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ANALYSIS OF AGGREGATE SHOCKS ON INTERNATIONAL TRADE VOLUME WITH HETEROGENEOUS FIRMS IN GRANULAR SETTING

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ABSTRACT

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Presence of large firm and granular structure of firms engaging in international trade has been one of the interesting trends in models of international trade for last five years. Solving international trade models now focuses more on large firms and the volatility caused by realization of a shock to these firms. The effect of shocks that affect a large firm and create aggregate volatility have been reviewed before. In this thesis, the effect of a shock on operating firms in a market that consist of large number of firms, which their sale sizes follow a power function, is analyzed in model with heterogeneous firms. The effect of this shock on price index and aggregate productivity is considered and it can catch some features of data on international trade. Results can explain the change in amount of trade in goods internationally while a shock is only realized by firms operating in a single country. Quantitative evaluation can show that the effect of this shock is higher for middle size countries and lower for small and large countries in the case that the reference country is the largest one in terms of economy size.

Keywords: *International Trade; Firm Heterogeneity; Granularity; Volatility.*

Dedicated to my mother, Atty

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Chapter 1

Introduction

Krugman model was the foundation of new trade theory. Second generation of models originating from it are the models of firm with heterogeneity in productivity starting from model of Marc Melitz in 2003. These models try to explain international trade in the age of globalization with focusing on the differences that stem in the firms, the very basics components of sectors operating in countries. Extensions and improvements on this subject is rapidly increasing since the foundation of this work was placed on 2003 Melitz model. In section 3 a detailed review on improvements, extensions and other relevant changes are presented.

One of the major changes in the theory is, in fact, the assumptions that was made in modeling about the size of firm, continuum of firms with large number of firms and small size related to each other and related to the market. This idea was challenged by Gabaix based on the empirical data on US firms size and is the beginning of the granularity concept.

Granularity showed the importance of shocks. Since economy is dominated by large firms, idiosyncratic shock to these firms will cause aggregate volatility. The idea further covers the volatility in trade but many aspect that might been affected by these shocks are still left unexplored. One the aspects that was not examined is the effect of shocks on the price levels in the time of their realization.

The fact that firms are large and example of them can be seen in many articles but not many take into account that changes in price index, and when they did, it was assumed to be constant and stable. The other aspect of these fluctuations are the aggregate shock that will occur in an economy and affect all firms. It is straight forward to show some changes in policy or even events like recession, war or even natural disasters have the ability of changing the overall productivity of the country. This effect in an open country would spread to the other countries in the trade network.

Explaining the time of occurrence is crucial in this research. Firms in a country realize a shock, but this shock is realized only after all firms in the reference country and the firms in other countries they trade (or have the possibility of trade) found their productivity, in other words, there is an equilibrium as it is described by Melitz in a free trade system with a number of countries and each with a number of firms serving domestic market, exporting or both.

The effect of this shock will change the overall productivity of the reference country and certainly changes the number of operating firms and their amount of export. Modeling what will happen to the other countries measured as the amount of net trade with relaxing the assumption that the shocks does not change the price levels is the core purposed of this work.

To note the importance of the view, it can be seen easily in spreading recessions and depressions started from large countries, the one that is remarked here is the financial crisis of 2007 that spread to the world based on their size, amount of trade and openness. Previously analyzed with another approach that showed the higher volatility for larger and more open countries.

The effect of changing productivity and hence cost of production is also related to another important area of research which states that if large firms in a granular setting can influence the aggregate price index by their choice of price, even with the assumption of constant elasticity of substitution, they can charge

variable mark-ups that before were considered constant over marginal cost. To further show the path of literature and how it reaches this stage, it is important to take a look at evolution of economic modeling.

Economic modeling dates back to early 18th century when economies were modeled by simple probabilistic equations. In 18th century works of Adam Smith, Bernoulli and Laplace significantly improved the concept. These models where simplistic and tried to explain the relationship between agents in the market. Early markets were defined as a network of producers and consumers. Although trade always played an important role in economies, not many tried to integrate it in their model.

Trade is an ancient concept that can be traced to the beginning of human history. Long distance trade trace back to around 150 thousand years ago and it was always an important component of all economies. The outlook of trade, on the other hand, have changed with years without reducing its importance.

Mercantilism was the dominant practice before 18th century. This school of thought was in favor of exporting and against import to always insure balance of trade. All imports of finished goods were kept at the lowest possible level and if possible been payed by domestic goods not gold and silver which been used as a monetary reserve those days. High taxes and tariffs for foreign goods and lower for encouraging domestic producers to export. This idea and other protectionism barriers were dominant in Europe when they were questioned by Adam Smith, the father of political economy. He discouraged barriers to trade and encouraged free competition. Later, Ricardo added the theory of inflation that explained how excess currency will lead to inflation, the concept which raised Monetarism.

Inspired by Smith's work, David Ricardo proposed theories about labor, rent and value and in particular, theory of comparative advantage. He opposed tariffs and mercantilism by explaining opportunity cost and efficient production of goods. If in a non distorted market or perfect competition, all producers focus

their resources on producing the good that they have a comparative advantage, with exporting it and importing the other goods, they can benefit from lower costs and more goods. This model therefore named Ricardian after its theorist.

Another step in modeling international trade was made by Eli Heckscher and Bertil Ohlin. They expand Ricardian model's dimensions by adding capital as another factor of production. These models and the concepts argued by Smith are the core of what is called classical economics. In late 18th century, economists focused more on satisfaction gained from the good or utility. Efforts on explaining prices ans wages through supply and demand by maximizing utility are the basics of neoclassical economics.

Neoclassical economics filled the gaps of classical models. It assumes that firms maximize their profit and consumers maximize their utility and with the present of perfect information, individuals act rationally. From notable works that we still use, it is necessary to name Alfred Marshall. His work on price selection by intersecting supply and demand curve made a great contribution to the foundation of what we have today. Although the ideal of formalizing equilibrium in a general economic system was first proposed by Walras but it was Marshal whom developed a model to analyze an economic system.

Imperfect competition was introduced by Joan Robinson and Edward Chamberlin in 1933, result in the popularity of many economics tool like marginal revenue curve and indifferent curves that we still use. Solving the problems of partial and general equilibrium needed strong mathematics and modeling become complicated. Specially with introduction of product differentiation when producers can charge more for their product, more than the one that perfect competition would allow them.

Cournot models of monopoly and duopoly was another contribution of mathematics in economics, his ideas about probability and formulating price as a function for economic analysis was a new approach. What he proposed for solving

was strategy and reaction function, game theory with non-cooperative game to be precise.

From here we have two branches, on one hand we have game theory and on the other hand new theory of international trade which both have Noble prizes in their resume. Each have their own strength and weaknesses but the approach to the problem solving is completely different. Game theory tries to explain the strategy behind the decisions and behavior of firm, consumers and market through games. Noticeable difference is for example, price of a good in a market is not necessary a function of its marginal cost, firms might set a higher or lower price (of course until they make a profit) based on information, competition and other characteristics of a game like symmetry, zero-sum and others.

Before going back to new theory of international economics, it is important to mention another school of thought, the Keynesian economics. As the name suggest is named after John Maynard Keynes for his ideas about severe world-wide economic depression in the early 19th also called great depression. All can be summarized in explaining the causes of recessions and they way out of it. Keynes proposed lowering the interest rate and creating business opportunities by government investment in infrastructure and for causes, he proposed excessive savings and high wages. The main idea is if the prices become adjusted, demand would change until full employment.

Development of this ideas lead to another aspect which is nominal rigidity better known as sticky wages and price. Dynamic stochastic general equilibrium (DSGE) models used by economists contributed to model uncertain conditions with stochastic output, also purchases, that was dependent on the price chosen by firm. Economist chose separate routes from here while some on them including Franco Modigliani, James Tobin and Gregory Mankiw pursued and emphasized more on microfoundations of consumption which led to what is called Neo-Keynesian, the others like Paul Samuelson emphasized on the similarities

with neoclassical economics what is called Neoclassical synthesis.

Neoclassical synthesis originally proposed by John Hicks but it was Paul Samuelson who used the word synthesis to show that in neoclassical microeconomics synthesis with Keynesian macroeconomics. This was the link which introduce supply and demand to Keynesian models.

Now returning to the new theory of international trade. Game theory was mainstream around 1960s, but The other branch was growing too. Works of Avinash Dixit, Joseph Stiglitz on elasticity of substitution and the most important one, Paul Krugman model with the preferences for diversity. The latest model assumes that consumer prefer a diverse choice of variety also knows as love of variety for consumers and economic of scale for producers. Krugman model is the the baseline for literature review and the rest of this research is organized as follow: In the next section, the used methodology is explained followed by literature review. In the section 4, the theoretical model is presented which is followed by section 5 that showed the numerical results of simulation and analysis of the results.

Chapter 2

Methodology

To evaluate the hypothesis, there should be a framework for mathematical calculations. This framework make it possible to evaluate the results of model with real data. How this research is organized and the chosen methods and parameters is explained in this section.

2.1. Theoretical Framework

In section 4 the model is presented and in this part the characteristics that are considered are explained. The approach toward each component will determine how the economy will be modeled. The first component is demand and consumption and it is the factor that characterize utility. Here it is assumed that goods produced by firms feature constant elasticity of substitution. CES demand function is vastly used in modeling, there are other alternatives to CES but CES demand best fit the expectations like love of variety. Another benefit of using CES is the simplicity of algebra due to the rich body of available knowledge.

The demand function comes with an ideal price index to complement the demand as price aggregation and it make it possible to set the constrain which is the total expenditure in the economy. This constrain is usually features labor,

quantity and price of the consumed good. In fact, this constrain will set the model with only one factor of production, labor. As can be seen in many models with assumption of intermediate goods, these goods are explained in unit of labor and a percentage of total expenditure. To model intermediate goods or other components, that is needed to produce one unit of the final goods, the general approach is to assume they feature Cobb-Douglas preferences. This setting will help a lot to fit the results of model to real data but does not make a significant change in the theoretical model since the parameters of the C-D are independent from the rest of the model.

With the explanations above, demand section will be cleared. Utility is measured in the amount of consumption of goods with the elasticity greater than one.(it is implicit that with elasticity of substitution approaching to zero, good are perfect complements and when it approaches to infinity goods are perfect substitutes) Ideal price index and the constrain of total expenditure is set featuring only one factor, labor, which is also the indicator of economic size.

Production is the part that usually differentiate the modeling approach. To model production with heterogeneity in firm's productivity, cost of production should be calculated by assuming at least one parameter as a function of productivity hence the simple way to do that is assuming a fix cost and a variable cost which is a function of productivity.

Cost of production should be characterized as labor and the link to do so it the wages. Recent researches showed to importance of wages and showed that they are not equal among countries. Wages act as a weight to adjust labor during the modeling of a trade. They will be appearing in both side of the total expenditure constrain therefore in simple approaches to modeling it is convenient for simplicity reasons to normalize them to one.

Pricing rules is driven from profit maximization, the general practice is that it is a constant mark-up over marginal cost. This is driven form the assumptions

of production cost, other methods, for example in Atkeson and Burstein (2008), used a setting with variable markups. Regarding to quantity supplied, it will be calculated by pricing rule and together will wrap up the production section.

All models of firm heterogeneity should have a level of cutoff indicating the minimum productivity level that a firm can operate and generate positive profit, to do so it is possible to use minimum productivity cutoff as was originally proposed by Melitz. The other approach which is more convenient for models using either more than one factor of production (using intermediate goods as well) or assuming Pareto distribution for productivity. This approach use the inverse of productivity and marginal cost to determine cut off value hence firm could generate positive profit as long as their marginal cost are below the maximum marginal cost.

Using marginal cost instead of productivity have an important benefit. If productivity follows Pareto distribution, the inverse of productivity have a power function and calculating integrals over this power function would be easier. The assumption of Pareto distribution of productivity is common practice in this area, other heavy tailed distributions sometimes proposed but until now, Pareto distribution is most common distribution used in modeling productivity.

The model is determined by calculating the new price index regarding to the maximum marginal cost form that the quantity supplied and number of firms will be clear. In the simple forms like this one, market will always clear because the quantity supplied is calculated based on the new price index and fix cost is explained as unit of labor so all together will satisfy the constrain of total expenditure.

For modeling the trade it is assumed that firms will pay a transportation cost and a fix cost of production. It is normal to differentiate the cost of production in other countries by assuming exploration cost or other similar ones to show that the foreign firms have to pay more to start exporting rather than paying just

a transportation cost. The disadvantage is that it will reduce the tractability of the model. The other approach that is used here is picking a fix cost of production in all countries but putting a transportation cost for exporters. It is important to note that there should be a cost to distinguish exporters form domestic produces otherwise there is no difference between those whom export and those whom just serve their domestic market. Transportation cost is considered as a percentage of the price (known as iceberg costs). It is a method to shift the cost of exporters higher or decrease their productivity.

There is no method for determining the parameters of the distribution of productivity therefore to link the theoretical model to data, a link should be created. This link is the distribution of firm size and the coefficient that links the exponent of productivity of the elasticity of substitution. Some extra calculation is necessary to link the model to available data in theoretical part and in the next part output of the model will be evaluated with the real data.

2.2. Quantitative Analysis

Quantitative analysis is consist of three parts. In the first part, calibration, parameters of model will be discussed as well as the reason of choosing and its source. It is natural to have a lot of resources to pick from, each reporting a different value. Choosing from these values on the other hand is not difficult because some values have been used considerably more by scholars and the reason why the other values might be biased is also mentioned by them.

In simulation, the theoretical model is programmed to generate the results. This part would be the core of numerical evaluation in the work and it will generate the main outlines. Almost all possible methods of simulation is explained in (Maliar and Maliar, 2013 ,Chapter 7), discrete event is the choice of this work.

Picking the method of simulation is heavily influenced by the scenario, here

it is assumed that firms enter the market without knowing their productivity, they will draw a productivity that also determines marginal cost of production. Respect to the realized cost of production they decide to stay and produce or exit, this limit is determined by maximum marginal cost of production. The firms decided to produce will then check if they can also export, if their cost of production is less than maximum cost of production multiple by transportation cost in another country, they decide to export. After everything is clear a shock been realized in reference country (United States) that generates an aggregate shock to the reference country, here it is explicit that with the increase of aggregate productivity, some firms exit. Again the process of drawing productivity starts, firms from all other countries still draw their productivity from the productivity function with initial parameters while the reference country realize a change in its productivity function.

The choice of software for calculating large number of firms and economies is an active branch in computer science both in choice of software and hardware. For example MATLAB is not supported completely on supercomputers (more than 32 core) and other software supported by supercomputers does not have its abilities.

looking to the available software and hardware and the process of drawing productivity, Arena as a software for discrete event simulation has been picked. It allows to model the process exactly as it is described above. The challenge is ensuring the timing of each event for all firms and countries remain the same meaning all firms enter the market in a same time. For productivity function the general method is the inverse transform sampling since we have the cumulative distribution function of Pareto distribution.

To evaluate the result, simulation should be run for both settings once with all countries with the same productivity distribution and another time for when only reference country has a different productivity function. For each setting the

simulation runs for 1001 irritation.

For collecting data from runs, three different method is usually used: picking mean, median or mode. Picking any of these have its advantages and disadvantages, choosing mean might not take into account the diversity, median doesn't consider skewness and mode does not care for mean. All these simple problems of descriptive statistics is technically doesn't matter since irritations generates enough numbers and each irritation is highly independent of the others, 1001 observation is large enough to benefit from central limit theorem and simply use the mean.

Chapter 3

Literature Review

3.1. Introduction

Many theoretical researches noted that with the use of micro level firm data in an industry, there would be a series of features like heterogeneity in productivity, size and some other economic characteristics that cannot be explained by the previous models. These researches let to the development of theoretical models that could catch these empirical challenges. There are two major branch of these models which is based on the two important framework although in recent works it is hard to separate them distinctively.

The one that is the main focus in this research is the Melitz (2003) model which is based on Hopenhayn (1992) dynamic industry model to monopolistic competition in a general equilibrium setting with the introduction of firm heterogeneity into the model of Krugman (1980) for intra-industry trade.

The second branch of models are based on the framework of Bernard, Eaton, Jensen, and Kortum (2003) which integrates a stochastic firm productivity into the multi-country Ricardian model. It is based on probabilistic formulation of competitive advantage in Eaton and Kortum (2002) which is an extension of

Dornbusch, Fischer, and Samuelson (1977) with an arbitrary number of N countries.

3.2. Firm Productivity

In Melitz (2003) there is a continuum of firms that each produces a single and different product variety, with all firms sharing a fix cost and different productivity level. Firms are uncertain about their productivity before entrance and after entrance they would have a productivity which is fixed and driven from a productivity distribution. All firms with the same productivity behave the same. With this assumption there would be a reallocation and selection among firms which can be a source of endogenous firm productivity growth.

Bernard, Redding, and Schott covered this subject thoroughly (Bernard *et al.* (2006b), Bernard *et al.* (2010) and Bernard *et al.* (2006a)) and their outcome exhibit substantial heterogeneity across products with firms and dominate production and exports. Some other scholars also explored this matter for example multi-product firms in Baldwin and Ottaviano (2001) that can reduce the inter-variety competition by locating production of some varieties abroad through FDI. In addition, Nocke and Yeaple (2006) developed a model that "organizational capabilities" is the single difference of the firms and productivity of all products decline when number of producing products incline.

In Bernard *et al.* (2006b), they further expand the theory by removing the restriction of producing a single product. They argued that firm productivity in a given product is a combination of two capabilities of firm-level ability and firm-product-level expertise which shows the within-industry heterogeneity in firm ability across multi-product firms.

Heterogeneity in productivity is not a charachtristic of monopolistic competition, many models of oligopoly also feature this trait as in Eckel and Neary

(2010) which introduced a model with multi-product firms in Cournot oligopoly using quasi-linear preferences. In their setting, exogenous number of firms can produce additional products by paying the adaptation costs and multi-product firms are considered homogeneous in same industries.

Numerous examples of models, supported with empirical data, can be found to demonstrate firms differ in productivity. It is now well known that, for sure, it differs from firm to firm but the source of it is not clear. Very inconsiderable information exist and no comprehensive research is done to find the source of this heterogeneity. As a consequence, the general practice is to focus at the outcome regardless of the cause. Need to remark that productivity modeled in Melitz (2003) does not follow a specific distribution, it need only to be fat-tailed, later with the aid of data it became a popular way to assume that it is Pareto distributed.

3.3. Welfare gains

Classical theories of international trade usually identify the source of welfare gains of trade as comparative advantage, product variety and resource endowment. In the theories of heterogeneous firms and trade, there is necessary a welfare gains form trade caused by the rise of the zero-profit productivity cutoff. Indirect utility in open and close economy is expressed in term of productivity cutoff and this rise can be translated as within-industry [1] reallocation of resources.

Firm-level allocation in the cause of three major source of gain between industries, firms and within firm:

[1]Categorize intra/inter industry trade usually done by using a described system that is adopted by the source of data like "Harmonized Commodity Description and Coding System", also known as the Harmonized System (HS).In this system, intra-industry trades are trades within a same industry code and inter-industry trade happen in different industry code. In the U.S. trade data, a product is defined as a ten digits Harmonized System (HS) category for production data it is defined as a five digits

3.3.1. Love of variety

Trade expands the available set of consumer choices. Consumers can buy any variety that is produced in the integrated market; moreover, producers can produce each variety for the whole integrated market that increases return to scale and decreases average production cost. Producers can benefit economic of scale since the fixed cost is spread over an increasing number of output unit.(Melitz and Trefler, 2012)

Empirical evidences have been found for many countries and several articles can be found in which they inspect the effect of trade on variety of offering products. As an example of those, more thoroughly results from US data in Bernard *et al.* (2006b) or for Canada in Baldwin *et al.* (2001) and Baldwin and Gu (2009) along with Baldwin *et al.* (2005) for US and Canada can be considered. All show a decrease in the product offering by firms regarding to the implementation of US-Canada free trade agreement in 1989. Furthermore, it stands for the rest of the world as Balistreri *et al.* (2011) states that if all the barriers to trade been eliminated, number of varieties in the world with rises by 3 percent, welfare rises by 2 percent and prices fall by 3 percent.

Bernard *et al.* (2006b) developed an equilibrium for multi-product firms and their behavior during trade liberalization. Their approach is in line with Krugman (1980),Krugman (1979) and Helpman and Krugman (1985) which not only validate the increase of varieties but also expand the theory to cover also firms with multiple products.

Another way of expressing this subject is presented in Helpman (2011) that show how international trade enlarged the market place, reduced the price and created more varieties, In addition, Mayer *et al.* (2011) take it to another dimension by highlighting how competition across market destinations affects both a firms exported product range and product mix.

3.3.2. Reallocation at the Firm Level

Reallocation at firm level is a result of shifting resources from less productive firms to the one with higher productivity. The gain form reallocation between firms is one of the behaviors that was not possible to explain with traditional models with identical firms.

With firms being heterogeneous in productivity and a fix setup costs, more productive firms would have lower marginal cost this will allow them to produce more with lower prices but a higher markup over marginal cost and earn higher profits (Melitz and Trefler, 2012).

As soon as the economy opens to trade, market size and level of competition will increase. This rise will lead to reallocation of production from firms with low productivity to the higher ones hence the aggregate productivity will increases but productivity of individual firms will remain the same. This openness in reality is the reduction of trade cost, but not eliminating it. Partial liberalization of the market Is the cause that some firms expand and export, some shrink and the worse productive one exits; therefore, it create the same reallocation effect.

With the presence of trade cost, the marginal cost of firms deciding to export to the foreign markets will increase and the profit and quantity sold will decrease. When the marginal cost, which also includes trade costs for exporters, crosses the maximum marginal cost of the market, operating in that market will not be profitable and the firm will only serve the domestic market.

To support this proposition, Baggs (2005), Baldwin and Gu (2006), Bernard *et al.* (2006a) examined FTAs and successfully showed that the free trade agreement tariff cuts raised the exit rate and Lileeva (2008) enhanced their findings by stating that the increase of exit rate only force non-exporters to exit.[2]

After the observation of reallocation at firm level caused by trade, the gains

[2]For a detailed summary on the relation between aggregate productivity and trade liberalization see: Wagner (2007) and Greenaway and Kneller (2007)

from reallocation became the scope of research in many economies and it was reported for many countries. Example of these observations is present in work of Bernard *et al.* (2003) for United States, Mayer and Ottaviano (2008) and Bartelsman *et al.* (2013) for European countries, Hsieh and Klenow (2007) for India, China and US, Pavcnik (2002) for Chile and Midrigan and Xu (2010) for South Korea, China and Columbia, moreover, more comprehensive in (Alfaro *et al.*, 2008) for more than 80 countries and Wagner (2007) for all the word.

3.3.3. Rising Within-Plant Productivity

Enhancing activities that happens within-plant to raises the productivity is another way of gain from trade. Firms who export have a bigger market, therefore, they have more possibility to investment for an innovative activity to increase their productivity. Their larger market causes the investment to spread over the enlarged market and decline for each unit of output. Nevertheless non-exporters been encouraged to engage in exporting and innovating to further cover the expenses of the innovative activities.

In other words, trade liberalization can motivate firms to expand their market (Melitz and Trefler, 2012). Although some firms should not been exporting because of their poor productivity (based on the theoretical frameworks), but empirical studies show that many firms which gain from trade liberalization, both form improved productivity and increased innovation, were low productivity firms which should not been exporting .[3]

Innovation is often considered as an enhancing activities, the characteristics of it is evaluated in Lileeva and Trefler (2010) that show low productivity firms gain more than high productivity firms from innovating, using data from Canada

[3]This kind of gain is not the qualification of heterogeneous firms. Here the discussion is about innovation gains with heterogeneous firms, for theories of this innovation gains from trade with homogeneous firms and country level evidence see: Grossman (1993) and Helpman (2009)

along with same observations in Baldwin and Gu (2003), Lileeva (2008) aso for Canada.

Other researches includes Van Biesebroeck (2005) for Sub-Saharan African countries, De Loecker (2011) for Slovenia, Bustos (2011) for Argentina and more comprehensively López (2005) for rest of the world also indicate a higher gain from innovation for low productivity firms, non-exporters. Their results like the ones for Canada and US are contradicting with Bernard *et al.* (2007), as it was discussed above.

In several ways, research and development is similar to innovation. It can be observed empirically in Aw *et al.* (2007), Aw *et al.* (2008) and Aw *et al.* (2011) that show the dynamics between decision to export and R&D using Taiwanese data also in Bloom *et al.* (2011) that show the increase of R&D as a respond to import from China in technologically advanced European countries. It can be seen theoretically modeled in Atkeson and Burstein (2007) which present a general equilibrium model of the response of firm's decisions to operate, innovate, and engage in international trade to a change in the marginal cost of international trade.

3.4. Types of competition

The first models of international trade like Ricardian and Heckscher-Ohlin where based on the *perfect competition*. These models where the primary method for explaining trade between countries. One notable feature of perfect competition is the large number of producers and consumers that take rational decision based on perfect information, without any market power to change the prices therefore considered as price takers. The other notable features are absent of economic of scale and homogeneous products.

The other type of competition is *monopolistic competition* which differs in

some aspects to perfect competition and widely known by theories of Chamberlin who thoroughly explained the concept. Monopolistic competition shares some features of perfect competition but differs in market power of producers. All producers have equal market power and prices are influenced by their production hence they have a slight power over prices. In addition, the assumptions about homogeneous goods is changes to differentiated goods and information available to individuals is no longer perfect.

This kind of competition removed many restriction and became popular around 1980. Many written articles in that time are the foundation of all model of heterogeneous firms today and between those, the Noble winning work of Krugman (1980). Since it was a new type of competition, new tools should be developed.

In pursuit of mathematical formulation, Helpman (1984) showed that production sector is efficient or constraint efficient and can be modeled mathematically, it is significant because it implied that the tools for perfect competition can be used also for monopolistic competition. While this results were standing for homogeneous firms, Feenstra and Kee (2008) showed that GDP function is also well-defined for heterogeneous firms with endogenous productivity, the other assumption he used, was the Pareto distribution of the firm's productivity. Although perfect and monopolistic competition are different in some basic concepts, they are similar in some aspects, both assume the firms are atomistic and do not compete strategically.

Strategic competition leads to the last type of structure, *oligopoly*. In oligopoly, market is dominated by small number of firms and It differs significantly with the other competitions mentioned above. There are some issues that will rise with oligopoly in general equilibrium which makes them hard to catch the empirical findings in micro level data, nevertheless, the concept of firm heterogeneity reached models of oligopoly. Peter Neary (2010) can shows the place

of the third type of competition in international trade. Considering this type, models of oligopoly are successful in explanation of dominance of large firms in export and distribution of firm size, which is fat-tailed.[4]

3.5. Gravity

One of the important tools to predicting bilateral trade between two countries is the gravity model. Extensive literature on aggregate value of trade between two countries supposed that this value is proportional to the product of their income and inversely related to the distance between them, this relation is known as gravity equation for bilateral trade flow.

Recent researches had considered other variables that might influence this equation to adopt ti for use in monopolistic competition. Using micro-data and micro-founded formulation, It can be shown that this equation can be extended to cover also the multilateral friction of all trade partners.

Moreover, it was proposed by (Bernard *et al.*, 2007) that it can yield the distinction of extensive margin (the measure of exporting firms) and the intensive margin (average exports conditional on exporting) in the gravity equation. Also, Chaney (2008) introduced firm heterogeneity in productivity and fix cost of exporting to Krugman (1980) gravity equations and showed that elasticity of substitution has opposite effects on each margin (intensive and extensive).

To analyze the effect of trade liberalization, Arkolakis (2008) generalized the models with constant marginal costs to reach additional consumers. By increasing marginal costs, the model shows that firms with low volume of trade prior to trade liberalization episode grow more than trade costs decline and there is a positive association between firm entry and market size with the existence of many small exporters in each exporting destination.

[4]More details on distribution of firm size is presented in the next section 3.6

In addition to this predictions, Helpman *et al.* (2007) model can predict positive and also zero trade flows across pairs of countries with variable number of exporting firms and can estimate the trade volume per exporter (intensive margin) and number of exporters (extensive margin). These results shows that the bias of traditional estimations is due to omission of the extensive margin.

3.6. Market Structure

Melitz (2003) uses continuum of varieties which, combines with the fact that his model is single product, means that market consists of many firms and these firms are small related to the whole market. Availability of firm level data reveals that assumption of many small firms is not a realistic one and firm size distribution is far from what it was assumed.

It is possible to find many examples in literature as in Korea, the top two firms, Samsung and Hundyai, account for 35% of exports, and 22% of Korean GDP (Di Giovanni and Levchenko, 2009). In Japan, the top 10 firms account for 35% of the exports (Canals *et al.*, 2007). In the US, the total sales of the top 50 firms are 24% of GDP (Gabaix, 2011).[5] These example lead to another unexplained concept which is: *What will happen if one of these large firms faces a strike or a successful innovation?*

Melitz (2003) model and all its inheritors share the same drawbacks and it is the lack of explaining firm specific shocks. These shocks that are different from economy-wide ones like inflation and change of policy, can also play and important role in explaining aggregate fluctuations.

Many of examples from these type of shocks are provide in Gabaix (2011). Noticeable ones are the case of one-time dividend payment of Microsoft that boosted personal income from 0.6% to 3.7% for a total value of $24 billion in

[5]For more example see:Peter Neary (2010)

US and the other is the case of Nokia that stand for 1.6 percentage points of Findlands GDP growth. Data on firm sales show that modern economies indeed consist of large firms that an idiosyncratic shock to one of large firms can lead to a aggregate shock which is not negligible. In other words models with assumption of continuum of small firms cannot explain the present of individual firm shocks that cause economic scale fluctuation that it is not diffused by combination of all firms.

3.6.1. Granular vs. Atomistic

The "Granular Hypothesis" proposed by Gabaix (2011) is explained as: *"many economic fluctuations are not due, primitively, to small diffuse shocks that directly affect every firm. Instead, many economic fluctuations are attributable to the incompressible "grains" of economic activity, the large firms".*

This hypothesis cleared some doubts about cause of macroeconomic fluctuation. These causes includes the dependence of the amplitude of GDP fluctuations on GDP level, the microeconomic composition of GDP, the distribution of GDP and firm-level fluctuations.

On the other hand, there is "atomistic" firms, the basic assumption of earlier models that firms are small related to each other and market. With increasing body of knowledge referring "grains" to large firms and "granular" to the market with large firms, the market structure with many small firms is called "atomistic".

Discovering features of markets with Granular structure is an active and relatively new area of research. To better define the granularity, another characteristic for firms in this environment is mentioned by Canals *et al.* (2007). It pointed out three levels of observed lumpiness, first is that few industries account for a large portion of the trade. Second is that large portion of export comes from exporting firms that are originated from small number of countries. Third is the few trade flows related to few countries and few industries account for a

large portion of the overall trade flow.

3.7. Distribution of firm size

The most comprehensive research about firm size in US is Axtell (2001). He analyzed the US firm level date and reported that distribution of firm size in US follows a power law and more precisely, Zipf's law. The superiority of his research is the source of data, He used Census[6] data and did a range of estimates between 0.996 and 1.059 with a very low standard error (around 0.055).

In other works, Hinloopen and Marrewijk (2006) and Easterly *et al.* (2009) showed this relation for the sectoral trade flows. The later one used a sample of 151 countries over a range of 3,000 products. In a more general explanation, if the variable of interest follows a geometric Brownian motion, Zipf's law can be observed (Rossi-Hansberg and Wright (2007), Luttmer (2007), Gabaix (1999)).

The exponent of the power function also plays a role in macroeconomic fluctuations as it is shown in Gabaix (2011) and Di Giovanni and Levchenko (2012). This role extended also to regulation of entry and executive compensation by Di Giovanni and Levchenko (2013) and Gabaix and Landier (2006). Theoretically, other distribution can also be considered but power law fits the date more accurately than the others.

Work of Axtell (2001) included all firms but if the firms have been separated to exporters and non-exporters, the results would change. With this setting the component of power law will be lower, Di Giovanni *et al.* (2011) using a large sample of French firms, reports that for non-exporters the component is nearly identical but for exporters is noticeably lower. Furthermore, if the sample restrict

[6]The Census Bureau is part of the U.S. Department of Commerce. The U.S. Census Bureau is overseen by the Economics and Statistics Administration (ESA) within the Department of Commerce. The Economics and Statistics Administration provides high-quality economic analysis and fosters the missions of the U.S. Census Bureau and the Bureau of Economic Analysis. *-From: http://www.census.gov/*

to larger exporter the component will converge to the domestic one.

In Models of firm heterogeneity based on Melitz (2003) with the assumption of Pareto distribution for the productivity, firm size will follow power law. This will hold in the close economy but with opening to international trade distribution of firm size systematically changes and it can lead to a false results because exporters tend to be larger and more productive. In an open country, Only domestic sales of companies follows a power law, this is one of the results presented in Di Giovanni *et al.* (2011).

Data

Although work of Axtell (2001) is still the most consolidated research about the topic since he used Census that lists all US firms, the period of data gathering is important in our case. Many scholars still use the same numbers and using the same data (US Census 1997) used by Axtell (2001), among them Gabaix (2011), Di Giovanni and Levchenko (2012), Di Giovanni and Levchenko (2013) and Di Giovanni *et al.* (2011) can be mentioned.

On the other hand, some scholars also started to gather new information and re-calculated the exponent. The downside of this is that since, for privacy reasons, US Census's data are not available to public, attempts to fit other data sources to a power function would failed.

Sensitivity of data source is namely explained by how they manage to index the firms with zero number of employees. Failing to record number of firms with few number of employees usually will result in a log-normal distribution as mentioned by Axtell (2001). He also mentioned that data of Compustat[7] are heavily censored in terms of small firms, inconsistent respect to Census and not monotonically decreasing when size of firm increases. Other recent calculations of

[7]Compustat is a database of financial, statistical and market information on active and inactive global companies throughout the world since 1962. It is a division of S&P Capital IQ, which is a division of McGraw Hill Financial.

firm's size are Podobnik *et al.* (2010) with data from bankruptcy.com[8], Alfarano *et al.* (2012) using Thomson Datastream.

3.8. Concluding Remarks

Models of monopolistic competition proved to be more efficient to catch empirical evidence and data. Models of firm heterogeneity are also very efficient to showing the variation of firms operating in a market. The cause of this variation, generally, assume to be their productivity and their productivity usually assumed to follow a Pareto distribution. What causes the productivity to differ from firm to firm or other factors that might causes heterogeneity is not clear. In addition, most contributions to analyze wages, consider wages inequality as a result while it is not clear if wage difference is another source of firm heterogeneity or a consequence of productivity difference.

Presence of large rang of horizontally differentiated varieties is encouraging to use CES preferences for utility and demand because of their implication of strong love of varieties. In addition to utility and demand, estimating welfare gain from micro-data have to be done in combination with trade models as its suggested in Arkolakis *et al.* (2009).

Firm sales should assume to follow a power law with parameter close to one and less than two, using continues distribution have the advantage of simplicity in solving integrals. It can be done by either assuming a large number of firms with one product or multi-product firms and large number of varieties. In models with constant markup over marginal cost, adopting Pareto distribution for productivity will cause a power law for firm sales.

The idiosyncratic shock that affect a firm will cause aggregate volatility. Previously to calculate the aggregate volatility, the effect of this shock on price

[8]BankruptcyData.com has been the industry's premier resource for corporate bankruptcy information and analysis since 1986 -*From: http://www.bankruptcydata.com/*

levels were neglected. The shock that is going to be used here take into account the also the effect of realization of this shock on price levels.

Chapter 4

Theoretical Model

The first sections introduce the basic setting of an economy with heterogeneous firms similar to Melitz (2003) and Krugman (1980), consumers maximize the CES objective over all available varieties of J in the country. It differs in a way that firms are able to produce more than one variety. The method for open economy and linking the model to data from Di Giovanni and Levchenko (2013) is considered to maintain the evidence that only domestic firm size follows a power law.

4.1. Demand

Utility function:

$$U \equiv Q = \left[\sum_{k=1}^{J} q(k)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{4.1}$$

Where $\sigma > 1$ is the elasticity of substitution between each two varieties and $q(k)$ is the total consumption of variety k.

$$I = \sum_{k=1}^{J} q(k)p(k) \tag{4.2}$$

$p(k)$ is the price of variety k and I is the total expenditure in the economy.

$$q(k) = \frac{I}{P^{1-\sigma}} p(k)^{-\sigma} \tag{4.3}$$

and P is the ideal price index in this economy:

$$P = \left[\sum_{k=1}^{J} p(k)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{4.4}$$

4.2. Production

In the country, there is a large number of potential entrants, each of them can produce multiple variety. If they decide to enter, they have to pay the entry cost of f, then they will realize their productivity and choose to exit or produce. There is one factor of production, Labor (L), which is also an indicator of the economy's size. Wages w is normalized to one. Firms are heterogeneous in productivity and cost of production consist of a fixed overhead cost for all firms but different variable cost based on their productivity φ.

$$l = f + \frac{q}{\varphi} \qquad ; \varphi, f > 0 \tag{4.5}$$

After a firm find out its productivity, it can decide to produce or exit the market, if it decided to stay, it will realize a shock which itself is Pareto distributed. Productivity is independent across firms therefore this shock is independently and identically distributed. After this uncertainty cleared, firms start to produce with a marginal cost function that have a reverse relationship with their productivity. This work is different from the one in Di Giovanni and Levchenko (2012) for the fact that the realized idiosyncratic shock to the firm is

not normalized to one.

$$\begin{aligned} \varphi = \varphi_{normal} &\sim Pareto(\alpha, b_1) \times z \sim Pareto(\beta, b_2) \\ &\sim Pareto(\theta = \alpha + \beta, b = \alpha\beta \frac{b_1^{\alpha} b_2^{\beta}}{\alpha + \beta + 1} \\ M(\varphi) &= \frac{1}{\varphi} \end{aligned} \tag{4.6}$$

All firms face the residual demand from (4.1) with elasticity of σ and chooses the same profit maximizing markup ($\frac{\sigma}{\sigma-1}$) over marginal cost $M(\varphi)$. Using φ instead of j will group all the firms with a same productivity that produces a single variety. Therefore, pricing rule can be determined and respecting to it, the quantity supplied become:

$$p(\varphi) = \frac{\sigma}{\sigma - 1} M(\varphi) \tag{4.7}$$

$$q(\varphi) = \frac{I}{P^{1-\sigma}} \left[\frac{\sigma}{\sigma - 1} M(\varphi) \right]^{-\sigma} \tag{4.8}$$

4.3. Aggregation

The profit function rearranged for $M(\varphi)$ is:

$$\pi(\varphi) = p(\varphi)q(\varphi) - [f + M(\varphi)q(\varphi)] = \frac{1}{\sigma} \frac{I}{P^{1-\sigma}} [\frac{\sigma}{\sigma - 1} M(\varphi)]^{1-\sigma} - f \tag{4.9}$$

A firm could operates as long as it produces positive profit, in zero-profit condition, the maximum cost of production is:

$$M^*(\varphi) = \frac{\sigma - 1}{\sigma} P [\frac{\sigma f}{I}]^{\frac{1}{1-\sigma}} \tag{4.10}$$

Relative output share of firms can be represented by distribution of its cost and its expected value which is independent from number of firms (N) operating

in this economy. Since firms do not produce with any cost more than $M^*(\varphi)$, putting (4.7) in (4.4) we have the price level:

$$P = \left[\sum_{k=1}^{J}\left[\frac{\sigma}{\sigma-1}M(\varphi)\right]^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{4.11}$$

Marginal cost of production has a reverse relationship with productivity hence follows a power law. With this assumption it is possible to calculate the expected value of marginal cost while it is less than the maximum. After plugging (4.10) and applying changes based on distribution assumption, price levels become:

$$P = \frac{1}{b}\frac{\sigma}{1-\sigma}\left(\frac{\theta}{\theta-(\sigma-1)}\right)^{-\frac{1}{\theta}}\left(\frac{I}{\sigma f}\right)^{-\frac{1}{\theta}\left(\frac{\theta-(\sigma-1)}{\sigma-1}\right)}N^{-\frac{1}{\theta}} \tag{4.12}$$

And N is the number of firms operating in the economy. In zero condition the total expenditure on investment should be equal to the total profit of the economy to clear the market for labor (L) adding this to the results before we have the number of firms operating in the economy:

$$N = \frac{\sigma-1}{\theta}\frac{L}{\sigma f} \tag{4.13}$$

4.4. Opening to trade

Regardless of country size, each firms can export their products to the other countries. Each firm that wants to export to country i has to pay the fix cost and another additional cost of transportation proportional to the price of their good of τ(equal to one for the home country). Increase in the country size have no effect on the firm level variable and producers divide their production in domestic and foreign market. It is also possible to differentiate the fix cost of production in the domestic country and the cost of investigation and fix cost of production in a foreign market; also, it is assumed that firms draw their productivity and then

decide to serve or not serve the foreign market. Firms that export have to set a higher prices since their marginal cost of production is increase by τ but firms in other countries except the reference country do not face the shock mentioned before and their pricing rule will be:

$$\begin{aligned} p_d(\varphi) &= \frac{\sigma}{\sigma-1} M_x(\varphi) \\ p_x(\varphi) &= \tau p_d(\varphi) \\ \varphi &\sim Pareto(\alpha, b_1) \end{aligned} \tag{4.14}$$

Accordingly, quantity supplied is:

$$q_x(\varphi) = \frac{I}{P^{1-\sigma}} \left[\frac{\sigma}{\sigma-1}\tau M_x(\varphi)\right]^{-\sigma} \tag{4.15}$$

The profit function for these firms are:

$$\pi_x(\varphi) = p_x(\varphi)q_x(\varphi) - [f + M_x(\varphi)q_x(\varphi)] = \frac{1}{\sigma}\frac{I}{P^{1-\sigma}}[\frac{\sigma}{\sigma-1}\tau M_x(\varphi)]^{1-\sigma} - f \tag{4.16}$$

Maximum marginal cost of production will be:

$$M_x^*(\varphi) = \frac{\sigma-1}{\sigma}\frac{P}{\tau}[\frac{\sigma f}{I}]^{\frac{1}{1-\sigma}} \tag{4.17}$$

Let N_x be the number of firms exporting to the first economy which share the marginal cost specified above the price levels after trade would be:

$$\begin{aligned} P = &\left[\frac{1}{b_1}(\frac{\sigma}{1-\sigma})(\frac{\alpha}{\alpha-(\sigma-1)})^{-\frac{1}{\alpha}}(\frac{I}{\sigma f})^{-\frac{1}{\alpha}(\frac{\alpha-(\sigma-1)}{\sigma-1})}\tau^{-\alpha}N_x^{-\frac{1}{\alpha}}\right. \\ &\left.+\frac{1}{b}(\frac{\sigma}{1-\sigma})(\frac{\theta}{\theta-(\sigma-1)})^{-\frac{1}{\theta}}(\frac{I}{\sigma f})^{-\frac{1}{\theta}(\frac{\theta-(\sigma-1)}{\sigma-1})}N^{-\frac{1}{\theta}}\right]^{\frac{1}{1-\sigma}} \end{aligned} \tag{4.18}$$

4.5. Firms size distribution

As discussed in Di Giovanni and Levchenko (2013), formulating of firms size distribution is important for calibrating the model to data and estimating the parameters. This has to be done with noting that only domestic sales follow a power law with parameter of $\frac{\theta}{1-\sigma}$. Let D be the domestic sales, following their calculations:

$$Pr(x > q) = Pr(DM(\varphi)^{\sigma-1} > q) = \left(\frac{b^{\sigma-1}D}{q}\right)^{\frac{\theta}{1-\sigma}} \tag{4.19}$$

Chapter 5

Quantitative Assessment

5.1. Calibration

To implement the model numerically, estimated values from various sources have been used. There are many comprehensive researches that are dedicated to calculate the values of parameters normally used in international trade models, therefore, rather than recalculation and re-estimation, those values are extracted from reliable articles.

For elasticity of substitution data on Anderson and Van Wincoop (2004) is used. They surveyed and evaluated different methods of obtaining the elasticity of substitution which is consist of: only trade barriers[1] (between 4.79 and 8.26), just with border-related barriers[2] (11.4 with a same non-tariff barriers for all industries and 7.9 with allowance of industry fixed effects), only tariffs and transport costs[3] (6.4), From observed trade cost(from 5 to 10, with 4 above and one below), estimate demand equations directly[4] (from 3 to 8.4), by putting observable and

[1] A combination of information about tariffs and/or transport costs with the estimation of theoretical gravity equations.

[2] Similar method as the previous one which used data from 1990-1995 for trades between US and Canada

[3] For OECD countries and focus on changes in trade flows from the period 1958-1960 to the period 1986-1988

[4] estimating by assuming the same supply elasticities for all countries and cross-section of

approximated in gravity equation[5] (9.28) and as a conclusion between 5 to 10. Here 8 is used to be close to the average.

For α, the estimation of $\frac{\alpha}{\sigma-1}$ have to be used since the model suggest a power law distribution for firm size. Main research around this ratio is Axtell (2001) which reports it to be around 1.06 using US firm level data. Another calculation is done in Gabaix (2011) which reports it to be 1.059 ± 0.054 therefore it is assume to be 1.06. Then α will be 7.42 from formula can be set to 7.77.

Value of θ needs more care to pick[6]. Ratio of $\frac{\theta}{\sigma-1}$ is set to 1.11 ± 0.01 following Podobnik *et al.* (2010) and based on their estimation of $\frac{\theta}{\sigma-1}$ for recent data, therefore, θ is 7.77. They calculated the Zipf plot for pre-petition book value of assets using last 20 years data which includes data for the financial crisis of 2007-2008 and hence can be a good match for this analysis. To show the difference between recent data and data from Census 1997, a comparison between those used by Axtell (2001) and recent data on Census website had been made and results can be seen in Table 5.1.

Table 5.1: Comparison of data from Census 1997 and 2007

Size Class	**Number of Firms**	
	Census 2007	**Census 1997**
0-4	3,705,275	3,358,048
5-9	1,060,250	1,006,897
10-19	644,842	593,696
20-99	532,391	487,491
100-499	88,586	79,707
500+	18,311	16,079
Total	**6049655**	**5541918**

The problem with the available Census data is that they only cover firms

the second moments. With data from US imports from various countries between 1967 and 1987.

[5]This is Eaton and Kortum (2002) approach based on their model and uses data on retail price levels for 50 manufactured products in 19 countries

[6]See section 3.7

with less than 500 employees. Although there is another data set that can provide 10 more point to fit the date on a curve, these points are not correctly distributed to form a bin and all they can cover is the first bin of Axtell (2001) which binned them in power of 3. Figure 5.1 shows these data and the trend-line in power function with exponent 0.699 and $R^2 = 0.9344$ for data of Census 1977 and exponent 0.694 and $R^2 = 0.9320$ for Census 2007.

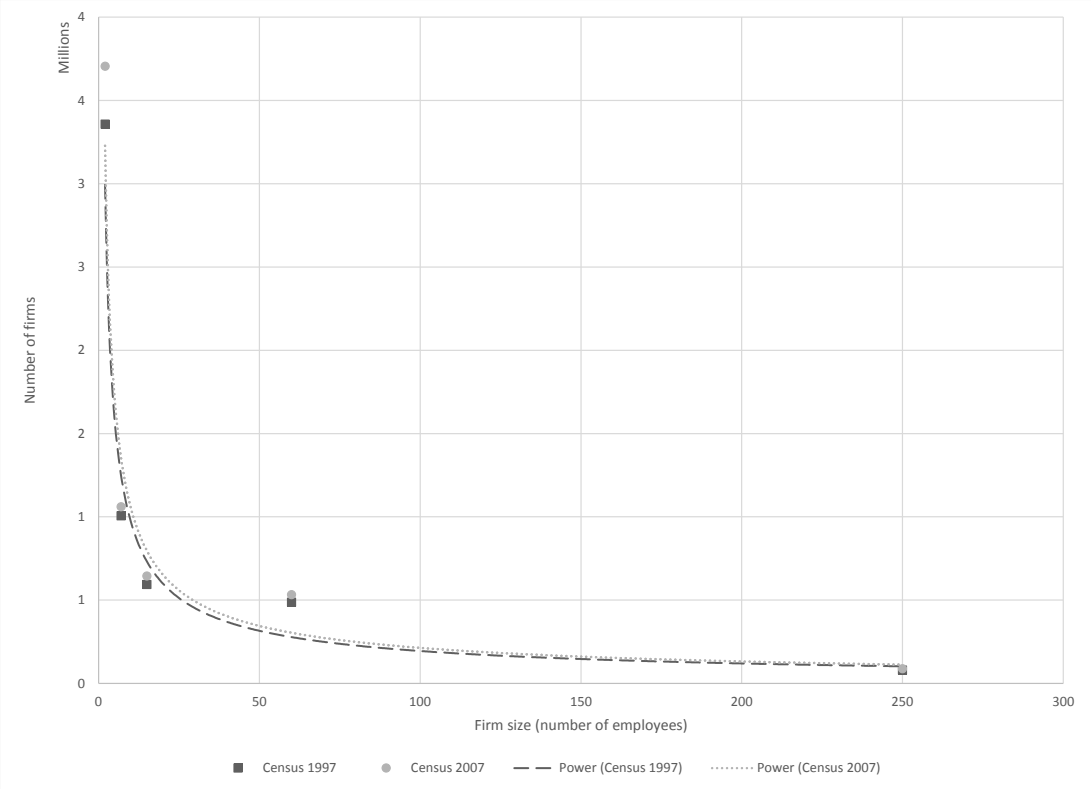


Figure 5.1: Comparison between data from Census 1997 and 2007 showing number of firms and firm size as number of employees.

When fitting data to power law, generally two extremes of the distribution are less good than the rest of points, first bins are tend to be less and last bins tend to be more. Because data is scars and it is only in the first bin, the exponent is statistically unclear but to show that recent estimates are potentially inline with previous ones, log-log coordinates is considered in Figure 5.2. Slop of old

data from ordinary least squares is (-0.6987) bigger than the new one (-0.6944) in terms of absolute value, both with the error in the same range (0.932 and 0.934).

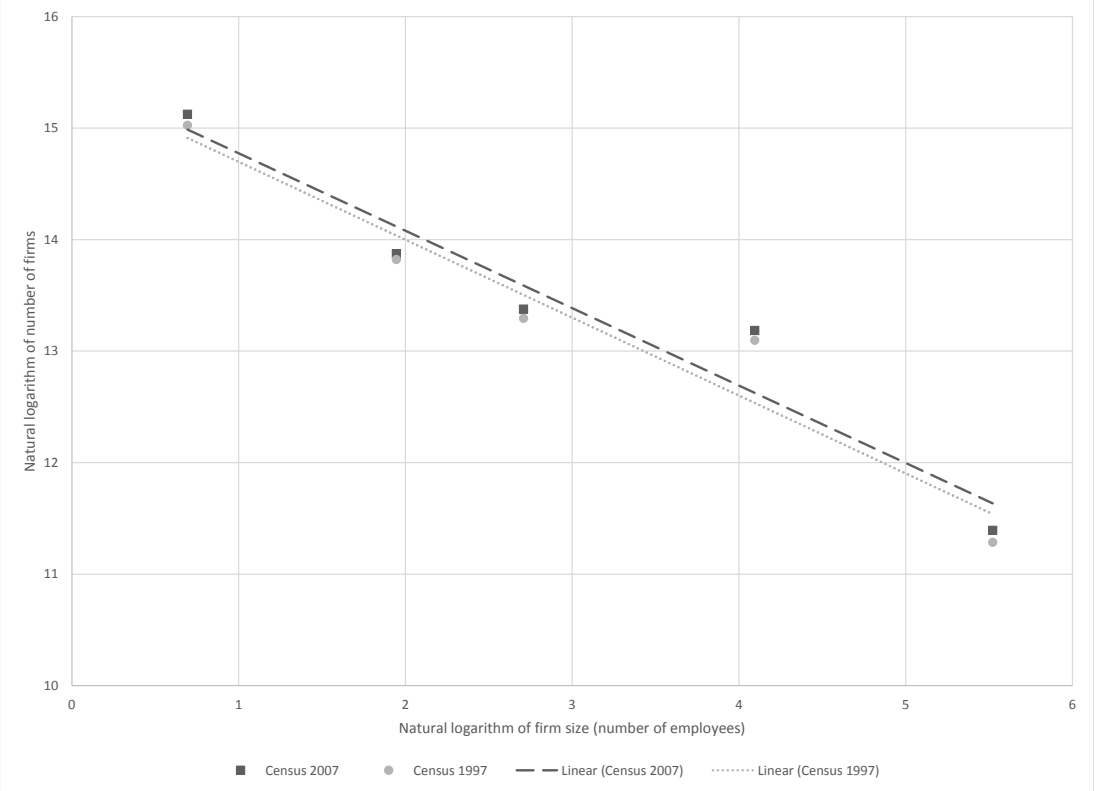


Figure 5.2: Comparison between data from Census 1997 and 2007 showing log of number of firms and log of firm size measured in number of employees, the shift is small.

If all the available data from Census 2007 been put into one cure, result would be Figure 5.3. It estimate a slope of -0.9906 and $R^2 = 0.9516$. Indeed, it is much lower than Axtell (2001) slope (2.059) and less accurate ($R^2 = 0.992$) but it can show that the slope (which is exponent of power law) have changed and more likely increased.

Putting assumed valued for α and θ, the value of β is calculated to be 0.35. β is the scale parameter of a Pareto distribution and since it is lee than 1, dictate that the mean is not converging, as a consequence, variance is also does not exist.

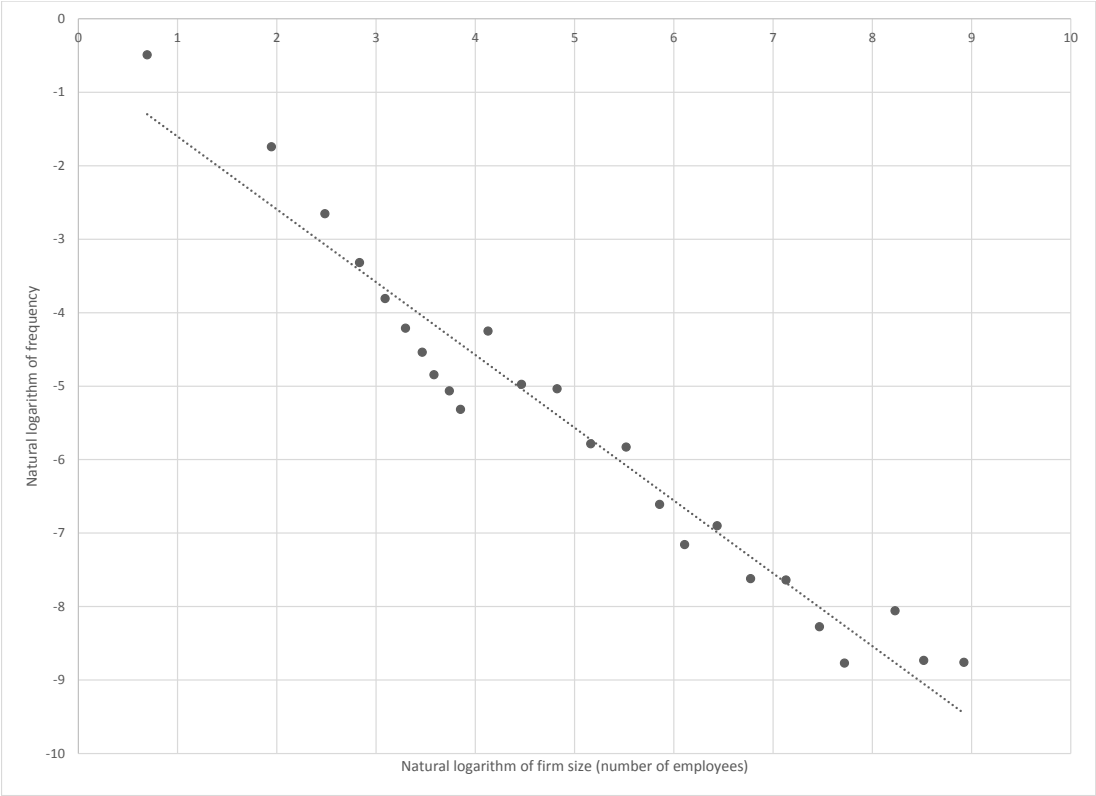


Figure 5.3: Log-log plot of frequency to firms size for available data on Census.gov. Still not enough point to make an accurate fit.

This does not change much in the calculation for size of economy and number of firms operating in it. By this values ($\beta < 1$), the average impact on productivity and marginal cost cannot be calculated.

This is another difference with Di Giovanni and Levchenko (2012), as, they isolated the shock and let the expected value to be $E(z^{1-\sigma}) = 1$, but here integrals are from the whole distribution with parameter of $\theta > 1$ that contains the shock. Range ofα can be defined along with θ and as long as the ratio of $\frac{\theta}{\sigma-1}$ remains less than 2 to make it possible to consider the market structure to be granular (suggested by Gabaix).

Moving on from firms size distribution to τ, the transportation cost. It is

important to use a symmetrical transport cost of symmetric countries, Di Giovanni and Levchenko (2012) set it to 2.30 based on estimates of Helpman *et al.* (2007)'s gravity model, here it is also set to 2.30 since it fits the empirical data the best.

Moreover, to adjust the consumption for share of services which are value added but not tradable, consumption should be adjusted for $S = 0.65$ of total consumption. This value is extracted form the database of Groningen Growth and Development Center extended in Uy *et al.* (2012). The mean value of services value added in total value added also used in Di Giovanni and Levchenko (2012).

Value of I is an indicator of economy size, it is assumed relative to GDP share of countries. Data is gathered from World Bank from 2000 to 2013, for 214 country. The average of these 14 data then have been calculated and then the ratio of GDP to world GDP is calculated. Here the first 47 countries with highest ratio have been chosen and the *Rest of Countries* is assumed another economy with ratio of 0.068 of the world economy.

"Rest of the world" countries each has less than 0.003 percent of world GDP, the ones with higher ratio are the mentioned 47 countries and are presented in Table 5.2, they cover 93.2% of total world GDP. Between these countries Singapore and Hong Kong have a trade with 385 and 376 percent of their GDP which shows a significant reexporting activities almost double of Malaysia and Ireland with 187 and 164 percent. Di Giovanni and Levchenko (2012) excluded these countries in their calibration, but in this part they would be included, the reason is their re-exporting does not cause any issue in this model rather adjust the average trade volume.

Finally, the value of f is partially extracted form from Census data. Census reports that there are almost 5.6 million companies operating in US(this also include firms with zero employees). With assumed values above and (4.13), value of f is 6.58 for US. By putting this value, almost always all firms in US export.

Table 5.2: Share of GDP to the GDP of the world in terms of US$ from 2000 to 2013 until 0.26% plus Rest of the World. *-From: World Bank World Development Indicators*

Country Name	**GDP Share**	**Country Name**	**GDP Share**
United States	0.254	Argentina	0.006
Japan	0.090	Austria	0.006
China	0.075	Iran, Islamic Rep.	0.005
Germany	0.056	Denmark	0.005
United Kingdom	0.043	South Africa	0.005
France	0.043	Greece	0.005
Italy	0.035	Venezuela, RB	0.004
Brazil	0.025	Thailand	0.004
Canada	0.024	United Arab Emirates	0.004
Spain	0.022	Finland	0.004
India	0.021	Colombia	0.004
Russian Federation	0.021	Nigeria	0.004
Mexico	0.018	Hong Kong SAR, China	0.004
Korea, Rep.	0.017	Ireland	0.004
Australia	0.016	Portugal	0.004
Netherlands	0.013	Malaysia	0.003
Turkey	0.010	Israel	0.003
Switzerland	0.009	Singapore	0.003
Indonesia	0.009	Chile	0.003
Sweden	0.008	Czech Republic	0.003
Saudi Arabia	0.008	Egypt, Arab Rep.	0.003
Belgium	0.008	Philippines	0.003
Poland	0.007	Pakistan	0.003
Norway	0.006	Rest of the world	0.068

Zero-sized firms will bias the final results because they contain a large portion of US firms. Value of f hence should be higher than 6.58 but this inaccuracy does not change the main results because it is used for both cases,in addition, this value also extended to all other countries.

Table 5.3: Summary of variables and their values

Parameter	Value	Source
σ	8	Anderson and Van Wincoop (2004)
α	7.42	From Axtell (2001), $\frac{\alpha}{\sigma-1} = 1.06$
θ	7.77	From Podobnik *et al.* (2010), $\frac{\theta}{\sigma-1} = 1.11$
β	0.35	$\theta = \alpha + \beta$
τ	2.3	Di Giovanni and Levchenko (2012)
f	6.58	To cover 5.6 Million operating firms in US.
I	Table 5.2	World Bank World Development Indicators

5.2. Simulation

General properties of theory has been set before, here a numerical simulation is used to evaluate the assumption made in the model, mainly to show if it can catch the features of world trade. The procedure consist of drawing productivity for firms entering the market and calculating the marginal cost of production for each firms. If their marginal cost of production is lower than the minimum value for that country, the firm start to produce otherwise it exits the market.

Operating firms are divided by two groups, those which their marginal cost after applying transportation cost (τ or iceberg cost of trade) is low enough to operate in another country, start to export and the others only serve their domestic market. For choosing the destination country, firms take in the account the difference between their marginal cost of production after trade and the destination minimum marginal cost of that country, they will choose the country which it has the highest difference of maximum marginal cost and their cost of production after trade.

This assumption is due to the fact that more productive firms are larger therefore it is realistic to assume they prefer to pick a target market that let them produce more. The second group cannot find a country with a maximum marginal cost, lower than their marginal cost (multiple by trade costs) to export so these firms only serve the domestic market.

This method is a combination of two widely use approaches. The first one, simulates the firm behavior by first drawing productivity, and starting from highest productivity (lowest cost in this case) to reach the cutoff productivity and calculate the price index. This will lead to an exogenous expenditure in the country since this amount is not clear until all firms realize their productivity. This is done in Eaton *et al.* (2012) with another difference which is wages inequality between countries. The complete view on this subject was proposed by Helpman *et al.* (2012), with wages inequality between sectors and impact of trade on wages dispersion within sectors. Wage dispersion is related to firms employment size and trade participation.

The second approach assumes that total expenditure in the country is endogenous mainly by connecting it to population as labor endowment. Number of firms drawing their productivity then can be estimated because of the linear relation between labor and number of firms. This approach uses an initial guess and continues to irritate to completely match the GDP ratio of all countries to the reference country (mainly US because of availability of data and size of economy).

Taking into account wages inequality will add another step to calculate in this approach. In the first step, the wages should be obtained and then the labor endowment, which is a multiplier of available labor and wages, have to be calculated, this approach used by Alvarez and Lucas (2007). Calculating wages and labor simultaneously to match the ratio of the GDPs will results in the same portion of labor for each country, specially if the model does not consider wage inequality, the results would be equal to simply let the labor ratio be the ratio of GDPs.

The approach used here, assume that initially, firms have to realize their productivity and if they could earn positive profit they will serve the market (domestic or foreign). Endogenous total expenditure calculated to fit exactly the

ratio of GDPs with normalizing for 316 million population of US in 2013. Combination of these two methods make it simple to relax two important assumptions commonly used in trade model, balance of trade and variation of price index caused by the realized shock.

Real data show many cases of trade surplus or deficit ranging from -9.2% to 34.3% in the one used here, usually higher for oil-based industries (like Kuwait, Qatar and Saudi Arabia) but close to zero for many others in the world. For changes in price index, it is obvious that if the shock is large enough to change the dispersion of productivity, price index being related to aggregate productivity will change. Accordingly this model can feature both of these assumption. The network of model is presented in appendix A

5.3. Fitting to data

Outputs of model can be fitted to data as shown in Figure 5.4 with two considerations. Since some variables normalized to one, namely wages and exploration cost for exporting markets, generated outputs should not fit data with slope of one. In fact, present of such variables play an important role in determining the amount of total and bilateral trade, considering more variables should decrease the slope close to one.

It can be interpenetrated that if an idiosyncratic shock is large enough in an economy to change the distribution of productivity, the total amount of trade between other countries lowered and this decline is larger in the middle size countries and smaller in large and small ones as it is shown in Figure 5.5.

Another observation is the amount of total trade for the middle size countries, while they receive a large amount of import, their exports is also high. In the real data economy of Singapore and Hong Kong show these features.

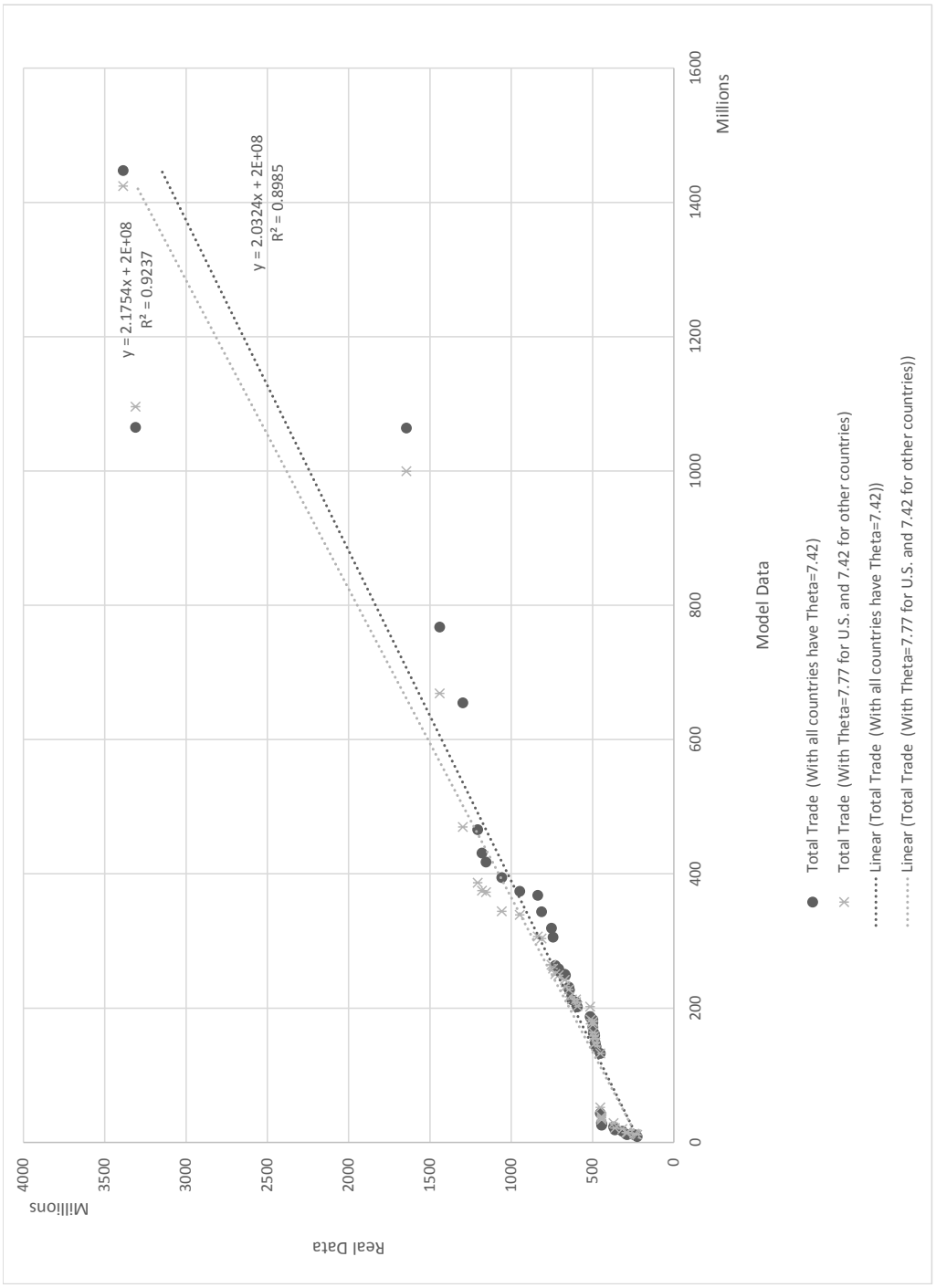


Figure 5.4: Relation of model generated data for $\theta = 7.42 and 7.77$ and real data, "Rest of The World" is not included.

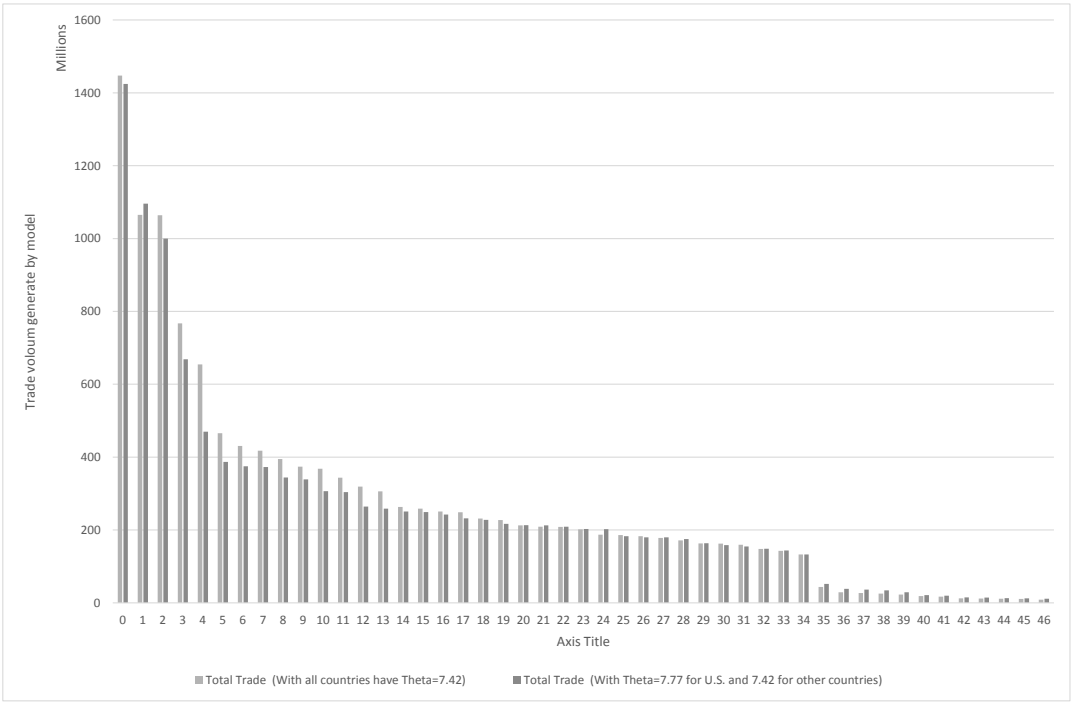


Figure 5.5: Total amount of trade before and after the realizing the shock. The left bars show total trade before and the right right bars show the total trade when only the dispersion parameter in US has changed from 7.42 to 7.77, "Rest of The World" is not included.

Chapter 6

Research Outline

6.1. Summary and Conclusion

This study was aimed at analyzing trade volume with realization of a distinctive shock in a model with heterogeneous firms in a granular setting. The thorough analysis in this thesis take into account the effect of the realized shock on price levels before and after its realization. In addition, it can measure the average impact regardless of its size.

In this thesis, a model of firm heterogeneity is presented. It features basic assumptions of heterogeneity with CES demand function with finite but large number of firms. Granularity of the market is ensured by allowing the distribution of domestic firm sales to follow power law with the parameter close to one. Considering the effect of an idiosyncratic shock on the price index and recalculating it along with a systematic method of measuring the average impact of the shock are two main features of this model that had not been explored before.

With the aid of simulation, the output of the model have been examined. The experiments showed the impact will transfer more toward the range of middle size countries as well as the noticeable decrease in size of the reference country and its trade amount. Based on the results, output of the model follows real

data with a fixed bias mainly caused by normalizing exploration costs assuming same trade cost for all countries. Also, the results fit to data of financial crisis of 2007 that lead to the global crisis assuming that these crisis caused by a shock to productivity.

6.2. Future Research and Recommendations

Models with heterogeneous firms with their short time of establishment explained many features of macroeconomics as well as international trade and microeconomics. Most of the initial concept of this area has been covered which in turn lead to rising of new problems. Reached border of models of firms heterogeneity features variable wages among countries, unequal transportation cost, unequal cost of exploration, differing fix cost of production and variable markups. Applying these feature in a economy with granularity which take into account the large firms is an active are of research.

Most researches are static hence researchers use the average of reported data and pays less attention to the trend of those over time. Firm dynamics is an interesting and relatively new that might answer the questions about the process that makes successful firms large and evaluate their respond to trade policies. Unlike many tools of perfect competition that been adopted to use in monopolistic competitions, many concepts of firm dynamics left intact for heterogeneous firms.

Moreover, researcher should work on more efficient methods for simulation and solving the models numerically. The steps to simulating a large economy is heavily change the time and resource needed for calculating. This issue rises each time another parameter is set as an variable. The optimal steps toward simulating a large scale economy is an interesting subject of research.

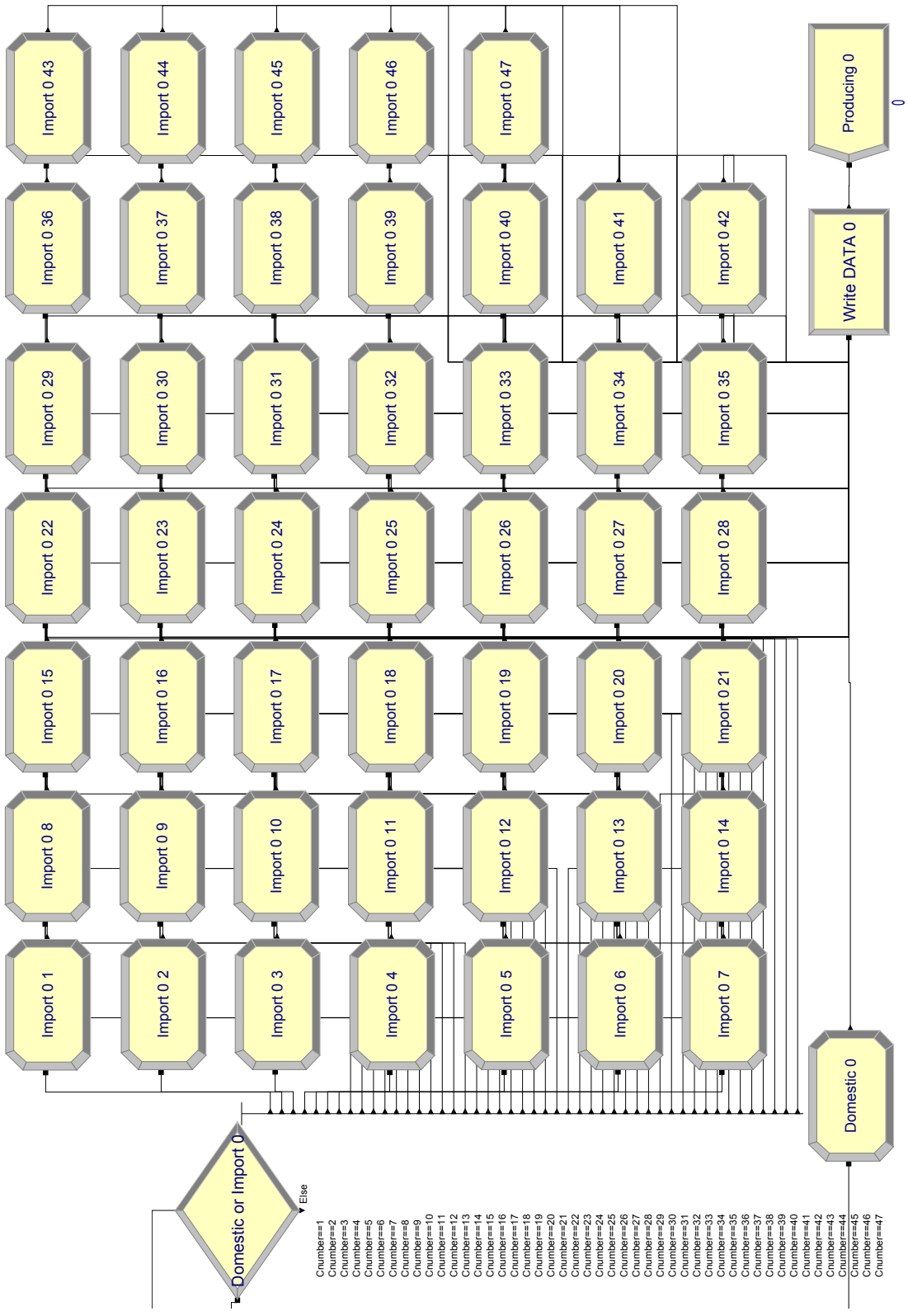
Appendix A

Model Network

Figure A.1 shows the network for the reference country. All components are indexed with zero to show that it is the network for the reference country. Replacing zero with $i = 1, 2, ..., 47$ will results in the network for other countries. These numbers are based on the relation of country's GDP to the GDP of the world as it is shown in Table 5.2. For tracking the total amount of export of country i, after each run, sum of all import form country i should be calculated. List of all of the activities done by each process is represented in Table A.1

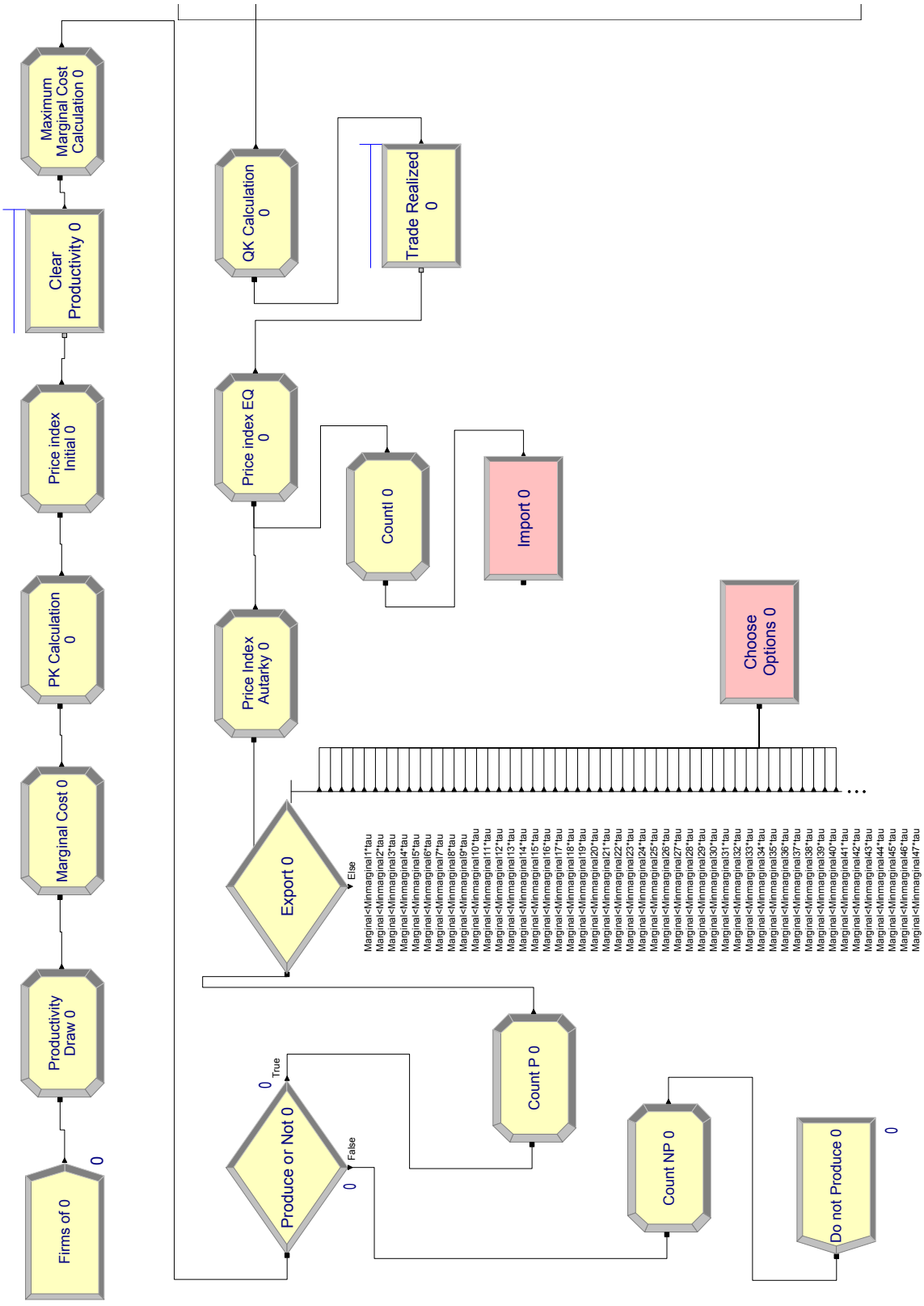
Table A.1: Processes and Their Activities

Process	**Activity**
Firms of i	Create a firm
Productivity Draw i	Draw a productivity from a Pareto distribution
Marginal Cost i	Calculate marginal cost
PK Calculation i	Calculate pk
Price index Initial i	Calculate the ideal price index
Clear Productivity i	Make sure that all firms drew their productivity
Maximum Marginal Cost Calculation i	Calculate the Maximum marginal cost
Produce or Not i	Decide if profit is positive
Count NP i	Count number of firms exiting (for controlling the process)
Do not Produce i	Terminate the firms not producing
Export i	Decide if the firm can export
Choose Options i	Pick a destination to export
Price Index Autarky i	Calculate a price index for domestic price index (for controlling the process)
Import i	Receive import form other countries
CountI i	Count number of firms importing (for controlling the process)
Price index EQ i	Calculate the price index
Trade Realized i	Make sure that all firms realized if they can trade or not
QK Calculation i	Calculate the quantities (qk)
Domestic or Import i	Differentiate if products are domestic or imported
Import i j	Track the amount of import from country j to i
Domestic i	Track the amount of domestic production ($i = j$)
Write DATA i	Write data to database
Producing i	Terminate producing firms



(a)

Figure A.1: Network for the reference country in Arena



(b)

Figure A.1: Network for the reference country in Arena

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