{\eta} h^{-\eta}$ with minimum effective labor units $\underline{h}_{mx}$. Similarly, assume that, in the United States, there is a mass of households m_{us} and a Pareto distribution of effective labor units $h : 1 - \underline{h}_{us}^{\eta} h^{-\eta}$. Notice that the mean effective labor in country j is

$$\bar{h}_j = \int_{\underline{h}_j}^{\infty} h\eta \underline{h}_j^{\eta} h^{-\eta-1}dh = -\frac{\eta}{\eta-1}\underline{h}_j^{\eta} h^{-\eta+1} \mid_{\underline{h}_j}^{\infty} = \frac{\eta}{\eta-1}\underline{h}_j \tag{2.6}$$

In a calibrated model, m_{mx} and m_{us} can be chosen to match the relative sizes of populations of Mexico and the United States, and $\underline{h}_{mx}$ and $\underline{h}_{us}$ can be chosen to match relative mean household incomes.

2.3.2 Firms

This model has two types of industries. One of them produces the numeraire good; it operates in both countries. Given that we can adjust $\underline{h}_{mx}$ and $\underline{h}_{us}$, we assume that the production fuctions are the same in Mexico and United States:

$$y_{oj} = h_{oj} \tag{2.7}$$

Assume that the numeraire good is freely traded across countries. If the numeraire good is produced in both countries in equilibrium, then the price of the numeraire good and wages per effective unit across countries are equalized in equilibrium, $p_0^{mx} = p_0^{us}$ and $w_{mx} = w_{us}$. Notice that this will be the case when the fraction of income spent on Tequila, γ, is sufficiently small.

The other industry is the Tequila sector. The producers in this sector are located in Mexico only. Each firm i in this industry has increasing returns to scale in the form of a fixed cost f_{mx}^{mx} of producing for domestic consumption plus a constant marginal cost $z(i)^{-1}$, where $z(i)$ is the efficiency of firm i. In case where the good is shipped to the United States, the firm pays a fixed cost f_{mx}^{us} and there is an iceberg cost to transport the good $\tau_{mx}^{us} - 1 \geq 0$. This model interprets NAFTA as a reduction in this cost. The production functions are

$$y_{mx}^{mx}(i) = z(i) \max\{h_{mx}^{mx}(i) - f_{mx}^{mx}, 0\} \tag{2.8}$$

$$y_{mx}^{us}(i) = \frac{z(i)}{\tau_{mx}^{us}} \max\{h_{mx}^{us}(i) - f_{mx}^{us}, 0\} \tag{2.9}$$

where $z(i)$ is drawn from a Pareto distribution $z(i) : 1 - z^{-\theta}$ with a cost of a draw ϕ.

2.3.3 Equilibrium

Since individual demands are linear in income, all that matters is the total labor endowment in each country:

$$H_J = m_j \int_{\underline{h}_j}^{\infty} h\eta \underline{h}^{\eta}_j h^{-\eta-1} dh = m_j \eta \underline{h}_j^{\eta} \int_{\underline{h}_j}^{\infty} h^{-\eta} dh = m_j \frac{\eta \underline{h}_j}{\eta - 1} \tag{2.10}$$

which, in turn, implies that the demand for good i is

$$c_{mx}^{mx}(i) = \frac{\gamma w H_{mx}}{p_{mx}^{mx}(i)^{\frac{1}{1-\rho}} P_{mx}^{\frac{-\rho}{1-\rho}}} \tag{2.11}$$

where

$$P_{mx} = \left(\mu \int_0^{n_{mx}^{mx}} p_{mx}^{mx}(j)^{\frac{-\rho}{1-\rho}} dj \right)^{\frac{\rho-1}{\rho}} \tag{2.12}$$

is the standard Dixit-Stiglitz price aggregator. Similarly, the demand for good i in the United States is

$$c_{mx}^{us}(i) = \frac{\gamma w H_{us}}{p_{mx}^{us}(i)^{\frac{1}{1-\rho}} P_{us}^{\frac{-\rho}{1-\rho}}} \tag{2.13}$$

where

$$P_{us} = \left(\mu \int_0^{n_{mx}^{us}} p_{mx}^{us}(j)^{\frac{-\rho}{1-\rho}} dj \right)^{\frac{\rho-1}{\rho}} \tag{2.14}$$

Solving the firm's profit maximization problem, we obtain

$$\begin{aligned} p_{mx}^{mx}(i) &= \tfrac{w}{\rho z(i)} \\ p_{mx}^{us}(i) &= \tfrac{\tau w}{\rho z(i)} \end{aligned} \tag{2.15}$$

From now on, firms will be indexed by z rather than by i, and wages will be normalized to one, $w = 1$. Consequently, the expressions for individual prices, price index, and aggregate demand per variety in Mexico are

$$p_{mx}^{mx}(z) = \frac{1}{\rho z} \tag{2.16}$$

$$P_{mx} = \left(\frac{\mu \rho^{\frac{\rho}{1-\rho}} (1-\rho)\, \theta \left(\widehat{z}_{mx}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}}{\theta(1-\rho) - \rho} \right)^{\frac{1-\rho}{-\rho}} \tag{2.17}$$

$$c_{mx}^{mx}(z) = \frac{(\theta(1-\rho)-\rho)\rho z^{\frac{1}{1-\rho}}\gamma H_{mx}}{\mu(1-\rho)\theta(\widehat{z}_{mx}^{mx})^{\frac{\rho-\theta(1-\rho)}{1-\rho}}} \tag{2.18}$$

Similarly, for the case of the United States

$$p_{mx}^{us}(z) = \frac{\tau}{\rho z} \tag{2.19}$$

$$P_{us} = \left(\frac{\tau^{\frac{-\rho}{1-\rho}}\mu\rho^{\frac{\rho}{1-\rho}}(1-\rho)\theta(\widehat{z}_{mx}^{us})^{\frac{\rho-\theta(1-\rho)}{1-\rho}}}{\theta(1-\rho)-\rho}\right)^{\frac{1-\rho}{-\rho}} \tag{2.20}$$

$$c_{mx}^{us}(z) = \frac{(\theta(1-\rho)-\rho)\rho z^{\frac{1}{1-\rho}}\gamma H_{us}}{\tau\mu(1-\rho)\theta(\widehat{z}_{mx}^{us})^{\frac{\rho-\theta(1-\rho)}{1-\rho}}} \tag{2.21}$$

where $\widehat{z}_{mx}^{mx}$ is the productivity of the least productive firm that makes Tequila for local consumption (also known as the cut-off productivity of local producers), $\widehat{z}_{mx}^{us}$ is the productivity of the least productive firm that exports (also known as the cut-off productivity of exporters), and μ is the mass of firms.

To calculate the cut-off productivities, it is necessary to use the zero profit condition of the leads productive firm:

$$p_{mx}^{mx}(\hat{z}_{mx}^{mx})\,c_{mx}^{mx}(\hat{z}_{mx}^{mx}) - \frac{c_{mx}^{mx}(\hat{z}_{mx})}{\hat{z}_{mx}^{mx}} - f_{mx}^{mx} = 0 \tag{2.22}$$

Thus, after substituting for the demands and the price, the cut-off productivity is

$$(\hat{z}_{mx}^{mx})^{-\theta} = \frac{(\theta(1-\rho)-\rho)\gamma H_{mx}}{\mu\theta f_{mx}^{mx}} \tag{2.23}$$

In a similar way, the zero profit condition of the least productive exporter can be used to derive the cut-off productivity of exporters:

$$p_{mx}^{us}(\hat{z}_{mx}^{us})\,c_{mx}^{us}(\hat{z}_{mx}^{us}) - \frac{\tau c_{mx}^{us}(\hat{z}_{mx}^{us})}{\hat{z}_{mx}^{us}} - f_{mx}^{us} = 0 \tag{2.24}$$

thus,

$$(\hat{z}_{mx}^{us})^{-\theta} = \frac{(\theta(1-\rho)-\rho)\gamma H_{us}}{\mu\theta f_{mx}^{us}} \tag{2.25}$$

Notice that both productivities, $\hat{z}_{mx}^{mx}$ and $\hat{z}_{mx}^{us}$, are written in terms of the mass of firms, μ, which is also an unknown variable. To find this number, it is necessary to use the costly entry condition.

The costly entry condition states that the cost of entering, ϕ, has to be equal to the value of entering to the economy. Mathematically, this is

$$\mu\phi = \mu \int_{\hat{z}_{mx}^{ms}}^{\infty} \left(p_{mx}^{mx}(z)\, c_{mx}^{mx}(z) - \frac{c_{mx}^{mx}(z)}{z} - f_{mx}^{mx} \right) \theta z^{-\theta-1} dz + \mu \int_{\hat{z}_{mx}^{us}}^{\infty} \left(p_{mx}^{us}(z)\, c_{mx}^{us}(z) - \frac{\tau c_{mx}^{us}(z)}{z} - f_{mx}^{us} \right) \theta z^{-\theta-1} dz \quad (2.26)$$

The previews expression can be simplified to

$$\mu = \frac{\gamma\rho\left(H_{mx} + H_{us}\right)}{\phi\theta} \quad (2.27)$$

Plugging this formula into the expressions for $\hat{z}_{mx}^{mx}$ and $\hat{z}_{mx}^{us}$, the values of the cut-off productivities are found:

$$\left(\hat{z}_{mx}^{mx}\right)^{-\theta} = \frac{\phi\left(\theta\left(1-\rho\right)-\rho\right) H_{mx}}{\rho\left(H_{mx}+H_{us}\right) f_{mx}^{mx}} \quad (2.28)$$

$$\left(\hat{z}_{mx}^{us}\right)^{-\theta} = \frac{\phi\left(\theta\left(1-\rho\right)-\rho\right) H_{us}}{\rho\left(H_{mx}+H_{us}\right) f_{mx}^{us}} \quad (2.29)$$

2.3.4 Analysis

Notice that the expressions for the cut-off productivities and the mass of firms do not depend on the value of transportation costs. Thus, this hypothesis is discarded as a possible explanation.

As a final remark, notice that this version of the model predicts there will be small producers specialized in exports if and only if

$$\frac{H_{mx}}{f_{mx}^{mx}} > \frac{H_{us}}{f_{us}^{us}} \quad (2.30)$$

2.4 Melitz model with liquor industries in both countries

This section the previous model by incorporating varieties of the same good being produced in the United States. In this framework, we assume that Tequila and Whiskey varieties are substitutable. However, given that Mexico systematically exports more liquor to the United States than the other way around, this section assumes that Mexico has a comparative advantage in the production of Tequila.

As it will be shown at the end of this section, this version of the model cannot account for the change in the distribution of Tequila producers, because, if this were the case, the model predicts that the number of Whiskey distilleries should have grown, opposite to what data reveals.

2.4.1 Consumers

Assume that the preferences of the consumers in this model are represented by the following indirect utility function:

$$\log(wh) - (1-\gamma)\log p_0 - \frac{\gamma}{1-\sigma}\log\left(\int_0^{n_{mx}^j} p_{mx}^j(i)^{1-\sigma}\,di + \int_0^{n_{us}^j} p_{us}^j(i)^{1-\sigma}\,di\right) \tag{2.31}$$

Notice that this utility is an extension of the one described by equation (1).

Similar to before, p_0 is the price of the numeraire good; wh is the income of an individual with efficiency units of labor h; $p_k^j(i)$ is the price of variety of liquor i produced in country $k \in \{mx, us\}$ and consumed in country $j \in \{mx, us\}$, and $\sigma = 1/(1-\rho)$ is the elasticity of substitution between varieties of liquor.

Using Roy's identity, the individual demand for each good is given by

$$c_0^j(h) = \frac{(1-\gamma)\,wh}{p_0^j} \tag{2.32}$$

$$c_j^k(i) = \frac{\gamma wh}{p_j^k(i)^{\frac{1}{1-\rho}}\,P_k^{\frac{-\rho}{1-\rho}}} \tag{2.33}$$

Where the price index, P_k, is the standard Dixit-Stiglitz (1977) price aggregator. The assumption regarding effective units of labor done in section 3 stays true for this section as well.

2.4.2 Firms

This section assumes that the production function of the numeraire good is the same as in section 3, given by equation (7). In the same way, the production technology of a variety of the liquor good is given by the following generalization of equation (8) production function:

$$y_j^k(i) = \frac{z(i)}{\tau_j^k} \max\left\{h_j^k(i) - f_j^k, 0\right\} \tag{2.34}$$

Where $y_j^k(i)$ is the amount of variety i produced in country j and exported to country k. As before, $z_j(i)$ is drawn from the Pareto distribution with c.d.f. $z_j(i) \sim 1 - \underline{z}_j^{\theta} z^{-\theta}$ with the cost of a draw ϕ_j. Since this section assumes that Mexico has comparative advantage at the production of liquor, the following inequality holds: $\underline{z}_{mx} > \underline{z}_{us}$.

2.4.3 Equilibrium

This paper is interested in equilibria in which there is a positive production of the numeraire good in both countries. This ensures that $w_{mx} = w_{us}$. Given that individuals have a homothetic utility function, all that matters is the total labor endowment in each country, as we had before, given by equation (10). Hence, the market demands for each variety of liquor is

$$c_j^k(i) = \frac{\gamma w H_k}{p_j^k(i)^{\frac{1}{1-\rho}} P_k^{\frac{-\rho}{1-\rho}}} \tag{2.35}$$

From now on, firms are indexed by z rather than by i, and w is normalized to 1.

Following the profit maximization strategy, the firms that operate decide to set the following prices

$$p_j^j(z) = \frac{w}{\rho z} \tag{2.36}$$

$$p_j^k(z) = \frac{\tau_j^k w}{\rho z} \tag{2.37}$$

which, in turn, implies the following demand

$$c_j^k(z) = \frac{\gamma H_k \rho^{\frac{1}{1-\rho}} z^{\frac{1}{1-\rho}}}{\left(\tau_j^k\right)^{\frac{1}{1-\rho}} P_k^{\frac{-1}{1-\rho}}} \tag{2.38}$$

where

$$P_k = \left(\frac{\rho^{\frac{\rho}{1-\rho}}(1-\rho)\theta\left(\mu_{mx}\left(\tau_{mx}^k\right)^{\frac{-\rho}{1-\rho}} \underline{z}_{mx}^{\theta}\left(\hat{z}_{mx}^k\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}} + \mu_{us}\left(\tau_{us}^k\right)^{\frac{-\rho}{1-\rho}} \underline{z}_{us}^{\theta}\left(\hat{z}_{us}^k\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}\right)}{\theta(1-\rho)-\rho}\right)^{\frac{1-\rho}{-\rho}} \tag{2.39}$$

Consequently,

$$c_j^k(z) = \frac{\rho\left(\theta\left(1-\rho\right)-\rho\right)\gamma H_k z^{\frac{1}{1-\rho}}}{\left(\tau_j^k\right)^{\frac{1}{1-\rho}}\left(1-\rho\right)\theta\left(\mu_{mx}\left(\tau_{mx}^k\right)^{\frac{-\rho}{1-\rho}}\underline{z}_{mx}^{\theta}\left(\hat{z}_{mx}^k\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}+\mu_{us}\left(\tau_{us}^k\right)^{\frac{-\rho}{1-\rho}}\underline{z}_{us}^{\theta}\left(\hat{z}_{us}^k\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}\right)} \tag{2.40}$$

the cut-off level of productivity for producing a good in country j for consumption in country k, $\hat{z}_j^k$, is determined by

$$p_j^{us}\left(\hat{z}_j^k\right)c_j^k\left(\hat{z}_j^k\right)-\frac{\tau_j^k c_j^k\left(\hat{z}_j^k\right)}{\hat{z}_j^k}-f_j^k=0 \tag{2.41}$$

which implies that

$$\frac{\left(\tau_j^k\right)^{\frac{-\rho}{1-\rho}}\left(\theta\left(1-\rho\right)-\rho\right)\gamma H_k\left(\hat{z}_j^k\right)^{\frac{\rho}{1-\rho}}}{\theta\left(\mu_{mx}\left(\tau_{mx}^k\right)^{\frac{-\rho}{1-\rho}}\underline{z}_{mx}^{\theta}\left(\hat{z}_{mx}^k\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}+\mu_{us}\left(\tau_{us}^k\right)^{\frac{-\rho}{1-\rho}}\underline{z}_{us}^{\theta}\left(\hat{z}_{us}^k\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}\right)}-f_j^k=0 \tag{2.42}$$

By dividing the equation that determines $\hat{z}_{mx}^{us}$ by that for $\hat{z}_{us}^{us}$, equation (43) follows:

$$\hat{z}_{mx}^{us}=\hat{z}_{us}^{us}\tau_{mx}^{us}\left(\frac{f_{mx}^{us}}{f_{us}^{us}}\right)^{\frac{1-\rho}{\rho}} \tag{2.43}$$

Similarly,

$$\hat{z}_{us}^{mx}=\hat{z}_{mx}^{mx}\tau_{us}^{mx}\left(\frac{f_{us}^{mx}}{f_{mx}^{mx}}\right)^{\frac{1-\rho}{\rho}} \tag{2.44}$$

The same procedure but for the cut-offs $\hat{z}_{mx}^{mx}$ and $\hat{z}_{mx}^{us}$ yields the following relationship

$$\frac{\left(\hat{z}_{mx}^{mx}\right)^{\frac{\rho}{1-\rho}}}{\left(\hat{z}_{mx}^{us}\right)^{\frac{\rho}{1-\rho}}}=\frac{H_{us}f_{mx}^{mx}}{H_{mx}f_{mx}^{us}}\left(\frac{\mu_{mx}\underline{z}_{mx}^{\theta}\left(\hat{z}_{mx}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}+\mu_{us}\left(\tau_{us}^{mx}\right)^{\frac{-\rho}{1-\rho}}\underline{z}_{us}^{\theta}\left(\hat{z}_{us}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}}{\mu_{mx}\left(\tau_{mx}^{us}\right)^{\frac{-\rho}{1-\rho}}\underline{z}_{mx}^{\theta}\left(\hat{z}_{mx}^{us}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}+\mu_{us}\underline{z}_{us}^{\theta}\left(\hat{z}_{us}^{us}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}}\right)\left(\tau_{mx}^{us}\right)^{\frac{-\rho}{1-\rho}} \tag{2.45}$$

Then, equation (42) can be rewritten for the case of Mexico:

$$\frac{\left(\theta\left(1-\rho\right)-\rho\right)\gamma H_{mx}\left(f_{mx}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{\rho}}\left(\hat{z}_{mx}^{mx}\right)^{\theta}}{\theta\left(\mu_{us}\underline{z}_{mx}^{\theta}\left(\tau_{mx}^{mx}\right)^{-\theta}\left(f_{mx}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{\rho}}+\mu_{us}\underline{z}_{us}^{\theta}\left(\tau_{us}^{mx}\right)^{-\theta}\left(f_{us}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{\rho}}\right)}=f_{mx}^{mx} \tag{2.46}$$

Consequently,

$$\left(\hat{z}_{mx}^{mx}\right)^{-\theta}=\frac{\left(\theta\left(1-\rho\right)-\rho\right)\gamma H_{mx}\left(f_{mx}^{mx}\right)^{\frac{-\theta(1-\rho)}{\rho}}}{\theta\left(\mu_{mx}\underline{z}_{mx}^{\theta}\left(f_{mx}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{\rho}}+\mu_{us}\underline{z}_{us}^{\theta}\left(\tau_{us}^{mx}\right)^{-\theta}\left(f_{us}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{\rho}}\right)} \tag{2.47}$$

Notice that the only variables on the right-hand side of equation (47) are μ_{mx} and μ_{us}. To calculate both, the entry condition must be solved:

$$\phi_{mx} = \frac{(1-\rho)\,\gamma H_{mx} \underline{z}_{mx}^{\theta} \left(\tau_{mx}^{mx}\right)^{\frac{-\rho}{1-\rho}} \left(\hat{z}_{mx}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}}{\left(\mu_{mx} \underline{z}_{mx}^{\theta} \left(\tau_{mx}^{us}\right)^{\frac{-\rho}{1-\rho}} \left(\hat{z}_{mx}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}} + \mu_{us} \underline{z}_{us}^{\theta} \left(\tau_{us}^{mx}\right)^{\frac{-\rho}{1-\rho}} \left(\hat{z}_{us}^{mx}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}\right)}$$
$$- \underline{z}_{mx}^{\theta} f_{mx}^{mx} \left(\hat{z}_{mx}^{mx}\right)^{-\theta} + \frac{(1-\rho)\,\gamma H_{us} \underline{z}_{mx}^{\theta} \left(\tau_{mx}^{us}\right)^{\frac{-\rho}{1-\rho}} \left(\hat{z}_{mx}^{us}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}}{\left(\mu_{mx} \underline{z}_{mx}^{\theta} \left(\tau_{mx}^{us}\right)^{\frac{-\rho}{1-\rho}} \left(\hat{z}_{mx}^{us}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}} + \mu_{us} \underline{z}_{us}^{\theta} \left(\tau_{us}^{us}\right)^{\frac{-\rho}{1-\rho}} \left(\hat{z}_{us}^{us}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}\right)}$$
$$- \underline{z}_{mx}^{\theta} f_{mx}^{us} \left(\hat{z}_{mx}^{us}\right)^{-\theta} \tag{2.48}$$

Substituting (47) into (48), the following equation is found:

$$\phi_{mx} = \sum_{j=mx,us} \left\{ \frac{(1-\rho)\,\gamma H_j \underline{z}_{mx}^{\theta} \left(\tau_{mx}^{j}\right)^{\frac{-\rho}{1-\rho}} \left(\hat{z}_{mx}^{j}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}}{\sum_{i'=mx,us} \mu_{i'} \underline{z}_{i'}^{\theta} \left(t_{i'}^{j}\right)^{\frac{-\rho}{1-\rho}} \left(\hat{z}_{i'}^{j}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}} - \frac{(\theta(1-\rho)-\rho)\,\gamma H_j \left(\tau_{mx}^{j}\right)^{-\theta} \left(f_{mx}^{j}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}}{\theta \sum_{i'=mx,us} \mu_{i'} \underline{z}_{i'}^{\theta} \left(\tau_{i'}^{j}\right)^{\frac{-\rho}{1-\rho}} \left(f_{i'}^{j}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}} \right\} \tag{2.49}$$

Substituting (49) in (47),

$$\sum_{j=mx,us} \left\{ \frac{H_j \left(\tau_{mx}^{j}\right)^{-\theta} \left(f_{mx}^{j}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}}{\sum_{i'=mx,us} \mu_{i'} \underline{z}_{i'}^{\theta} \left(\tau_{i'}^{j}\right)^{\frac{-\rho}{1-\rho}} \left(f_{i'}^{j}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}} \right\} = \frac{\phi_{mx}\theta}{\rho\gamma} \tag{2.50}$$

Similarly for the United States,

$$\sum_{j=mx,us} \left\{ \frac{H_j \left(\tau_{us}^{j}\right)^{-\theta} \left(f_{us}^{j}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}}{\sum_{i'=mx,us} \mu_{i'} \underline{z}_{i'}^{\theta} \left(\tau_{i'}^{j}\right)^{\frac{-\rho}{1-\rho}} \left(f_{i'}^{j}\right)^{\frac{\rho-\theta(1-\rho)}{1-\rho}}} \right\} = \frac{\phi_{us}\theta}{\rho\gamma} \tag{2.51}$$

Equations (50) and (51) determine the mass of firms operating in each market, μ_{mx} and μ_{us}, which, using equation (47) determines the cut-off for Mexican firms selling to their domestic market, $\hat{z}_{mx}^{mx}$. Finally, equations (43), (44), and (45) determine the remaining cut-offs: $\hat{z}_{us}^{mx}$, $\hat{z}_{mx}^{us}$, and $\hat{z}_{us}^{us}$. Hence, this becomes a system of six equations with six unknowns. This system characterizes the equilibrium.

2.4.4 Analysis

This part shows that this model in unable to account for a fall in the cut-off producer in Mexico, and increase in the measure of firms producing in Mexico, while it keeps the mass of firms in the United States and the cut-off producer in the US unchanged. This is done by introducing a tariff reduction, $\triangle\tau_{us}^{mx} < 0$ and $\triangle\tau_{ms}^{us} < 0$, in the six equations that characterize the equilibrium – equations (43), (44), (45), (47), (50), and (51) – and showing that it is impossible to keep the variables in the United States without changing – $\triangle\hat{z}_{us}^{us} = 0$, $\triangle\hat{z}_{us}^{mx} = 0$, and $\triangle\mu_{us} = 0$ – while the cut-off firm in Mexico falls, $\triangle \min\{\hat{z}_{mx}^{us}, \hat{z}_{mx}^{mx}\} < 0$, and the mass of firms operating in Mexico increases, $\triangle\mu_{us} = 0$.

From equations (43) and (44), it can be seen that a fall in both iceberg costs, while keeping constant the cutoffs for the United States, is consistent only with a fall in the export cut-off in Mexico, and an increase in the domestic cut-off for Mexican firms selling to the domestic market. This, together with the condition that the lowest cut-off in Mexico should fall after the fall in tariffs implies that our equilibrium requires $\hat{z}_{mx}^{us} < \hat{z}_{mx}^{mx}$. This condition can easily be met as long as the size of the United States is sufficiently larger than the size of Mexico (see equation (45)). Furthermore, from the analysis of equations (43) and (44), it can be deduced that the changes in cut-offs has to satisfy $\triangle\hat{z}_{mx}^{us} = \triangle\tau_{mx}^{us}$ and $\triangle\hat{z}_{mx}^{mx} = -\triangle\tau_{us}^{mx}$.

Now, lets focus on equation (45). Notice that this equation can meet the desired requirements outlined before as long as the change in the mass of firms from Mexico is proportional to the change of tariffs, $\triangle\mu_{mx} = -\triangle{\tau_{mx}^{us}}^{\theta}$, and as long as the change in tariffs are of the same magnitude, $\triangle\tau_{us}^{mx} = \triangle\tau_{mx}^{us}$. Even more, under these restrictions, equation (47) still holds.

However, the problem arises when it is verified if these restrictions can be applied to the last two equations, (50) and (51). For example, pick equation (50). Under the aforementioned restrictions, it is easy to see that the left-hand side term should fall (both denominators increase, and the numerator of one of the terms falls while the other one stays constant), but the right-hand side term has to stay constant. Hence, it cannot be reconciled, at once, the fall in the cut-off for Mexican firms, the increase in the mass of Mexican firms, and the absence of change in the mass of US firms.

2.5 "Price independent generalized linearity" preferences

This section describes an international trade model of Tequila with a change in the preferences from the the standard models. The demand structure follows "price independent generalized linearity" preferences proposed by Muellbuer (1975) which cannot, in general, be expressed by means of direct utility functions, but, instead, are represented by indirect utility functions. However, the class of preferences described by this indirect utility function is consistent with well-behaved utility functions.

2.5.1 Consumers

Consumers derive utility from the following version of the indirect utility function of Boppart (2014), in which, different from Boppart, we assume that one of the sectors is a Dixit-Stiglitz aggregate of Tequila:

$$v\left(wh, \left(p_{mx}^{j}(i)\right), p_0^j\right) = \frac{1}{\varepsilon}\left(\frac{wh}{\left(\int_0^{n_{mx}^j} p_{mx}^j(i)^{\frac{-\rho}{1-\rho}}\, di\right)^{\frac{1-\rho}{-\rho}}}\right)^{\varepsilon} - \frac{\beta}{\gamma}\left(\frac{p_0^j}{\left(\int_0^{n_{mx}^j} p_{mx}^j(i)^{\frac{-\rho}{1-\rho}}\, di\right)^{\frac{1-\rho}{-\rho}}}\right)^{\gamma} \tag{2.52}$$

where p_0^j is the price of the numeraire good by an individual with efficiency units of labor h (and, hence, income wh) of country $j \in \{mx, us\}$, $p_{mx}^j(i)$ is the price of variety of Tequila i, n_{mx}^j is the measure of varieties of Tequila consumed in $j \in \{mx, us\}$, and $\sigma = 1/(1-\rho)$ is the elasticity of substitution between varieties of Tequila. As in Boppart, this paper assumes that $\varepsilon < \gamma < 1$.

The indirect utility in (52) induces the following consumption functions:

$$\begin{gathered} c_{mx}^j(i) = \left(1 - \beta\frac{h^{-\varepsilon}p_0^{\gamma}}{\left(\int_0^{n_{mx}^j} p_{mx}^j(i)^{\frac{-\rho}{1-\rho}} di\right)^{\left(\frac{\rho-1}{\rho}\right)(\gamma-\varepsilon)}}\right)\frac{hp_{mx}^j(i)^{\frac{-1}{1-\rho}}}{\int_0^{n_{mx}^j} p_{mx}^j(i)^{\frac{-\rho}{1-\rho}} di} \\ c_o^j = \beta\left(\frac{h^{1-\varepsilon}p_0^{\gamma.1}}{\left(\int_0^{n_{mx}^j} p_{mx}^j(i)^{\frac{-\rho}{1-\rho}} di\right)^{\left(\frac{\rho-1}{\rho}\right)(\gamma-\varepsilon)}}\right) \end{gathered} \tag{2.53}$$

This section makes use of the same assumptions of effective labor units as in Section 3.1.

2.5.2 Firms

Similarly, this section follows the same assumptions regarding the distribution of technologies, the production of the numeraire good, and the iceberg cost done in Section 3.2.

2.5.3 Equilibrium

Hence, by normalizing the price of good 0, the market demand for each variety can be found by adding all individual demands for that variety. Equation (54) shows the market demand in country j for the variety of Tequila produced using productivity z:

$$Q_{mx}^{j}(z) = \left(H_{j,1} - \beta H_{j,2} P_j^{-\varepsilon+\gamma}\right) P_j^{\frac{\rho}{1-\rho}} p_{mx}^{j}(z)^{\frac{-1}{1-\rho}} \tag{2.54}$$

where the price index is the standard Dixit-Stiglitz price aggregator, like the one shown in (12), and the wealth aggregates are given by

$$H_{j,1} = m_j \int_{\underline{h}_j}^{\infty} h\eta \underline{h}_j^{\eta} h^{-\eta-1} dh = \frac{m_j \underline{h}_j \eta}{\eta - 1} \tag{2.55}$$

$$H_{j,2} = m_j \int_{\underline{h}_j}^{\infty} h^{1-\varepsilon} \eta \underline{h}_j^{\eta} h^{-\eta-1} dh = \frac{m_j \underline{h}_j^{1-\varepsilon} \eta}{\eta + \varepsilon - 1} \tag{2.56}$$

Solving the firm's maximization problem, the profit-maximizing price given productivity z is

$$p_k^j(z) = \frac{\tau_{mx}^{j}}{\rho z} \tag{2.57}$$

Consequently, the aggregate price index is exactly the same as in the first model:

$$P_j = \frac{\tau_{mx}^{j}}{\hat{z}_{mx}^{j} \rho} \left(\frac{\mu\theta (1-\rho)}{\theta(1-\rho) - \rho} \left(\frac{\underline{z}_{mx}}{\hat{z}_{mx}^{j}} \right)^{\theta} \right)^{\frac{\rho-1}{\rho}} \tag{2.58}$$

Now, the cut-off productivity for a firm in Mexico selling in country j can be determined:

$$\hat{z}_{mx}^{j-\theta} = \frac{(1-\rho)\theta - \rho}{\underline{z}_{mx}^{\theta} \mu \theta f_j} \left(H_{j,1} - \beta H_{j,2} P_j^{-\varepsilon+\gamma}\right) \tag{2.59}$$

This model also requires that the costly entry condition is satisfied. Just like it was done before, this is achieved by equating expected profits from entering to the market with the cost of entry, which, in turn, delivers

$$\mu = \frac{\rho}{\theta\phi} \left(H_{mx,1} - \beta H_{mx,2} P_{mx}^{-\varepsilon+\gamma} + H_{us,1} - \beta H_{us,2} P_{us}^{-\varepsilon+\gamma}\right) \tag{2.60}$$

Substituting (60) into the two version of equation (59), the two cut-off conditions are found:

$$\left(\hat{z}_{mx}^{mx}\right)^{\theta}=\frac{1+\frac{H_{us,1}-\beta H_{us,2}P_{us}^{-\varepsilon+\gamma}}{H_{mx,1}-\beta H_{mx,2}P_{mx}^{-\varepsilon+\gamma}}}{\left(\frac{\phi}{\rho}\right)\left(\frac{(1-\rho)\theta-\rho}{\underline{z}_{mx}^{\theta}f_{mx}}\right)} \tag{2.61}$$

$$\left(\hat{z}_{mx}^{us}\right)^{\theta}=\frac{1+\frac{H_{mx,1}-\beta H_{mx,2}P_{mx}^{-\varepsilon+\gamma}}{H_{us,1}-\beta H_{us,2}P_{us}^{-\varepsilon+\gamma}}}{\left(\frac{\phi}{\rho}\right)\left(\frac{(1-\rho)\theta-\rho}{\underline{z}_{mx}^{\theta}f_{mx}}\right)} \tag{2.62}$$

2.5.4 Impact of a reduction in tariffs

This part shows that a reduction in transportation costs increases the cut-off productivity of Tequila producers that export, and it has no impact on the cut-off productivity of the distilleries that sell in Mexico.

To prove this, first, this section constructs an equation that characterizes the mapping from parameters to equilibrium variables. Then, it implicitly differentiates each of the cut-off productivities with respect to the transportation cost. Finally, it shows that the value of the derivative of the cut-off productivity of the firms that sell in Mexico with respect to the transportation cost is zero while the derivative of the cut-off productivity of the firms that export is strictly positive.

To build the equation that characterizes the mapping from parameters to equilibrium variables, I add the three conditions stated in the following definition of equilibrium:

The equilibrium in this environment is a vector $(\hat{z}_{mx},\hat{z}_{us},\hat{\mu})$ such that satisfies the following three conditions: (i) $\pi_{mx}(\hat{z}_{mx},\hat{\mu})=0$, (ii) $\pi_{us}(\hat{z}_{us},\hat{\mu})=0$, and (iii) $\hat{\mu}\phi=\hat{\mu}\int_{\hat{z}_{mx}}^{\infty}\pi_{mx}(z,\hat{\mu})\,\theta z^{-\theta-1}\underline{z}^{\theta}dz+\hat{\mu}\int_{\hat{z}_{mx}}^{\infty}\pi_{mx}(z,\hat{\mu})\,\theta z^{-\theta-1}\underline{z}^{\theta}dz$.

The first condition is the zero-profits condition of the firms with the cut-off productivity that supplies Mexico; the second condition is the equivalent zero-profits condition for the firms with the cut-off productivity that supply the US; and (iii) is the costly-entry condition.

Thus, the equation that characterizes the equilibrium is

$$\int_{\hat{z}_{mx}}^{\infty}\pi_{mx}(z,\hat{\mu})\,\theta z^{-\theta-1}\underline{z}^{\theta}dz + \int_{\hat{z}_{mx}}^{\infty}\pi_{mx}(z,\hat{\mu})\,\theta z^{-\theta-1}\underline{z}^{\theta}dz-\phi+\pi_{mx}(\hat{z}_{mx},\hat{\mu})+\pi_{us}(\hat{z}_{us},\hat{\mu})=0 \tag{2.63}$$

To show the impact on the cut-off productivities caused by a reduction in transportation costs, this section differentiates both cut-offs with respect to transportation costs using (63).

(64) shows the derivative of the cut-off productivity of the distilleries that supply the US with respect to transportation costs:

$$\begin{aligned} &-\beta p_0^{\alpha}\left(\varepsilon-\gamma\right)P_{us}^{\varepsilon-\gamma-1}w^{1-\varepsilon}H_{us,2}\left[\left(\frac{\partial P_{us}}{\partial\hat{z}_{us}}\right)\left(\frac{\delta\hat{z}_{us}}{\partial\tau}\right)+\frac{\partial P_{us}}{\partial\tau}\right]\left[\hat{z}_{us}^{\theta}\left(\theta\left(1-\gamma\right)-\gamma\right)+1-\rho\right] \\ &\quad+\left(wH_{us,1}-\beta p_0^{\gamma}P_{us}^{\varepsilon-\gamma}w^{1-\varepsilon}H_{us,2}\right)\left(\theta\left(1-\rho\right)-\rho\right)\theta\hat{z}^{\theta-1}\left(\frac{d\hat{z}_{us}}{d\tau}\right) \\ &\quad\quad+\theta\hat{\mu}wf_{us}\underline{z}_{us}^{\theta}\hat{z}_{us}^{-\theta-1}\left(\frac{d\hat{z}_{us}}{d\tau}\right)=0 \end{aligned} \tag{2.64}$$

Notice that

$$\frac{\partial P_{us}}{\partial\hat{z}_{us}}=\left(\frac{\theta\left(1-\rho\right)-\rho}{\rho}\right)\frac{P_{us}}{\hat{z}_{us}} \tag{2.65}$$

$$\frac{\partial P_{us}}{\partial\tau}=\frac{P_{us}}{\tau} \tag{2.66}$$

Thus, the impact of a reduction in transportation costs on the cut-off productivity of firms that sell in the US is negative:

$$\frac{d\hat{z}_{us}}{d\tau}<0 \tag{2.67}$$

Now, I will take the derivative of the cut-off productivity of the firms that supply Mexico with respect to transportation costs:

$$\begin{aligned} &-\left(\varepsilon-\gamma\right)\beta p_0^{\gamma}P_{mx}^{\varepsilon-\gamma-1}w^{1-\varepsilon}H_{mx,2}\left(\frac{\partial P_{mx}}{\partial\hat{z}_{mx}}\right)\left(\frac{d\hat{z}_{mx}}{d\tau}\right)\left[\hat{z}_{mx}^{\theta}\left(\theta\left(1-\rho\right)-\rho\right)+1-\rho\right] \\ &+\left(wH_{mx,1}-\beta p_0^{\gamma}P_{mx}^{\varepsilon-\gamma}w^{1-\varepsilon}H_{mx,2}\right)\theta\hat{z}_{mx}^{\theta-1}\left(\frac{d\hat{z}_{mx}}{d\tau}\right)\left(\theta\left(1-\rho\right)-\rho\right)+\theta\hat{\mu}wf_{mx}\underline{z}_{mx}^{\theta}\hat{z}_{mx}^{-\theta-1}\left(\frac{d\hat{z}_{mx}}{d\tau}\right)=0 \end{aligned} \tag{2.68}$$

Therefore, the value of the derivative is zero:

$$\frac{d\hat{z}_{mx}}{d\tau}=0 \tag{2.69}$$

2.5.5 Analysis

This final part shows that the the model predicts that the smallest firm that exports increases size after a reduction in transportation costs. Nonetheless, this is not consistent with data. Data shows that the smallest firms are still producing less than 300,000 liters of Tequila, but there are many more of these distilleries operating now.

To show that the smallest firm increases size after a reduction in tariffs, I employ equation (57) and the zero profits condition of the smallest firm. these two equations imply the following relation:

$$p(\hat{z})\,Q(\hat{z}) - \frac{w\tau}{\hat{z}}Q(\hat{z}) - wf = p(\hat{z})\,Q(\hat{z})\,(1-\rho) - wf = 0 \tag{2.70}$$

Equation (57) implies that a reduction in transportation costs and an increment in the cut-off productivity reduces the price of the Tequila supplied by the cut-off technology. Thus, by using equation (70), it is easy to verify that the quantity produced of the firm with the cut-off productivity must increase to make zero-profits. Otherwise, its profits would be negative.

2.6 Conclusions

This paper develops three versions of the Melitz (2003) to show its incapability to account for the sharp increase in the number of Tequila distilleries, especially the small and high price exporters after NAFTA. Each version includes a realistic and particular feature of the Tequila industry.

The first version addresses the Denomination of Origin protection that NAFTA assigns to Tequila producers in Mexico. This feature is incorporated into the Melitz (2003) model by assuming that Tequila does not have a close substitute being produced in the US. In studying this version of the model, it finds that a reduction in transportation costs has no impact on the size distribution of Tequila distilleries. Hence, this assumption version is discarded as a possible explanation.

The second version addresses that NAFTA protects Bourbon and Tennessee Whiskey producers in the US similarly to the way it protects Tequila producers in Mexico. This feature is incorporated into Melitz (2003) by assuming that Bourbon and Tennessee Whiskey are close substitutes to Tequila. As this paper shows, this version of the model cannot account for an increase in the number of small, high-priced producers in Mexico while not changing the number of producers in the United States after a reduction in transportation costs. Yet, data shows that the number of producers in both american industries remained mostly unchanged.

The third version addresses the impact of income distribution on the market demands for Tequila, Bourbon, and Tennessee Whiskey producers. This feature is incorporated by making consumer preferences be non-homothetic. Instead, this paper employs the "price independent generalized linearity" utility functions developed by Muellbauer (1976). In this version, Tequila does not have a close substitute being produced in the US. This paper shows that a reduction in transportation costs induces a growth in the size of the smallest producer according to this model. This is not what data shows though. Data shows that the size of the smallest producers remains unchanged, but there are many more of them operating today.

Therefore, this paper concludes that Melitz (2003) cannot account for the change in size distribution of Tequila distilleries even when the model is extended to more real scenarios.

Chapter 3

The History of Economic Thought about Upward Sloping Demands

3.1 Introduction

In 2008, Jensen and Miller (2008) showed that Giffen behavior (i.e. upward sloping demands) is a sign of calorie deprivation; moreover, their research suggests that Giffen behavior could be quite common among poor people in developing countries. However, in spite of these overwhelming results, economists still have not developed utility-based models to perform welfare analysis in environments of subsistence consumption and Giffen behavior, partly because no one had characterized utility functions suitable for this task.

Now, this is not an excuse anymore. Thanks to Armendariz (2015), there is an explicit utility function that can be employed for developing models of welfare analysis in environments of subsistence consumption. Therefore, it is convenient to summarize all the literature regarding Giffen behavior written until now so it can be employed to start developing the first generation of utility-based models for welfare analysis.

In this paper, I provide such a summary. In it, I describe a literature review about Giffen behavior. To facilitate the exposition, I have chosen to devide the literature in four historical periods. Each period identifies a different set of *dialectic* debates regarding Giffen behavior. The four periods in chronological order are

1. Early period

2. Classical period

3. Empirical period

4. Synthesis period

For the unaware, *dialectics* is a systematic discussion process in which a thesis is challenged by an anti-thesis, and the conclusion of this debate is known as synthesis (O'Connor, 2003). This process can be reapeated *ad infinitum*, because every synthesis is a thesis by construction. Thus, eventually, someone challenges this new thesis with a corresponding anti-thesis, and the cycle repeats. As the reader might suspect, describing the *dialectic* process about Giffen behavior is, in fact, describing the evolution of economic thought about that topic.

The history of economic thought about Giffen behavior starts with the Early period. In this period, the thesis of Giffen behavior was born and began two dialectic debates about upward sloping demands: (1) is Giffen behavior paradoxical?, and (2) is Giffen behavior real?

The Early period is followed by the Classical period. In the Classical period, Giffen behavior stopped being a puzzle; economists realized that the theory of utility was strong enough that it could explain upward sloping demands. Nevertheless, they still left an important element unsolved: they could not contruct an explicit model that predicts upward sloping demands without using extra ingredients that are not standard in consumer theory.

In the first half of the XX century, at the time when many economists were engaged in the theory of Giffen behavior, few empirical economists noticed that Giffen behavior had not been documented. Thus, they shifted the discussion from creating models that predict this phenomenon to finding actual empirical evidence of its existence in the real world, and this gave birth to the Empirical period.

Finally, in the Synthesis period, economists succesfully documented Giffen behavior and built a model that explains this phenomenon. Today, we live in this period. That is, today, economists have enough tools to start designing and evaluating policies that deal with Giffen behavior and subsistence consumption. This is why it is important to provide a summary of where we stand in terms of our understanding of this phenomenon. This summary reduces the time that economists spend studying the literature; and, as a consequence, it increases the time available to start solving the global problem of malnutrition.

This paper distinguishes itself from the other surveys of Giffen behavior in two ways: first, it is the first literature review to be written after Giffen behavior was succesfully modeled; and second, it focuses on how to apply our current knowledge about upward sloping demands to generate policies that target undernutrition. For example, Haagsma (2012b) only specializes in summarizing utility functions that induce upward sloping demands. Yet, it does not include Armendariz (2015).

3.2 The early period

Marshall (1895) wrote the following paragraph in the third edition of his *Principles of Economics*:

> There are, however, some exceptions. For instance, as Mr. Giffen has pointed out, a rise in the price of bread makes so large of a drain on the resources of the poorer labouring families and raises so much the marginal utility of money to them, that they are forced to curtail their consumption of meat and the more expensive farinaceous goods; and, bread being still the cheapest food which they can get and will take, they consume more, and not less of it. But such cases are rare; when they are met with they must be treated separately.

This paragraph, which later became known as the Giffen paradox, set the beginning of one of the longest debates in the history of economic thought, mostly due to Marshall's relevance as an economist in that time.

However, there were few cases of economists that referenced upward sloping demands before Giffen. One example is Gray (1815):[1]

[1] According to Masuda and Newman (1981), Rashid (1979) claims priority for the Reverend Henry

> To raise the price of corn in any degree, tends to increase the general consumption of that necessary.

In fact, I have decided to start the history of economic thought about Giffen behavior with Gray's publication. The reason is, in spite of his lack of fame, standard academia recognizes Gray as the economist who proposed this thesis for the first time.

Due to lack of evidence, I pressume that not much happened in the literature of Giffen behavior between Gray's publications and Marshall's *Principles*. As a matter of fact, Marshall believed that Mr. Giffen was the first to notice upward sloping demands (Marshall et al., 1966a). Hence, I devide the early period in two parts: pre-1895 and post-1895. In this division, Gray's statements characterize the pre-1895 part, while the dialectic debates between Marshall and other economists characterize the post-1895.

The post-1895 period contains two different dialectic debates: one theoretical and one empirical. The theoretical debate challenges Marshall's proposal of upward sloping demands as paradoxical, while the empirical debate challenges the existence of upward sloping demands. In both debates, Marshall is the main economist that defends the Giffen paradox thesis. On the other hand, the anti-theses were supported by a wide range of economists, especially in the theoretical debate.

3.2.1 Pre-1895: Gray's anti-thesis to downward sloping demands

Most economic historians today recognize Gray as the original proposer of upward sloping demands as a thesis (Masuda and Newman, 1981). However, Marshall did not know about him back then. This is why Marshall did not recognize Gray's contribution to economic theory. For instance, in the *Memorandum on Fiscal Policy and International Trade* (1903), Marshall says

> [...] as Sir R. Giffen seems to have been the first to observe, a rise in the price of wheat still leaves bread the cheapest food, which they will consent to eat in any quantity; so that, having to curtail their purchases of more expensive foods, they buy, not less bread than they would have done, but more.

Beeke who gave a brief discussion which can bear a *Giffinesque* interpretation in an unpublished paragraph of 1800.

Today, we have records about Gray's pioneering work on Giffen behavior in Schultz et al. (1938), Stigler (1965), and Rashid (1979). Yet, these references are brief and not based on Gray's original work, but on a critique that Powell (1896) wrote. Alternatively, the best known project that tried to resurrect Gray as the pioneer of upward sloping demands is Masuda and Newman (1981). Masuda employs original quotes from Gray to give him the place he deserves in the history of economic thought; he argues that upward sloping demands should be known as *Gray goods* (instead of Giffen goods).

As many other scientists, Gray tried to introduce his work in the literature by challenging standard theories. In particular, Gray used his exposition of upward sloping demands to challenge the thesis of the market as a maximizer of social welfare; but his efforts were in vain, because his writings were not widely known. In fact, Masuda refers to Gray as "a writer on economics of great pretensions but of less success" after having found that Gray wrote two other books under a pseudonym to praise his own work.

Gray has a strong proposition about Giffen behavior. He argues that not only individual demands are upward sloping but also the market one. He defends this thesis by arguing that the measure of the population that shows Giffen behavior is large enough to affect the slope of the market demand. For example, in the following paragraph, Gray conjectures that low income consumers who highly depend on wheat as the main source of food could show Giffen behavior:

> If wheat should rise only so high as to make but a difference of 2d. in the quartern loaf, I imagine, there will be no great difference in the quantity of bread eaten by a nation. The mass that lives chiefly or considerable on bread, will be urged by the rise to be more economical in that article, and use little more of others, such as potates. And this rise scarcely sufficient to prevent that body from being able to purchase the usual, or even a larger quantity of other articles. But in proportion as the quartern loaf rises above this, will the great mass of population be obliged to confine itself more and more to bread and potatoes. When the quartern loaf, at the present price of labour with us, rises to fourteen pence, the consumption will be sensibly increased. At eighteen pence per loaf, the great body will be nearly confined to bread and potatoes. Beyond this, the poorer of the middle ranks, with large families, will be much in the same predicament.

And, in this paragraph, he conjectures that the size of the population that shows Giffen behavior is so large that they will affect the market demand:

> There is no paradox here. The cause is as clear, as the effect is unquestionable. At entering on the subject, it must be observed, that perhaps more than three fourths of the bread used, is consumed by the working classes, not only on the account of the proportion which the number of this description of population bears to the whole, but because this body lives more than the other classes on bread. if we add to these the inferior classes of tradesmen, and manufacturers with large families, who also very much live on bread and pudding, we shall perhaps find, that this mass of population consumes nine tenths of the whole quantity of bread corn.

Finally, notice how enphatic he is about how subsistence consumption induces Giffen behavior; even more, his intuition is surprisingly close to Jensen and Miller's finding 200 years later as the following quote shows:

> It will be asked, why do they not buy something else than this very thing, which is grown so dear? The answer is obvious. They have it not in their power to buy anything else.

In other words, Gray argues that poor agents do not subsitute away from this product which is increasing in price because there are no subsitutes available. The surprising element is, Jensen and Miller argue exactly the same statement when they design their experiment to find Giffen behavior among poor consumers without referencing to Gray.

3.2.2 Post-1895: the empirical debate

Marshall's thesis proposal (i.e. the demand for staples is upward sloping in the U.K.) started two dialectic debates in academia: an empirical debate and a theoretical debate.

The empirical debate was mostly between Marshall and Edgeworth. Back then, Edgeworth was an emerging academic economist in England who challenged the existence of upward sloping demands (Edgeworth, 1909). For example, Edgeworth wrote the following statement in the Economic Journal:

> Even the milder statement that the elasticity of demand for wheat may be positive, although I know it is countenanced by high authority, appears to me so contrary to a priori probability as to require very strong evidence.

Even more, Edgeworth refered to upward sloping demands as "contrary to general experience and common sense."

Despite Edgeworth's solid critique, which remained valid until 2008, Marshall did not drop his thesis. Instead, he kept the dialectic debate going. For instance, as Stigler (1947) notices, "there could be little doubt of the identity of the 'high authority, and Marshall rose to the defense of the paradox:"

> But the hint that a rather rash and random guess has been made by those who suggest that a (moderate) rise in the price of wheat might increase its consumption in England (not generally) provokes me to say that the matter has not been taken quite at random.

However, Marshall's defense is not strong enough as he still refers to personal experiences:

> Ever since I saw Giffen's hint on the subject, I have set myself to compare the amounts of bread (and cake, wheaten biscuits and puddings) eaten at first class dinners in private houses and expensive hotels, with the consumption in the middle class houses and second-rate hotels; and again with the consumption in cheap inns, including a low grade London hotel: and I have watched the baker's supplies to cottages. And I am convinced that the very rich eat less than half as much bread as the poorer classes, the middle classes coming midway. This proves nothing conclusively: but it is a fair basis, I think, for a surmise as to a probability.

Some economists stood with Marshall in this debate. For instance, Rea (1908) says, "a rise in the price of wheat would increase rather than decrease the consumption in this country." On the other hand, other economists took a more policital stand. For example, Pigou said, "I agree that it is possible that the elastcity of the English demand for wheat may be positive. This certainly used to be the case; but I doubt if it is appreciable the case now" (Rea, 1908).

3.2.3 Post-1895: the theoretical debate

In his *Principles of Economics*, Marshall proposes Consumer Surplus as an actual measure of utility. The problem is, for this to be true, it is necesary to have downward sloping demands. In other words, Giffen behavior does not fit in his theory. Even more, to make Consumer Surplus be an accurate measure of utility, the utility function must be additively separable; that is, the marginal utility of each input cannot be a function of the other inputs. For example,

$$u(x, y) = f(x) + g(y)$$

where

$$\frac{\partial f}{\partial y} = \frac{\partial g}{\partial x} = 0$$

As a consequence, Marshall's thesis started two debates in economic theory: (1) the accuracy of Consumer Surplus as a measure of utility, and (2) the possibility of upward sloping demands.

Marshall's thesis about Consumer Surplus is consistent with the standard technique for modeling preferences in the late 1800's. For instance, famous eonomists as Jevons and Walras were known for using separable utilities in the late 1870's. What's more, Pareto assures that separable utility is a good approximation of preferences because evidence suggests that demands are downward sloping (e.g. Stigler, 1947; Haagsma, 2012b).

In spite of the popularity of separable utilities, other economists challenged this view. The most prominent of this set was Edgeworth. Edgeworth proposed the general form of the utility function in 1881 (the form we currently use today). In his proposition, Edgeworth says that the marginal utility of a good does not have to be independent of the other commodities, but this anti-thesis did not have much acceptance in academia.

Constant marginal utility of money

Marshall's thesis regarding Consumer Surplus as a measure of utility also requires to assume that the marginal utility of income is constant. To understand this element, consider the following Lagrange function:

$$L = f(x) + g(y) + \lambda [I - p_x x - p_y y]$$

where x and y are consumption goods, p_x and p_y are their respective prices, I is income, and f and g are strictly increasing, strictly concave and continuously differentiable. Also, notice that this Lagrange funtion implies that λ is the marginal utility of income.

Now, I will show that the change in utility is equal to the change in Consumer Surplus when λ is constant. To begin, notice that the first order conditions characterize the demands in this case; that is, $f'(x) = \lambda p_x$ characterizes the demand for x, and $f'(y) = \lambda p_y$ characterizes the demand for y. Now, let the price of y change from p_{y0} to p_{y1}, and also let y_i be the quantity demanded for y when its price is p_{yi}. Therefore, this change in price implies that the change in Consumer Surplus is

$$\int_0^{y_1} f'(y)\,dy - \int_0^{y_0} f'(y)\,dy = f(y_1) - f(y_0)$$

in other words, the change in Consumer Surplus is equal to the change in utility.

However, according to Dooley (1988), other economists challenged this assumption as well. Some examples are Patten (1893), Baron (1894), and Nicholson (1894).[2] Unfortunately for these economists, their anti-theses had the same fate as Edgeworth's: they did not have much success academically.

Utility function that makes Consumer Surplus be a measure of utility

As far as I know, only quasi-linear utilities can make Consumer Surplus be an accurate measure of utility regardless of income (Mas-Colell et al., 1995). For example, consider the following utility function:

$$u(x, y) = x + \alpha \log y$$

Hence, in an interior solution, the demands are

$$y = \frac{\alpha p_x}{p_y}$$

$$x = \frac{I}{p_x} - \alpha$$

[2] Mason (1989) and White (1990) review this literature.

where I is income, p_x is the price of x, and p_y is the price of y. Now, let the price of y decrease by 50%. By normalizing $p_x = 1$, we find that the gain in utility is equal to $\alpha \log 2$. Notice that this number is exactly equal to the gain in Consumer Surplus.

3.3 The Classical Period

The classical period refers to the time when economists realized that the theory of utility was strong enough to predict Giffen behavior. This realization happened thanks to Eugen Slutsky, a Russian economist who published in 1915 the so called "Slutsky Equation."

The Slustky Equation is a mathematical identity that splits the total change in quantity demanded induced by a change in price into two effects: substitution effect and income effect. In principle, substitution effect is always negative; that is, an increase in the price of a commodity will make a consumer to substitute away from it (reduce its quantity demanded). In contrast, the income effect can have either a positive or a negative sign. Therefore, there is no constraints in its direction. Furthermore, its size can be large enough that it can take over the negative force from the subsistution effect. Hence, this equation redefines Marshall's Law of Demand as follows (Jehle and Reny, 2011):

> There is a negative relationship between price and quantity demanded. However, when the relationship is positive, the income effect must be negative.

Mathematically, the Law of Demand can be written in terms of elasticities:

$$\varepsilon = -\left(\kappa\eta + (1-\kappa)\,\sigma\right)$$

where ε is the price elasticity of the demand for a given commodity (call it "X"), η is the income elasticity of X, σ is the elasticity of subsitution between X and a "composite" good that aggregates all the other commodities, and κ is the proportion of income spent on X. As it can be seen in this equation, the sign of ε is ambiguous, because, even though $(1-\kappa)\,\sigma$ is always positive, the sign of $\kappa\eta$ can be negative and large enough to make the price elasticity of the demand be positive. That is, the income elasticity can make the demand show Giffen behavior.

It is important to note that, the Slutsky Equation is not a theorem of the existence of an upward-sloping demand function, but rather a statement that says that there is nothing in the theory of utility that restricts it from predicting Giffen behavior. Therefore, this equation leaves the debate regarding the existence of upward sloping demands still open until there is an explicit example of a utility function that induces Giffen demands.

Today, economists recognize Slutsky as the proponent of this identity. Yet, this recognition did not happen until after World War II ended despite of having published his proposition 30 years earlier. Originally, English-speaking economists thought that Hicks and Allen (1934) were the first to find this identity, mainly because Slutsky (1915) published in Italian. However, to avoid confusions and in order to give the credit he deserves, Allen (1936) explicitly explains that Slutsky is the original founder of this identity (Barnett, 2004).

3.3.1 Adding constraints to the Consumer Problem

Since the Early period, Marshall had a debate with other economists about the possibility of observing Giffen behavior, despite of proposing a theory that cannot explain why Giffen behavior would exist. Therefore, to show how Giffen behavior is possible without contradicting his own theory, Marshall constructed Consumer Problems with extra constraints besides the budget constraint. For instance, when Marshall was introducing one of his examples, he said

> I object to the phrase negative elasticity, because I think it tempts people to carry analytical mathematics beyond their proper scope. In this case, for instance, [an upward-sloping demand] suggests a paradox. And I submit that there is no paradox at all... What but needless perplexity can result from calling this negative elasticity, on the abstract ground that that name is in harmony with mathematical symbols, which are being pushed beyond their proper scope? (Marshall et al., 1966b)

In the examples that Marshall introduced, the consumers increase the quantity demanded as price increases, because the extra constraints force them to do so. For instance, in a letter to Edgeworth, Marshall et al. (1966b) explains how a poor consumer may increase the distance he will travel on a cheap mean of transportation that increases its price:

> I believe that people people in Holland travel by canal boat instead of railway sometimes on account of its cheapness. Suppose a man was in a hurry to travel 150 kilos. He had two florins for it, and no more. The fare by boat was one cent a kilo, by third class train two cents. So he decided to go 100 kilos by boat, and fifty by train: total cost two florins. On arriving at the boat, he found the charge had been raised to $1\frac{1}{4}$ cents per kilo. 'Oh: then I will travel $133\frac{1}{3}$ kilos (or as near as may be) by boat, I can't afford more than $16\frac{2}{3}$ kilos by train.' Why not? Where is the paradox?

Notice that this example says that the consumer is in a hurry (that is, he needs to travel as fast as possible). Thus, the goal of this consumer is to minimize the time it will take him to travel 150 kilometers. To achieve this, he has two options: to travel by boat or by train. Travelling by train is faster than travelling by boat; however, his budget does not allow him to travel by train the whole distance. Therefore, he can opt for travelling by boat part of the journey and travelling by train the remaining part. That is, the consumer travels part of the distance by boat because he is poor. Hence, the poorer he is, the longer he will have to travel by boat; and since an increment in price makes the consumer poorer in real terms, his demand for time travelled by boat increases with price.

After Marshall's example, other economists employed this technique to explain Giffen behavior. The best known examples in this category are Pareto (1896), Wicksell (1934), Dooley (1988), and van Marrewijk and van Bergeijk (1990). In all these cases, Giffen behavior arises when a consumer is so poor that activates an extra constraint. For example, consider the Problem of a Consumer who wants to maximize his utility by buying bundles of bread (b) and meat (m) and is constrained by his budget and by a caloric requirement. In particular, let his problem be the following:

$$\max \{\log(b) + \log(m)\}$$

subject to

$$p_b b + p_m m \leq I$$
$$\alpha_b b + \alpha_m m \geq \bar{C}$$

where the former constraint is the budget constrain, and the latter is the caloric requirement. In this problem, p_b and p_m are the prices of bread and meat respectively, α_b and α_m are the calories that one unit of bread and meat provide respectively, and $\bar{C}$ is the minimum amount of calories necessary to survive.

In this problem, there are two types of solutions: either the constraint that represents the caloric requirement is active or not. In the latter type of solution, the demands for bread and meat are downward-sloping. However, when the caloric requirement constraint is active, the demand for the cheapest source of calories shows Giffen behavior.

Now, we will verify that the consumer may have Giffen behavior for the cheapest source of calories. First, assume that both constraints are active. Therefore, the solution to the consumer problem is characterized by the following system of equations:

$$p_b b + p_m m = I$$
$$\alpha_b b + \alpha_m m = \bar{C}$$

In other words, the demand for bread is

$$b = \frac{\overline{C} p_m - \alpha_m I}{p_m \alpha_b - \alpha_m p_b}$$

Now, let bread be the cheapest source of calories. That is, assume that the following inequality holds

$$\frac{\alpha_b}{p_b} > \frac{\alpha_m}{p_m}$$

Therefore, the derivative of the demand for bread with respect to its own price is positive.

3.3.2 Increasing marginal utility

Slutsky found that, when the utility is additive and convex and when theere is one good with increasing marginal utility while all the other goods have decreasing marginal utility, the income effect of the former good is positive while the income effect of all the latter goods is negative. A modern version of this insight can be found in Liebhafsky (1969).

Hence, since "Giffen goods" are inferior, Slutsky's insight suggests a recipe on how to create demands with Giffen property. A broad explanation of how this is done can be found in Silberberg and Walker (1984). In this paper, I will only provide one example shown in Haagsma (2012a)

Consider the following utility function:

$$u(x_1, x_2) = \log(x_1 - 1) - 2\log(2 - x_2)$$

and restrict its domain to $x_1 > 1$ and $0 \leq x_2 < 2$. Then, by taking the first order conditions, one can easily verify that the marginal utility of each good is positive:

$$\begin{aligned} \tfrac{\partial u}{\partial x_1} &= \tfrac{1}{x_1 - 1} \\ \tfrac{\partial u}{\partial x_2} &= \tfrac{2}{2 - x_2} \end{aligned}$$

Moreover, notice that the marginal utility of x_2 is strictly increasing. Finally, also notice that the indifference curves are strictly convex to the origin. Thus, in an interior solution, the demand functions are characterized by the Euler Equation and the budget constraint holding with equality. That is, by solving this system of equations, the demand for x_1 is found to be

$$x_1 = 2 - \frac{1}{p_1}(I - 2p_2)$$

where I is the income, and p_1 and p_2 are the prices of x_1 and x_2 respectively.

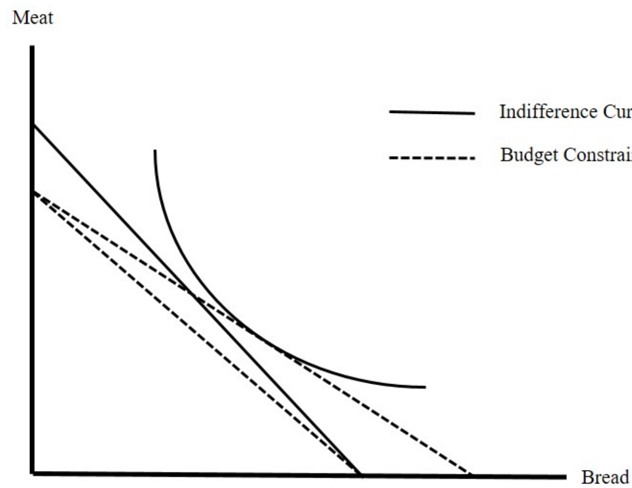
Clearly, the demand for x_1 shows Giffen behavior when $I - 2p_2 < p_1 < I - p_2$.

3.3.3 Subsistence environments may change preference ordering

In 1994, Davies (1994) published an alternative explanation for Giffen behavior. In his paper, he argues that rich consumers may order preferences differently than poorer consumers due to difference in motives. In particular, the order of preferences of rich consumers may be motivated by social values or taste, whereas the order of preferences of poor consumers may be motivated by caloric intake.

As Davies notes, the change in preferences between rich and poor consumers may induce Giffen behavior, because an increment in price makes consumers be poorer in real terms, which could lead a change in motives that order preferences. The next figure explains this point:

Figure 3.1: Indifference curves and demand for bread



3.3.4 Getting rid of the substitution effect

As it was previously mentioned, the Slutsky equation splits the total change in quantity demanded for a commodity into two effects: substitution effect and income effect. The substitution effect always pushes on the same direction, making the demand be downward sloping. Thus, in order to obtain Giffen behavior, the income effect must push in the opposite direction and be stronger than the subsitution effect. As Sorensen (2007) shows, one way to obtain this result is by creating a utility function that turns off the subsitution effect and has an inferior good. For example, consider the following utility function:

$$u\left(x_1, x_2\right) = \min\left\{x_1 + 1, 2\left(x_1 + x_2\right)\right\}$$

This utility function makes use of the min operator to create a “kink” in the indifference curves. At the kink, there is not substitution effect. Moreover, since the utility is monotone, the demand is located at the kink when the solution is interior. In particular, using this utility, the demand for x_2 is

$$x_2 = \frac{p_1 - I}{2p_1 - p_2}$$

Therefore, when $p_1 > I$ and $p_1 > p_2$, the demand for x_2 is upward sloping.

3.3.5 General Equilibrium Effects

So far, all the previous arguments try to explain Giffen behavior in highly controlled environments, where the only variable changed is the price of the commodity in question while everything else is kept constant. However, this might not be the case in reality. In fact, in his text Value and Capital, Hicks (1939) mentions how General Equilibrium effects may induce Giffen behavior even when the income elasticity of all the goods is positive:

> What happens if this is not so, if he comes to the market not only as a buyer but also as a seller? Suppose he comes with a fixed stock of some commodity X, of which he is prepared to hold back some for his own consumption, if price conditions are favourable to that course of action.
>
> [...]
>
> But what happens if the price of X varies? The substitution effect will be the same as before. A fall in the price of X will encourage substitution of X for other goods; this must favour increased demand for X, that is to say, diminished supply. But the income effect will not be the same as before. A fall in the price of X will make a seller of X worse off; this will diminish his demand (increase his supply) unless X is for him an inferior good.
>
> The significant difference between the position of the seller and that of the buyer thus comes out at once. In the case of the buyer income effect and substitution effect work in the same direction save in the exceptional case of inferior goods. In the case of the seller, they only work in the same direction in that exceptional case. Ordinarily they work in opposite directions.
>
> The position is made more awkward by the fact that sellers' income effects can much more rarely be neglected. Sellers usually derive large parts of their incomes from some particular thing which they sell. We shall therefore expect to find many cases in which the income effect is just as powerful as the substitution effect, or is dominant. We must conclude that a fall in the price of X may either diminish its supply or increase it.

Similarly, Rosen (1999a) explains thoughly that the famine experienced in Ireland in the 1800's can be accounted by a General Equilibrium model in which the demands are normal, not Giffen. In particular, he claims the following:

> Price and quantity data prove that Irish potatoes in the 1840s were not Giffen goods. Intertemporal trade-offs required by the fact that a sizable fractions of the potato crop is needed for seed crops can produce unusual market dynamics. The Irish experience is well described by a normal demand model in which a permanent decline in the productivity of seed potatoes was at first mistaken as a transitory crop failure. These mistakes provoked "over-saving" of seed crop in a population in dire circumstances. With the benefit of hindsight, consumption of seed crop capital was warranted. Erroneous expecations of potato productivity by growers delayed necessary agricultural adjustments and contributed to the catastrophe later on.

Finally, Nachbar (1998) shows that a good is normal when its price and quantity consumed fall simultanously using a General Equilibrium model. Thus, the commodity cannot be Giffen.

3.3.6 Alternative Theories of Giffen behavior

While historically most of the literature written regarding Giffen behavior talks about this phenomenon in environments of subsistence consumption, few economists have developed theories that predict that upward sloping demands may exist in other environments. One example of this is Ng (1972). Ng suggests that consumers may solve their problem using a step-optimization instead of the standard form. This step optimization helps consumers to save on decision costs; instead, they first allocate money in different broad categories (for example, housing). Then, they choose how to spend that money allocated in each category. A price change only changes the allocation within each category, and not the allocation across categories. As Ng shows, this effect can induce Giffen behavior.

Another theory is the one presented by Garratt (1997). Garrat shows that expensive indivisible commodity may cause Giffen behavior in other (divisible) and cheap commodities. Finally, Hoy and Robson (1981) show that the demand for insurance may show Giffen behavior.

3.4 The Empirical Period

Throughout the Early and Classic periods, most economists argued about the existence of upward sloping demands based on personal experiences rather than using solid evidence. In fact, Mr. Giffen personally clarified that there is no evidence of an upward sloping demand. For instance, according to Stigler (1947), Giffen (1909) wrote in the Economic Journal the following paragraph:

> Fears are expressed that this rise in wheat will affect the consumption of the working classes seriously, and be bad for trade, but this is certainly contrary to long experience. Until 30 years ago wheat was always thought cheap when it was anywhere under 50s., and no particular bad effects on consumption were experienced from fluctuations below that figure. It remains to be seen whether there will be any different effect now from an advance to near 50s. When people have become so long accustomed to much lower figures.

Consequently, given the lack of counter-evidence, no one seriously disputed the Giffen paradox as a valid example of upward sloping demands. Yet, economists were aware that the Giffen paradox is just a conjecture, not scientific evidence nor a consistent theory.

3.4.1 Was the demand for bread or wheat Giffen in Marshall's time?

For a long time, the existence of upward sloping demands for bread and wheat in Marshall's time remained unchallenged; no economist had been able to put together facts that either support or discredit its existence. The first serious criticism against the existence of upward sloping demands in the real world came from Stigler (1947). Stigler based his criticisms on two fronts: at a market level and individual consumption level. At a market level, Stigler finds that there is a negative relationship between total quantity consumed of wheat and its price. Thus, he conjectures that the market demand cannot be upward sloping. Then, he focuses at the individual consumption level. He uses a table from the Board of Trade's 1904 study of workmen's budget to argue that the income elasticity of bread an flour was positive for low income families, which implies that the individual household demand for bread could not be upward sloping.

However, Stigler's criticism did not remain unrivaled. A year after Stigler published his critique, Prest (1948) published a comment showing that Stigler's arguments are not valid. First, Prest mentions that the quantities that Stigler employed to test the slope of the market demand are traded quantities. Thus, they cannot be employed to test the slope of the demand. Second, Prest notes that the Stigler's analysis about the income elasticity does not consider the size of the household. If such a consideration had been made, Stigler's argument would have been "weakened." And third, Prest reveals a different data set, one about agricultural laborers' families from that time, that suggest a negative income elasticity of bread and wheat. Yet, he is clear about the statistical significance of this evidence, and argues that it should not be considered as a suggestion that Giffen's conjecture is accurate.

Consequently, the debate between Stigler and Prest kept the question open until Koenker (1977) put a final answer to it. Koenker uses historical data to argue that wheaten bread and meat are both normal goods.

3.4.2 The other classical (fallacy) example of Giffen behavior

In his textbook called *Economics*, Samuelson argues that the demand for potatoes during the Irish Potatoe Famine in 1845 - 1849 is Giffen. This example became a classic in the next 30 to 40 years as many authors of textbooks of Microeconomics used it to explain upward-sloping demands. Nevertheless, despite of its popularity in economic lectures, this example is flawed. In that time, the total amount of potatoes available fell drastically. Thus, quantity demanded could have risen as a consequence. The first to notice this fallacy is Dwyer and Lindsay (1984), and another reference that explains how the market demand for potatoes could not have been Giffen is McDonough and Eisenhauer (1995). Aletrnatively, Rosen (1999a) shows a theory that explains what caused the Irish Potatoe Famine.

3.4.3 Creating evidence in laboratories

Fueled by the unsuccesful attempts to find "real World" evidence of upward sloping demands and by the rising popularity of Experimental and Behavioral Ecomomics, some scientists started to run experiments in highly controlled environments to generate upward sloping demands. The two best known cases are Battalio et al. (1991) and DeGrandpre et al. (1993). Battalio et al. (1991) uses rats to show they have an upward sloping demand for a quinine solution while root beer was a normal good. Alternatively, DeGrandpre et al. (1993) used 7 smokers to show that less preferred brands of cigarrets are inferior commodities for them. Even more, 2 out of those 7 smokers showed upward sloping demand for the less preffered brands.

3.5 The Synthesis Period

The Synthesis Period refers to the time when both things happened: first, rigorous evidence of upward sloping demands was found; and second, an explicit utility function that models the Giffen paradox was characterized.

Jensen and Miller (2008) found evidence of upward sloping demands in an experiment they performed in two Chinese regions where a significant fragment of the population lives in conditions similar to those described in the Giffen Paradox. Jensen and Miller's experiment consisted on subsidizing the prices of dietary staples for extremely poor households in the Chinese provinces of Hunan and Gansu. In their experiment, they found strong evidence of Giffen behavior for rice in Hunan, and weaker evidence for wheat in Gansu.

Specifically, their experiment consisted on subsidizing the primary staple of randomly chosen houses who live in “subsistence conditions” for five months. This subsidy was intended to test the change in quantity consumed of the staple as a response to the change in its price. Jensen and Miller found that the experimental subsidy caused households to reduce their demand for rice in Hunan and for wheat in Gansu, and removing the subsidy had the opposite effect.

The relevance of Jensen and Miller's finding is that their experiment suggests that Giffen behavior may be quite common among poor people in developing countries, despite of not having been documented earlier. What makes it even more relevant is that Giffen behavior is a sign of starvation, which definitely calls for immediate intervention.

When Jensen and Miller published their findings, theoretical economists had not developed a utility function that rationalizes their observations yet. Instead, we had to wait for another 6 years for this characterization. In 2014, as part of my Job Market

Paper, I presented the first characterization of a utility function that rationalizes Jensen and Miller's observations and models preferences that match the description of the Giffen paradox.

3.5.1 The Giffen Paradox Utility Function

120 years ago, Marshall (1895) said that a rise in the price of bread, a primary staple for low income consumers back then, caused poor British families to buy more bread. Today, economists refer to this statement as the Giffen paradox.

Ever since Marshall published the Giffen paradox, the theoretical possibility of upward sloping demands (i.e. Giffen behavior) has been profoundly divulged. In fact, it has been included in virtually every upper level textbook of microeconomics (e.g. Mas-Colell et al. (1995), Jensen and Miller (2011), and Varian (1992)). And, as the Slutsky Equation testifies, economic theory cannot rule out the possibility of predicting upward sloping demands using solely a budget constraint and a utility function that is strictly increasing, strictly quasi-concave, and continuously differentiable. Consequently, it is highly surprising that, after all this time, no one has explained the Giffen paradox under these conditions yet. In particular, this theoretical emptiness has forced upper level textbooks to explain Giffen behavior by either drawing indifference curves or showing that the Slutsky Equation does not rule out that possibility. So far, there are two attempts to explain the Giffen paradox using a utility function. The first attempt employs an extra constraint besides the budget constraint (e.g. Dooley (1988) and van Marrewijk and van Bergeijk (1990)), and the second attempt uses a non-differentiable utility function (Davies, 1994).

Now, the search for such a utility function is an official mathematical challenge called the Strong Giffen Problem (Heijman and von Mouche, 2012a). Specifically, the Strong Giffen Problem is to propose a "concrete utility function that is strictly increasing and quasi-concave [...] where the Giffen property can be shown by solving the equation of budget balancedness together with the equation saying that the price ratio equals marginal rate of substitution." So far, a very few number of economists have reached a level of completeness in this task (e.g. Wold (1948), Moffatt (2002), Sorensen (2007), and Doi et al. (2012)).[3] Yet, none of these examples model the subsistence consumption

[3] Haagsma (2012b) summarizes many theories of upward sloping demands.

environment portrayed in the Giffen paradox; instead, their only purpose is to generate upward sloping demands. Moreoever, after finding the first evidence of upward sloping demands in a real world environment that replicates the Giffen paradox, Jensen and Miller (2008) turned this mathematical challenge into a scientific puzzle.[4]

In this section, I construct the first concrete utility function that models the Giffen paradox and solves the Strong Giffen Problem. Furthermore, after adding a simple adaptation, this utility function can account for Jensen and Miller's 2008 finding regarding Giffen behavior (i.e. an inverted "u-shape" relation between income and price elasticity of the demand for bread, where the poorest of the poor and the least poor have downward sloping demands and the consumers in the middle show Giffen behavior.)

The utility function I propose represents CES preferences for two hedonic characteristics of food: calorie surplus and flavor. I define calorie surplus as total calories consumed minus a minimum amount of calories to survive. To ingest calories, the consumer must buy bread or meat. Bread and meat are perfect substitutes at the provision of calories. However, meat is the only food that provides flavor as well. This utility function is strictly increasing, strictly quasi-concave, and continuously differentiable; it solves the Strong Giffen Problem, and its properties allow to derive the demands in close form.

To account for Jensen and Miller's finding, I turn the utility function into a piecewise function: the utility function is CES when calorie surplus is a strictly positive number; otherwise, the utility function equals to the value of calorie surplus. With this adaptation, the utility function rationalizes the indifference curve map drawn by Jensen and Miller to explain their findings and, as a consequence, it rationalizes the inverse "u-shape" relation between income and price elasticity of the demand.

The utility function I propose in this paper unifies two theories regarding Giffen behavior: Lancaster (1966) and Davies (1994). The CES piece of the utility function materializes Lancaster's theory of hedonic preferences, where consumer preferences are defined over a set of non-market characteristics; and, to obtain these characteristics, consumers must go to the markets to buy commodities. This utility function is the first explicit example of how Lancaster's theory can rationalize Giffen behavior.[5] The

[4] Jensen and Miller used an indifference curve map to explain the theoretical background of their findings.

[5] Lipsey and Rosenbluth (1971) show that Lancaster's theory can explain Giffen behavior; yet, they

other piece of the utility function materializes Davies's theory. As Davis proposes, consumption priorities change when the consumer is reduced to a subsistence condition. As a consequence, caloric intake becomes the only service that the consumer cares about.

The utility function

The utility function represents a preference relation over two services: *calorie surplus* and *flavor*. These services cannot be bought in the markets separately. The consumer must go to the markets to buy bread and meat to obtain these services.

Calorie surplus is defined as total calories consumed from eating bread and meat minus a calorie requirement to survive. Therefore, its production function is

$$c = \alpha_b b + \alpha_m m - \bar{c} \tag{3.1}$$

where c is calorie surplus, b is the quantity of bread consumed, α_b is the calories that each unit of bread provides, m is the quantity of meat consumed, α_m is the calories that each unit of meat provides, and $\bar{c}$ is the calorie requirement to enjoy flavor.

Flavor is an abstract service that can only be produced using meat as an input. Its production function is δM, where δ is the amount of flavor that each unit of meat provides.

The functional form of the utility is

$$u(b, m) = [(\alpha_b b + \alpha_m m - \bar{c})^\rho + (\delta m)^\rho]^{\frac{1}{\rho}} \tag{3.2}$$

where $\sigma = {}^{1}/_{(1-\rho)}$ is the elasticity of substitution between calorie surplus and flavor.

Properties of the utility function

The utility function is strictly increasing, strictly quasi-concave, and continuously differentiable on bread and meat. It satisfies Inada Conditions on meat, while the marginal utility of bread is finite when the consumption of bread is zero and tends to zero as the consumption of bread grows unboundedly. Thus, the indifference curves are differentiable, downward-sloping, and strictly convex to the origin.

---

do not provide a concrete example.

Deriving the demands

According to the theory of utility, the demand for bread and meat is the solution to the consumer problem. The consumer problem is defined as choosing an affordable basket of bread and meat such that maximizes the utility. That is,

$$\begin{aligned} \max_{\{b,m\}} u(b,m) \quad s.t.: \quad & p_m m + p_b b \leq i \\ & m, b \geq 0 \end{aligned} \tag{3.3}$$

where i stands for income, p_b for the price of bread, and p_m for the price of meat.

Since the utility function is strictly increasing, the budget constraint holds with equality in the solution. That is, $p_m m + p_b b = i$. And, due to Inada Conditions on meat, we know that the consumer will always buy meat in the optimum. Thus, there are two solution types: either the solution is interior (i.e. the consumer purchases a positive amount of bread and meat), or the consumer spends all her budget on meat.

In an interior solution, the demands are characterized by the budget constraint holding with equality and the Euler Equation (the marginal rate of substitution equals the ratio of prices). After solving this system of equations, the demands become

$$b = \frac{i\left(\delta - \mu\left(p_b, p_m\right)\alpha_m\right) + \mu\left(p_b, p_m\right) p_m \bar{c}}{p_b\left(\delta - \mu\left(p_b, p_m\right)\alpha_m\right) + \mu\left(p_b, p_m\right) p_m \alpha_b} \tag{3.4}$$

$$m = \frac{\mu\left(p_b, p_m\right)\left(i\alpha_b - p_b\bar{c}\right)}{p_b\left(\delta - \mu\left(p_b, p_m\right)\alpha_m\right) + \mu\left(p_b, p_m\right) p_m \alpha_b} \tag{3.5}$$

whereμ is the following function:

$$\mu\left(p_b, p_m\right) = \left(\frac{p_m\alpha_b - p_b\alpha_m}{p_b\delta}\right)^{\frac{1}{\rho-1}} \tag{3.6}$$

Giffen behavior in the demand for bread

I will simplify the proof by constraining the utility function to the Cobb-Douglas case. That is, when $\rho = 0$. To see the general proof, go to Armendariz (2015).

According to Marshall's version of the Giffen paradox, bread was the cheapest food that families could obtain. In this model, I will interpret that as bread being the cheapest source of calories. That is,

$$\frac{\alpha_m}{p_m} < \frac{\alpha_b}{p_b} \tag{3.7}$$

Also, I will constraint consumer to being poor enough that they cannot survive buying bread only, but no so poor that they cannot afford meat to live. That is,

$$\frac{p_b\bar{c}}{\alpha_b} < i < \frac{p_m\bar{c}}{\alpha_m} \tag{3.8}$$

Finally, the Cobb-Douglas case has the pecularity that can make bread be a normal good, depending on the ratio of prices. The problem is, very poor consumers may run out of budget before bread becomes an inferior good. To avoid this case, I will also constraint income to be

$$\frac{p_m\bar{c}}{2\alpha_m} < i \tag{3.9}$$

I use the derivative of the demand for bread with respect to its own price to prove that the demand for bread shows Giffen behavior. I show that the value of the derivative is strictly positive when the price of bread is close enough to its upper bound defined by (8).

The derivative of the demand for bread with respect to its own price is

$$\frac{\partial b}{\partial p_b} = \frac{p_b^2\alpha_m\left(p_m\bar{c} - 2\alpha_m i\right) + p_m\alpha_b i\left(2p_b\alpha_m - p_m\alpha_b\right)}{2p_b^2\left(p_m\alpha_b - p_b\alpha_m\right)^2} \tag{3.10}$$

First, notice that the denominator is strictly positive. Therefore, (10) is positive whenever its numerator is positive.

Second, plug the upper bound for the price of bread, that is

$$p_b = \frac{i\alpha_b}{\bar{c}} \tag{3.11}$$

Thus, by plugging (11) into the numerator of (10), we find that (7), (8), and (9) make the numerator positive.

And third, by continuity, the demand for bread shows Giffen behavior at any price of bread close enough to (11).

3.6 Conclusions

This paper showed the history of economic thought regarding Giffen behavior. It devided the history into four different periods: Early, Classical, Emprical, and Synthesis. Each period refers to a particular set of dialectic debates happening in economic literature regarding Giffen behavior.

In the Early period, the thesis of Giffen behavior was born and began two dialectic debates about upward sloping demands: (1) is Giffen behavior paradoxical?, and (2) is Giffen behavior real? In the Classical period, Giffen behavior stopped being a puzzle; economists realized that the theory of utility was strong enough that it could explain upward sloping demands. Nevertheless, they still left an important element unsolved: they could not contruct an explicit model that predicts upward sloping demands without using extra ingredients that are not standard in consumer theory.

In the first half of the XX century, at the time when many economists were engaged in the theory of Giffen behavior, few empirical economists noticed that Giffen behavior had not been documented. Thus, they shifted the discussion from creating models that predict this phenomenon to finding actual empirical evidence of its existence in the real world, and this gave birth to the Empirical period.

Finally, in the Synthesis period, economists succesfully documented Giffen behavior and built a model that explains this phenomenon. Today, we live in this period. That is, today, economists have enough tools to start designing and evaluating policies that deal with Giffen behavior and subsistence consumption. This is why I provided a summary of where we stand in terms of our understanding of this phenomenon. This summary reduces the time that economists spend studying the literature; and, as a consequence, it increases the time available to start solving the global problem of malnutrition.

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Appendix A

Indifference curves that induce Giffen behavior

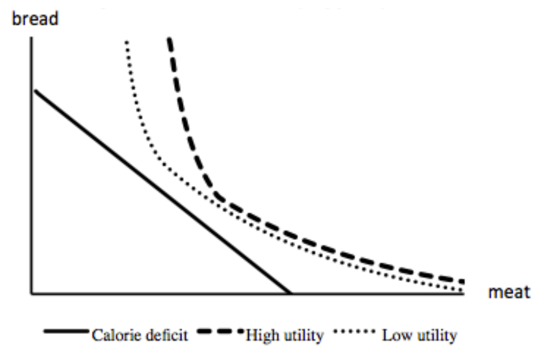
This appendix shows an example of the indifference curves map generated by this utility function. The map shows "elbow" shaped curves, just like the ones presented by Jensen and Miller (2008).

Table A.1 shows the values of the parameters employed in this example. Figure A.1 shows the map.

Table A.1: Value of parameters

Parameter	Value
Calories per unit of meat	1.20
Calories per unit of bread	2.00
Calorie requirement to enjoy flavor	1.50
Flavor per unit of meat	0.10
Elasticity of Substitution	0.16

Figure A.1: Indifference curves



Notice that there are only two shapes of indifference curves in graph 1: linear and convex. According to equation (1.2), the linear indifference curves are all parallel to the curve labeled as "Calorie deficit"; they characterize the preferences for the bundles that do not meet the requirement of calories to enjoy flavor (the bundles that keep the consumer calorie deprived), and they assign a negative value of utility. In this case, the value of the utility equals to the value of the calorie surplus. The convex indifference curves characterize the preferences for the bundles that satisfy the requirement of calories to enjoy flavor. These curves show the "elbow" shape mentioned in Jensen and Miller.

Appendix B

Numerical example of Giffen demands

This appendix shows a numerical example of the demands for bread that the Cobb-Douglas utility generates; it replicates the inverse u-shape relationship between income and price elasticity documented by Jensen and Miller (2008).

Table B.1 shows the value of the parameters used in this appendix. Using those values, this appendix generates two graphs: figure B.1 and B.2. The first graph shows an example of the demand curves at different income levels; and the second graph shows the inverse u-shape curve that this model generates when the price of bread changes from 1.60 to 1.65.

Table B.1: Value of parameters

Parameter	Value
Calories per unit of meat	1.00
Calories per unit of bread	2.00
Calorie requirement to enjoy flavor	1.00
Flavor per unit of meat	0.10

Figure B.1: Demand for bread

Figure B.2: Price elasticity of demand

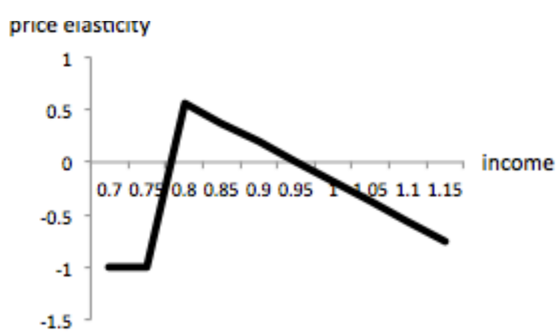


Figure B.1 illustrates three different demand curves. The only difference between these demands is the income level. All the demands satisfy equation (1.9). The demand curves with the lowest and highest income violate (1.8); the income levels in these two cases are right in the borders of the interval. As (1.8) shows, the borders are not included in the rage of incomes that induce Giffen property. The only income in this exercise that satisfies (1.8) is 0.75 (demand curve labeled as "Giffen behavior").

The range of prices of bread can be divided into three different subsets: prices that make bread be a normal good, prices that make bread be an inferior good but with a stronger substitution effect than income effect, and prices that induce Giffen behavior.

When income is 0.5 (demand curve labeled as "Low income"), the demand ends right at the border of prices that make bread be inferior. At this price, the consumer is spending all her income in bread and barely meats the requirement to enjoy flavor. Thus, when the price of bread increases, she becomes calorie deprived and her demand disappears because it violates (1.9). But, if we allowed her income to violate (1.9), then she would specialize her consumption in bread.

In the range of prices that make bread be inferior, the demand curve of the consumer with an income of 0.75 is higher than the demand curve of the richest consumer ("High income" demand). Yet, the poorer consumer is the only that shows Giffen behavior. The Giffen property in her demand happens only when the price of bread is at least:

$$\tilde{p}_b = \frac{p_m \alpha_b \left(i\alpha_m \mp \left[\left(i^2 - 2i \right) \alpha_m^2 + \alpha_m p_m \bar{c} \right]^{\frac{1}{2}} \right)}{\alpha_m \left(2\alpha_m i - p_m \bar{c} \right)} \tag{B.1}$$

$\tilde{p}_b$ is the price of bread that makes (12) equal to zero. Thus, applying the quadratic formula to the numerator of (12), the value of $\tilde{p}_b$ is found.

Figure B.2 shows how this model can account for the inverse u-shape documented by Jensen and Miller (2008). It shows the price elasticity of demand for bread at different income levels when the price of bread changes from 1.60 to 1.65.

First, notice that the price elasticity of demand is -1 when income is 0.7 and 0.75. This happens because agents with that income level are calorie deprived. Thus, they spend all their income in bread.

Second, the curve shows positive numbers when the income range is between 0.8 and 0.95. These consumers show Giffen behavior.

Last, the consumers with an income greater or equal to 1 have demands for bread that satisfy the Law of Demand. These consumers, just like the ones with Giffen behavior, perceive bread as an inferior good. But, the least poor consumers are rich enough that the income effect does not dominate the substitution effect.