ESSAYS ON INTERNATIONAL ECONOMICS

BY

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ABSTRACT

The first paper presents a general equilibrium framework to quantify the welfare impact of firm level shocks in the home country and abroad. We take our framework to data using sectoral level and firm level data from Portugal in 2004. We find that welfare change at home and abroad depends on firms domestic and foreign market shares and also the sector of the firm. Our estimations show that exit of a large firm or a productivity increase of 10% could have significant welfare impacts on consumers up to 1%. Our results also highlight the importance of international trade in transmitting firm level shocks internationally and impacting the welfare of consumers.

The second paper presents a general equilibrium framework of trade and multinational production to quantify the impact of changes in corporate tax rates on the location choice of multinational firms and aggregate outcomes. Our model and results show that the British and Swedish tax rate cuts of 2012 increased the welfare of their consumers around half a percentage point at the expense of most of other countries.

Financial Crises have always been very costly for the countries who experience them. In the third paper, we focus on the welfare value of the firms that enter or exit during the Portuguese Crisis of 2010-14. We find that the total and average value of exiting firms is much higher than the entering firms during the downturn years, but these values are much closer or even equal during the recovery years. We also realize that the total and average value

of exiting firms is much higher during the crisis years compared to recovery years, even though these numbers are almost constant for entering firms.

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CHAPTER 1

THE GLOBAL WELFARE EFFECTS OF GRANULAR SHOCKS

1.1 Introduction

A small number of giant firms dominate exports in many countries. Freund and Pierola (2015) use firm level data from 32 countries and show that more than half of a country's export and export growth can be accounted by top one percent of firms. Multiple empirical papers, like Gabaix (2011) and Di Giovanni et al. (2014a), show that shocks to large firms are responsible for large portions of aggregate fluctuations.

Companies like Samsung or Nokia are national pride of their countries and are responsible for a large share of its export but how valuable are these companies for their country? if one of these firms exits the market, what would be the welfare impact on households on that country? What is the welfare impact of a change in a firm's productivity?

It's also important to study how a large firm's productivity change or exit can affect other countries' welfare through international trade. So far, literature has been mostly focused on spillover effects of productivity growth of a country, Eaton and Kortum (2002), or an industry level productivity growth, Hsieh and Ossa (2016). However, as large firms dominate international trade, their idiosyncratic shocks can have large effect not only in the home country but in its trading partners.

To answer these questions, we formulate and estimate a general equilibrium

international trade framework to quantify the effects of firm level granular shocks in home and foreign countries. We'll show how international trade and these shocks interact to affect the welfare of consumers and resource allocation. The shocks that we consider could range from very small firm specific shocks to total exit of a firm from the market. By considering the exit of a firm, we can estimate the value of a firm to a country and also, it's trading partners. By exporting to foreign countries, assuming a trade balance, large firms make it possible for consumers to have access to imported foreign goods. Consumers gain excess welfare by consuming cheaper foreign goods and more varieties. We would like to quantify these welfare gains for consumers.

We find that major factors in determining welfare changes are the market shares of the firm in the home and foreign countries and patterns of comparative advantage. In a granular economy, idiosyncratic firm productivity shocks can affect sectoral comparative advantage. As these changes interact with existing patterns of comparative advantage, prices and welfare change. Our results show that terms of trade is a very important factor in determining welfare changes and in a given sector, larger firms can change this factor more.

Our main finding is that firm level shocks can significantly affect the welfare of consumers. Using sectoral trade data and firm level data from Portugal in 2004, we find that exit of the largest exporter in each sector can reduce the welfare of that country's consumers by up to 1%. A 10% productivity increase in one of the largest exporters of each sector can improve welfare in Portugal by up to almost 0.5%. We also estimate welfare changes in the rest of the world resulted from these shocks. Given the small size of Portugal and it's not so large firms, we still find welfare changes as large as 0.003% in the

rest of the world.

Starting with Melitz (2003), international trade literature consider firm heterogeneity and how it shapes the firm level decision of selection into markets. However, most of the papers assume a continuum of firms in each sector where each firm is infinitesimal and its idiosyncratic shocks don't have any welfare impact. We will relax this assumption by assuming discrete and finite number of firms in each sector.

Large firms have special characteristics that distinguishes them from other firms. Large firms are not just scaled up versions of smaller firms, they have significant differences. Empirical studies like Bernard et al. (2003) and Eaton et al. (2011) find that many large firms export and exporters are larger than non-exporters on average. Larger firms also import bigger shares of their intermediate inputs from foreign countries. Amiti et al. (2014) use firm data from Belgium to show that large exporters are large importers simultaneously. As shown in De Loecker et al. (2016) and Amiti et al. (2014) large firms charge higher markups and their mark up elasticity with respect to firm price is also higher, meaning that larger firms offset the reduction of their marginal cost by increasing their markups.

These empirical findings confirm that we need a framework with international trade, firm level imports and variable markups to be able to fully capture the impacts of firm level shocks in a granular economy.

Our paper is related to several strands of literature. There is a growing literature on granular trade models started by Eaton et al. (2012) and Di Giovanni and Levchenko (2012). These papers depart from the convention of treating firms as points of continuum so shocks to individual firms can have aggregate effects.

Recently, Gaubert and Itskhoki (2016) estimate a multi-sector granular trade

model using French firm level data. They are mostly focused on how granularity affects the comparative advantage pattern in a country and welfare gains from trade. However, we are focused on welfare effects of firm level shocks. They use a data generating process and draw productivities from a pareto distribution but we use actual firms so we can estimate the welfare value of existing firms.

There are a few other papers like Atkeson and Burstein (2008), Edmond et al. (2015) and Amiti et al. (2014) that allow firms to be large compared to their market and as a result, firms strategically interact with each other. We follow these literature when extending our model to a Bertrand competition.

Our paper is related to the literature that estimate welfare impact of productivity changes in open economies. Hsieh and Ossa (2016) estimate the welfare effect of Chinese productivity growth between 1995-2007 and Di Giovanni et al. (2014b) simulate the spillover effects of hypothetical Chinese growth. In contrast to these papers, we are focused on productivity changes of firms and firm exits.

A large group of international trade literature apply exact hat algebra to solve quantitative trade models. We apply the methods used in Dekle et al. (2008a) and Caliendo and Parro (2015) but we take it to a new level by using it for firm level variables.

Recently, a group international trade papers, Halpern et al. (2015), Gopinath and Neiman (2014) and Blaum et al. (2015), have tried to estimate the productivity and welfare changes from imported inputs. Similar to these papers, we consider the impact of firm level imports on the price index of consumers and their welfare.

Our paper also relates to classical trade literature on immiserizing growth. Bhagwati (1958a) and Bhagwati (1958b) show that in a two-country, two-

commodity model, under certain circumstances, economic growth may reduce the real income of the growing country. This happens when there is sufficient deterioration in terms of trade to the extent that it offsets the beneficial effects of expansion.

Samuelson (2004) uses a simple two-country, two-sector model to illustrate how China's technical progress in its export sector might lower China's per capita real income. We'll show in our empirical part that productivity growth of a granular firm in comparative advantage sector of a country, can lead to reduction in the welfare of that country.

1.2 Model

We build a quantitative general equilibrium trade model that is multi-sector and takes into account inter-sectoral linkages. Our model is based on the models of Caliendo and Parro (2015) and Hsieh and Ossa (2016) but the number of firms in each sector is discrete and finite.

There are N countries in the world, indexed by the superscript j or $n = 1, 2, ..., N$. There are S sectors in each country, indexed by s with M_s^n number of firms that we take as fixed.

The production function for a firm in country n is given by a Cobb-Douglas function using labor, capital and intermediate good bundle:

$$Y_{si}^n = A_{si}^n K_{si}^{\alpha_s^n} L_{si}^{\beta_s^n} Q_{si}^{1-\alpha_s^n-\beta_s^n} \tag{1.1}$$

Where A_{si}^n is the total factor productivity of the firm.

Each firm's output can be consumed at home or can be exported to any of the foreign countries. Resource constraint of a firm in country n can be

written as:

$$Y_{si}^{n} = \sum_{j=1}^{N} \tau_{nj} Y_{si}^{nj} \tag{1.2}$$

Where Y_{si}^{nj} is the output of firm i that is exported from country n to country j. τ_{nj} is the iceberg trade cost of shipping from country n to j and $\tau_{nn} = 1$. Sectoral bundle for exports from country n to country j is a CES aggregate of firm exports:

$$Y_{s}^{nj} = \left(\sum_{i=1}^{M_s^n} {Y_{si}^{nj}}^{\frac{\sigma_s - 1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s - 1}} \tag{1.3}$$

$\sigma_s > 1$ is the elasticity of substitution across different firm outputs within a sector and it changes from sector to sector.

Sector output Y_s in country j is also a CES aggregate of sectoral bundles of export from different countries to country j:

$$Y_{s}^{j} = \left(\sum_{n=1}^{N} {Y_{s}^{nj}}^{\frac{\sigma_s - 1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s - 1}} \tag{1.4}$$

To calculate the demand for firm outputs, we maximize the profit of each sector in each country. Solving the problem for sector s output in country j gives following inverse demand equations for each firm in each country:

$$P_{s}^{nj} {Y_{s}^{nj}}^{\frac{1}{\sigma_s}} {Y_{si}^{nj}}^{-\frac{1}{\sigma_s}} = P_{si}^{nj} \tag{1.5}$$

Firm profits are given by:

$$\pi_{si}^{n} = \sum_{j=1}^{N} P_{si}^{nj} Y_{si}^{nj} - w^n L_{si}^{n} - R^n K_{si}^{n} - P_{Q_{si}}^{n} Q_{si}^{n} \tag{1.6}$$

We are not including any fixed cost in our profit equation and we abstract from entry and exit of other firms in the event of an idiosyncratic shock to

one firm.

Obviously, a productivity shock to a large firm will cause some other firms to exit or enter the market, but the firm that operates on the margin of producing or not is small and its exit or stay will have negligible impact on aggregate outcomes. Edmond et al. (2015) check this intuition in their paper. They set the fixed costs to zero and find that treating the set of firms as fixed is a good approximation for their model. We believe that the same holds in our paper. Our empirical results at the end of the paper show that median firms have small aggregate values and smaller firms would be even less valuable.

Extensive margin will be important in models that take into account the chain effect of firm exit like Baqaee (2016). When production networks are considered, extensive margin of firm entry and exit could greatly amplify idiosyncratic firm shocks. However, absent detailed firm to firm trade data and detailed input-output tables, our model abstracts from such networks.

Assuming that firms don't take into account the effect of their pricing decision on the price index, we solve the profit maximization problem of firms. Later, we relax this assumption and let firms take into account the effect of their prices on price index, taking other firms' prices as given. This will result in a Bertrand competition.

Maximizing (2.5) subject to (2.2), (1.2) and (1.5) yields the equations for the price of firm i's good shipped from country n to j:

$$P_{si}^{nj} = \frac{\sigma_s}{\sigma_s - 1} \psi_{si}^{n} \frac{\tau_{nj}}{A_{si}^{n}} \tag{1.7}$$

Where ψ_{si}^n is the unit cost of inputs for firm i and is given by:

$$\psi_{si}^n = \left(\frac{R^n}{\alpha_s^n}\right)^{\alpha_s^n} \left(\frac{w^n}{\beta_s^n}\right)^{\beta_s^n} \left(\frac{P_{Q_{si}}^n}{1-\alpha_s^n-\beta_s^n}\right)^{1-\alpha_s^n-\beta_s^n} \tag{1.8}$$

As expected, firm prices are a fixed markup over marginal cost. Also, from profit maximization of firm we get the factor demand equations:

$$R^n K_{si}^n = \alpha_s^n \frac{\sigma_s - 1}{\sigma_s} \sum_{j=1}^{N} P_{si}^{nj} Y_{si}^{nj} \tag{1.9}$$

$$w^n L_{si}^n = \beta_s^n \frac{\sigma_s - 1}{\sigma_s} \sum_{j=1}^{N} P_{si}^{nj} Y_{si}^{nj} \tag{1.10}$$

$$P_{Q_{si}}^n Q_{si}^n = (1-\alpha_s^n-\beta_s^n) \frac{\sigma_s - 1}{\sigma_s} \sum_{j=1}^{N} P_{si}^{nj} Y_{si}^{nj} \tag{1.11}$$

Using (1.7), (1.3) and (1.5), we can derive an equation for Price index of industry s product exported from country in country n:

$$P_s^{nj} = \left(\sum_{i=1}^{M_S^n} {P_{si}^{nj}}^{1-\sigma_s}\right)^{\frac{1}{1-\sigma_s}} \tag{1.12}$$

Price index of sector s in country j can be written the same way:

$$P_s^j = \left(\sum_{n=1}^{N} {P_s^{nj}}^{1-\sigma_s}\right)^{\frac{1}{1-\sigma_s}} \tag{1.13}$$

And we can write total expenditure on industry s goods imported from country n in country j as:

$$P_s^{nj} Y_s^{nj} = \sum_{i=1}^{M_s^n} P_{si}^{nj} Y_{si}^{nj} \tag{1.14}$$

In order to take this model to data, we calculate a firm from country n's share in sectoral revenue of country j spent on goods from country n:

$$\omega_{si}^{nj} = \frac{P_{si}^{nj} Y_{si}^{nj}}{P_s^{nj} Y_s^{nj}} = \left(\frac{P_{si}^{nj}}{P_s^{nj}} \right)^{1-\sigma_s} \tag{1.15}$$

Aggregate sector s good exported from country n to j, Y_{si}^{nj}, can be used as consumption good by consumer or as intermediate good by firms, meaning that production has a roundabout nature:

$$Y_s^{nj} = C_s^{nj} + Q_s^{nj} \tag{1.16}$$

These consumption and intermediate goods will be combined across sectors using a Cobb-Douglas production technology:

$$C^{nj} = \prod_{s=1}^{S} (C_s^{nj})^{\xi_s^{nj}} \quad , \quad Q^{nj} = \prod_{s=1}^{S} (Q_s^{nj})^{\zeta_s^{nj}} \tag{1.17}$$

The parameter ξ_s^{nj} is the share of consumption goods from sector s in total imports of consumption goods from country n into country j and the parameter ζ_s^{nj} is the share of intermediate goods from sector s in total imports of intermediate goods from country n into country j.

We then combine the bundles of consumption goods imported from different countries to create a final consumption good in each country using a CES aggregator and do the same for bundles of intermediate goods:

$$C^j = \left(\sum_{n=1}^{N} C^{nj \, \frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}} \quad , \quad Q^j = \left(\sum_{n=1}^{N} Q^{nj \, \frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}$$

Where ϵ is the elasticity of substitution among bundles of consumption and intermediate goods imported from different countries.

1.2.1 Import behavior of firms

Large firms import larger share of their intermediate input from foreign countries. To take into account the effects of these imports on the price index and welfare of consumers, we allow different firms to have different sourcing strategies in this model.

Ω_{si} is the set of countries from which firm i imports intermediates. We take this set to be fixed. As Gopinath and Neiman (2014) empirically demonstrate, firm entry into and exit from import status is not very important for aggregate outcome. We also don't include a fix cost of importing in our profit function because in our model, firms only import the overall aggregated good from each country and we don't consider import of each good.

Intermediate bundle used by firm i in sector s is given by:

$$Q_{si}^{n} = \left(\sum_{j \in \Omega_{si}} {Q_{si}^{jn}}^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}} \tag{1.18}$$

Using this equation, Firm i's input price index can be calculated as:

$$P_{Q_{si}}^{n} = \left(\sum_{j \in \Omega_{si}} {P_{Q}^{jn}}^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}} \text{ Where } \quad P_{Q}^{jn} = \prod_{s=1}^{S} \left(\frac{P_{s}^{jn}}{\xi_{s}^{jn}} \right)^{\xi_{s}^{jn}} \tag{1.19}$$

In order to take the model to data, we calculate share of inputs that firm i imports from country j:

$$\gamma_{si}^{jn} = \frac{P_{Q}^{jn} Q_{si}^{jn}}{P_{Q_{si}}^{n} Q_{si}^{n}} = \left(\frac{P_{Q}^{jn}}{P_{Q_{si}}^{n}} \right)^{1-\epsilon} \tag{1.20}$$

1.2.2 General Equilibrium

We assume there is a representative consumer in country n that supplies L^n units of labor and K^n units of capital inelastically. The representative consumer owns all the firms in country n and all the firm profits will return to the consumer. As a result, representative consumer's budget constraint in country n can be written as:

$$P_C^n C^n = w^n L^n + R^n K^n + \Pi^n - D^n \tag{1.21}$$

Where $\Pi^n = \sum_{s=1}^{S} \Pi_s^n$ and:

$$\Pi_s^n = \sum_{i=1}^{M_s^n} \pi_{si}^n = \frac{1}{\sigma_s} \sum_{i=1}^{M_s^n} \sum_{j=1}^{N} P_{si}^{nj} Y_{si}^{nj} \tag{1.22}$$

D^n is an exogenous international transfer to the consumer to account for trade imbalance and we have $\sum_{n=1}^{N} D^n = 0$. We consider it to be fixed share of sectoral revenue in each country as in Dekle et al. (2008a). It can be calculated by aggregating over net exports of sectors.

Using (1.16) and (1.17), we can write:

$$P_s^{nj} Y_s^{nj} = \zeta_s^{nj} \gamma^{nj} P_Q^j Q^j + \xi_s^{nj} \lambda^{nj} P_C^j C^j \tag{1.23}$$

Where γ^{nj} is the share of intermediate goods in country j imported from country n and λ^{nj} share of final good in country j imported from country n. Combining (2.19) with (1.23) and (1.9)-(1.11), we can write an equation for

total expenditure in country n from sector s goods imported from country j:

$$P_s^{nj}Y_s^{nj} = \zeta_s^{nj}\gamma^{nj}\sum_{t=1}^{S}\frac{w^j L_t^j}{\beta_t}(1-\alpha_t-\beta_t) + \xi_s^{nj}\lambda^{nj}\sum_{t=1}^{S} w^j L_t^j\left(1+\frac{\alpha_t}{\beta_t}+\frac{1}{(\sigma_t-1)\beta_t}\right) - \xi_s^{nj}\lambda^{nj}D^j \quad (1.24)$$

Also, factor market clearing indicates that:

$$L^n = \sum_{s=1}^{S} L_s^n \quad (1.25)$$

$$K^n = \sum_{s=1}^{S} K_s^n \quad (1.26)$$

We assume labor and capital are freely mobile across sectors but can't move between countries. This equalizes wages and capital rents across sectors in each country.

1.2.3 General equilibrium effects of granular firm shocks

In this part, we'll investigate the effects of exogenous shocks to productivity of firms, A_{si}. In the extreme case, the welfare value of an exporting firm can be calculated meaning that if the firm shuts down, how much the total welfare in a country will go down.

We use the hat algebra method proposed by Dekle et al. (2008a). By using this method, we'll be able to solve the model for proportional changes of equilibrium variables. Proportional change in variable x is defined as $\hat{x} = x'/x$ where x' is the value of variable x in the counterfactual equilibrium.

We first apply the hat algebra to the unit cost of inputs for each firm or ψ_{si}^n. Using equations (1.8) and (1.20), we can write the proportional changes in

the unit cost of inputs as:

$$\hat{\psi}_{si}^{n} = \hat{R}^{n^{\alpha_s}} \hat{w}^{n^{\beta_s}} \left[\sum_{j \in \Omega_{si}} (\hat{P}_{Q}^{jn})^{1-\epsilon} \gamma_{si}^{jn} \right]^{\frac{1-\alpha_s-\beta_s}{1-\epsilon}} \tag{1.27}$$

Where $\hat{P}_{Q}^{jn} = \prod_{s=1}^{S} \left(\hat{P}_{s}^{jn} \right)^{\xi_s^{jn}}$.

Similarly, we use the price index equation, (2.1), to write it in proportional changes:

$$\hat{P}_{s}^{nj} = \left[\sum_{i=1}^{M_S^n} \omega_{si}^{nj} \left(\frac{\hat{\psi}_{si}^{n}}{\hat{A}_{si}^{n}} \right)^{1-\sigma_s} \right]^{\frac{1}{1-\sigma_s}} \tag{1.28}$$

$\hat{A}_{si}^{n}$ is the exogenous productivity shock to firms in country n. In the extreme case that a firm shuts down, we set $\hat{A}_{si}^{n}$ to zero.

Applying the hat algebra to equation (1.10), we obtain:

$$\hat{w}^{n} \hat{L}_{s}^{n} = \frac{\sum_{j=1}^{N} P_{s}^{nj} Y_{s}^{nj} \frac{\hat{P}_{s}^{nj}{}^{1-\sigma_s}}{\hat{P}_{s}^{j}{}^{1-\sigma_s}} \hat{P}_{s}^{j} \hat{Y}_{s}^{j}}{\sum_{j=1}^{N} \sum_{i=1}^{M_S^j} P_{si}^{nj} Y_{si}^{nj}} \tag{1.29}$$

Knowing that $P_{s}^{j} Y_{s}^{j} = \sum_{n=1}^{N} P_{s}^{nj} Y_{s}^{nj}$, we can write:

$$\hat{P}_{s}^{j} \hat{Y}_{s}^{j} = \sum_{n=1}^{N} \frac{P_{s}^{nj} Y_{s}^{nj}}{P_{s}^{j} Y_{s}^{j}} \hat{P}_{s}^{nj} \hat{Y}_{s}^{nj} \tag{1.30}$$

We can also write from (1.13):

$$\hat{P}_{s}^{j} = \left[\sum_{n=1}^{N} (\hat{P}_{s}^{jn})^{1-\sigma_s} \frac{P_{s}^{nj} Y_{s}^{nj}}{P_{s}^{j} Y_{s}^{j}} \right]^{\frac{1}{1-\sigma_s}} \tag{1.31}$$

Equations for capital and intermediate goods can be written based on labor equations:

$$\hat{R}^{n} \hat{K}_{s}^{n} = \hat{w}^{n} \hat{L}_{s}^{n} \tag{1.32}$$

We also write (1.24) in proportional changes:

$$\hat{P}_s^{nj}\hat{Y}_s^{nj} = \zeta_s^{nj}\gamma^{nj}\left(\frac{P_Q^{nj}}{P_Q^j}\right)^{1-\epsilon}\sum_{t=1}^{S}\frac{w^j L_t^j}{P_s^{nj}Y_s^{nj}}\frac{\hat{w}^j\hat{L}_t^j}{\beta_t}(1-\alpha_t-\beta_t)$$
$$+\xi_s^{nj}\lambda^{nj}\left(\frac{P_C^{nj}}{P_C^j}\right)^{1-\epsilon}\sum_{t=1}^{S}\frac{w^j L_t^j}{P_s^{nj}Y_s^{nj}}\hat{w}^j\hat{L}_t^j\left(1+\frac{\alpha_t}{\beta_t}+\frac{1}{(\sigma_s-1)\beta_t}\right)$$
$$-\xi_s^{nj}\lambda^{nj}\left(\frac{P_C^{nj}}{P_C^j}\right)^{1-\epsilon}\frac{D^j}{P_s^{nj}Y_s^{nj}} \quad (1.33)$$

Capital and labor market clearing conditions, equations (1.25) and (1.26), could also be written as proportional changes:

$$\sum_{s=1}^{S}\frac{w^n L_s^n}{w^n L^n}\hat{L}_s^n = 1 \quad (1.34)$$

$$\sum_{s=1}^{S}\frac{R^n K_s^n}{R^n K^n}\hat{K}_s^n = 1 \quad (1.35)$$

Equations (1.27)-(1.35) create a system of equations with $\{\hat{A}_{si}^n\}$ as exogenous input and
$\{\hat{P}_s^{nj}, \hat{Y}_s^{nj}, \hat{L}_s^n, \hat{K}_s^n, \hat{Q}_s^n, \hat{w}^n, \hat{R}^n\}$ as unknown that will be endogenously determined.

Using the hat algebra has made it possible to write the equations with coefficients that are observable in the data. Given the values of the parameters $\{\zeta_s^{jn}, \xi_s^{jn}, \alpha_s^n, \beta_s^n, \sigma_s, \epsilon\}$ and firms' sectoral revenue share in their domestic and export markets, we can calculate the unknowns using these equations.
Using hat algebra, we don't need to estimate some unknown parameters and variables like $\{A_{si}^n, \tau_{nj}, L^n, K^n\}$. We just impose restrictions on the values of these parameters such that predicted expenditures perfectly match actual expenditures given values of $\{\zeta_s^{jn}, \xi_s^{jn}, \alpha_s^n, \beta_s^n, \sigma, \epsilon\}$.

1.2.4 Extension: Variable Markups

So far, we have been assuming firms don't take account the effect of their pricing decisions on sectoral price index and consequently, everything was derived under a monopolistic competition setup.

To take into account firm strategic complimentarities, we solve firm's profit maximization equation (2.5) again but this time assuming firm internalize the effect of its price on price index, taking other firms' prices as given. This will result in a Bertrand competition.

Firm's pricing equation can now be written in proportional changes as:

$$\hat{P}_{si}^{nj} = \hat{\mu}_{si}^{nj} \frac{\hat{\psi}_{si}^{n}}{\hat{A}_{si}^{n}} \tag{1.36}$$

Where μ_{si}^{nj} is the markup that firm i charges over its marginal cost. In a Bertrand competition:

$$\mu_{si}^{nj} = \frac{\epsilon_{si}^{nj}}{\epsilon_{si}^{nj} - 1} \tag{1.37}$$

Where

$$\epsilon_{si}^{nj} = \sigma_s(1 - \omega_{si}^{nj}) + \omega_{si}^{nj} \tag{1.38}$$

We can use these equations to calculate the counterfactual market shares and prices of each firm and then calculate the counterfactual markup and proportional change in markups.

1.2.5 Welfare Analysis

. Assuming an identical utility function, welfare of the representative consumer can be written as her consumption: $\mathcal{W}^n = C^n$. Using the consumer's budget constraint, we can calculate proportional change in the welfare. First

we manipulate the budget constraint:

$$P_C^n C^n = \sum_{s=1}^{S} \left(w^n L_s^n (1 + \frac{\alpha_s^n}{\beta_s^n} + \frac{1}{(\sigma_s - 1)\beta_s^n}) \right) - D^n \tag{1.39}$$

Knowing that $P_C^n = \left(\sum_{j=1}^{N} {P_C^{jn}}^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}}$, we can write: $\hat{P}_C^n = \left[\sum_{j=1}^{N} \lambda^{jn} (\hat{P}_C^{jn})^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}$. After solving proportional change equations, we can calculate changes in welfare resulted from firm shocks.

$$\hat{\mathcal{W}} = \hat{C} = \frac{\sum_{s=1}^{S} \left(\frac{wL_s}{PC} \hat{w} \hat{L}_s (1 + \frac{\alpha_s}{\beta_s} + \frac{1}{(\sigma-1)\beta_s}) \right) - D}{\left[\sum_{j=1}^{N} \lambda^{jn} (\hat{P}_C^{jn})^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}} \tag{1.40}$$

Where: $\hat{P}_C^{jn} = \prod_{s=1}^{S} \left(\hat{P}_s^{kj} \right)^{\zeta_s^{kj}}$.

1.3 Quantitative Analysis

In this section, we explain the data sets that we use, estimate the parameters and describe the algorithm to solve the model. We use firm level data from Portugal to quantify the impacts of firm levels shocks in 2004.

1.3.1 Data

We consider a 2 country world where one country is portugal and all other countries are combined as rest of the world. The model can be estimated for any N country setting but we only consider a two-country world for now.
We obtain sector level trade and expenditure data from the World Input-Output Database, Timmer et al. (2015). This dataset provide sectoral level

expenditure on goods from all countries and all sectors dissected into intermediate good expenditure and final consumption expenditure. We combine all sectors from "Electricity, Gas and Water Supply" to "Private Households with Employed Persons" into one sector called Non-tradables and use other sectors as World Input-Output tables. As a result, we end up with 17 sectors.
We use 2 sources of firm data from Portugal. The firm balance sheet level data for 2004 is obtained from Instituto Nacional de Estatstica (INE), the Portuguese Statistics Institute. This data set provides information on firm's sector of operation, gross output, intermediate good consumption, employment and also country of origin.
Customs data for 2004 is provided by Foreign Trade Statistics (FTS). This data set is the country's official data source for foreign trade statistics. It contains information on all export and import transactions of firm's located in Portugal by production category and country of source or destination. Trade transactions in this dataset are free on board, meaning they exclude any duties or shipping charges. These Portuguese datasets are used for different analyses in Bastos et al. (2016) and Dias et al. (2016).
For each firm we calculate two sufficient statistics from the firm level data: firm's market share in Portugal and rest of world, ω_{si}, and the share of firm's intermediate inputs that is imported from foreign countries, γ_{si}. We calculate these values for every firm that exists in both customs and balance-sheet data and use them to exactly match the model to firm level data.

1.3.2 Parameter Estimation

Elasticity of substitution in each sector, σ_s, is a very important parameter in this analysis. This parameter is used to determine the elasticity of sub-

stitution between different firm outputs and also between sectoral bundles imported from different countries. We use the methodology of Oberfield and Raval (2014) and Blaum et al. (2015) to estimate these elasticities from firm level data.

It can be shown from equations (1.9)-(1.11) that for each firm i in sector s:

$$\frac{\sum_{j=1}^{N} P_{si}^{nj} Y_{si}^{nj}}{R^n K_{si}^n + w^n L_{si}^n + P_{Q_{si}}^n Q_{si}^n} = \frac{\sigma_s}{\sigma_s - 1} \tag{1.41}$$

We calculate elasticities for each firm and then averages at each sector to get the values of σ_s. Table 1.1 shows these elasticities of substitution and a list of 17 sectors that we use. Our values have an average of 3.21 which is in the range of other literature and elasticity values for different countries.

To estimate values of α_s and β_s, we use the Socio economic accounts of World Input-Output table. These data file contains values of employment and capital stocks at the sector level for all countries and thus, it can be easily used to estimate α_s and β_s values for each country using the following equations:

$$\alpha_s = \frac{\sigma_s}{\sigma_s - 1} \frac{Capital\ Compensation\ in\ sector\ s}{Gross\ output\ of\ sector\ s}$$

$$\beta_s = \frac{\sigma_s}{\sigma_s - 1} \frac{Labor\ Compensation\ in\ sector\ s}{Gross\ output\ of\ sector\ s}$$

ζ_s^{nj} and ξ_s^{nj}, the shares of final and intermediate expenditure from each country and for each sector, are calculated from data using sectoral expenditure on foreign and domestic goods.

As in Gopinath and Neiman (2014), we take the value of ϵ to be 4. This parameter manages the elasticity of substitution among bundles of goods imported from different countries and it's value won't change the results much.

1.3.3 Solving for the general equilibrium

To solve the general equilibrium values of unknown variables, we use an algorithm similar to Alvarez and Lucas (2007) and Caliendo and Parro (2015). We first guess a vector of wages and capital rents for all countries: $\hat{w}^n$ and $\hat{R}^n$. Having these values we iterate on equations of price index and unit cost, (1.27) and (1.28), until they converge to values consistent with given wages and capital rents. Given the obtained price indexes, we can solve equations of $\hat{w}^n \hat{L}_s^n$ and $\hat{P}_s^{nj} \hat{Y}_s^{nj}$, (1.29) and (1.33). Then, we check if equations (1.25) and (1.35) hold, meaning that labor and capital markets clear. If they don't clear, we return to the first step and adjust vectors of $\hat{w}^n$ and $\hat{R}^n$.

The main challenge of this iteration compared to sectoral level analyses is that when we try to solve equations (1.29) and (1.33), we convert them to a system of SN linear equations in SN unknowns. But, since our firm level shocks are very small, the corresponding matrix is very close to a singular matrix and calculating its inverse creates big errors, if possible at all. To resolve this issue, we don't solve the inverse of the matrix everyone and instead, starting from equilibrium, we calculate the changes from previous iteration until we get convergences.

Once we extend the model to include strategic complementarity among firms, another layer of iteration will be added to our algorithm. When calculating the price indexes, we also need to iterate on the changes in markup of each firm until all values are consistent.

We check for the uniqueness of our solution by starting from different initial guesses for $\hat{w}^n$ and $\hat{R}^n$ and making sure they all result in convergence to the same solution.

1.4 Counterfactual Analysis

Our framework is well-suited for variety of counterfactual analyses including exit of one firm or multiple firms and productivity changes to one or multiple firms. Since we exactly match our model to observed firm level statistics from firm level data, we can estimate these counterfactuals for actual existing firm as opposed to simulated firms that are drawn from a certain parametric distribution.

We can also use the model to isolate the impacts of an observed firm productivity change or exit from other changes in the economy over a certain time period.

1.4.1 Impact of firm productivity growth

We, first, consider the impacts of productivity growth of a single firm. Our goal is to quantify the welfare impacts of a plausible productivity shock that could happen in the economy to an existing firm. Literature take values between 8% to 20% for the standard deviation of the innovation to idiosyncratic productivity shocks, as in Carvalho and Grassi (2015) and Clementi and Palazzo (2016).

To comply with literature, we quantify the impacts of a 10% productivity change. Table 1.2 shows the result of such quantification. For each sector, we apply the shock to the largest firm and the median firm in terms of exports, and also in terms of domestic sale.

Results emphasize the importance of the large firms for the economy and also the importance of international trade in determining the welfare values. These shocks could improve the welfare of the Portuguese consumer by up to 0.4%.

The market share of the firm at home and rest of the world and the sector of the firm determine the value of this welfare change. As classical literature show, patterns of comparative advantage could make this impact positive or negative. If a firm in a comparative advantage sector of Portugal faces a positive productivity change, rest of the world could experience a positive terms-of-trade effect but Portugal could experience a negative terms of trade welfare change.

As we can see in table 1.2, Portugal's welfare goes down after a positive productivity shock to the largest exporters in sector 1 which is a comparative advantage sectors for Portugal. This firm is a export-oriented firm with much more export than domestic revenue. As their productivity increases, Portuguese exports become cheaper and a negative term-of-trade effect dominates the welfare change. When we run the same simulation for some other firms in sector 1 with more domestic sale than export, we get positive welfare changes. This is shown in table 1.2 for the largest firm of sector 1 in terms of domestic sale. As the productivity of this firm increases, the negative terms of trade impact is not as large as the largest exporter case and it's comepnsated by the direct postive impact of productivity increase and cheaper goods that consumers access at home.

To gain more insight on this result, we check the relative change in real wages after productivity shock to these two firms. When productivity of the firm with largest domestic sales increases, the change in real wages of sector 1, or $\hat{w}/\hat{P}_1$, is 0.057%, which results in welfare improvement for consumers. However, when productivity of the largest exporter increases, sector 1's real wage increases only by 0.007% which is not enough to increase the real consumption at home and will lead to welfare decline at home.

Samuelson (2004) shows this counterintuitive outcome with a simple exam-

ple of China and US trades. He mentions that China's technological progress in it's export sector may lower China's per capita income. In Samuelson's numerical example, US always gains from such change because its terms of trade improves. But, depending on elasticities, China's terms of trade could deteriorate so much that it's consumption per capita plunges below it's value before this change.

1.4.2 Impact of exogenous firm exit

We, then, consider a counterfactual in which a firm exits the market for an exogenous reason and calculate the aggregate impacts of this exit. In a model with continuum of firms, such an exit will not have any aggregate impact but it will be shown that, in our granular model, this can have significant impacts on consumer and the economy at home and abroad.

Table 1.3 shows the simulated welfare impact of firm exit. For each sector, the welfare change from the exit of the largest firm and median firm in terms of export, and also in terms of the doemstic sale are shown.

Results emphasize the value of large firms for the economy of Portugal. Exit of the largest firms of different sectors could reduce the welfare of the Portuguese consumer by up to 1%.

Like the productivity increase case, we see some counterintuitive results. Exit of the largest firms in one of the sectors has positive welfare change for Portugal, confirming that the sector of each firm has a very important role in determining the value of that firm.

When a firm exits the market, labor and capital move from the sector of that firm to other sectors. To examine this sectoral reallocation we show

the labor proportional changes after the exit of the largest exporter of sector 15 in table 1.4. Sector 15's labor decline by 27% and other sectors gain labor. Since elasticities of substitution are different, sectors with higher σ_s gain more than sectors with lower σ_s.

To better understand the labor reallocation and remove the effect of elasticities, we simulate the exit of largest exporter in sectors 10 and 15 with $\sigma_s = 3.2$ for all sectors. As we see the results of labor reallocation in Portugal in table 1.5, the pattern of reallocation changes. Since are model is granular, a shock to a large firm could change the pattern of comparative advantage. As a large exporter in a sector exits, that sector loses comparative advantage and some other sectors gain comparative advantage. The labor then reallocates from the sector that loses comparative advantage to the sectors that gain it.

1.4.3 Variable Markup Extension

In table 1.6, we compare the welfare impacts of a 20% productivity increase in the largest exporters of all sectors using constant markup and variable markup models. We have selected a large, 20%, productivity shock to highlight the difference between the constant and variable mark up model. For smaller shocks, values are almost the same.

As results show, welfare gains for home country is mostly smaller using the variable markups. This is mainly because large firms absorb the productivity shock in their mark ups and don't decrease their price and increase their output as much as the constant markup model. In the constant markup model, there is a perfect pass-through from productivity to price.

Other firms reduce their markups as a result of productivity growth of the largest firms. This reduction is bigger for larger firms. As a result of this,

prices drop for other firms and consumers gain in welfare. If this effect is larger that the effetc of the lower price decrease of the firm that faces the productivity shock, welfare change of the variable markup case is higher. We see this effect in the productivity shock to sector 15's largest exporter. Otherwise, welfare change is higher in the constant markup case.

Overall, results are very similar to the constant markup case and it indicates that, in most cases, there may not be a need to consider the oligapolistic competitions.

1.4.4 Immobile labor and capital across sectors

So far, we have assumed that both labor and capital are freely mobile across sectors. However, many empirical studies, Brascoupe et al. (2010) and Dix-Carneiro (2014), have shown that labor market transition may take several years. Capital also responds sluggishly to different shocks and adjusts to new sectors slowly.

To show the effects of intersectoral capital and labor reallocations, we estimate a new version of our model that assumes labor and capital are totally immobile across sectors. This can be considered as a short run version of the model. We continue to assume that labor and capital freely reallocation inside each sector across different firms. In the new model, we'll have a separate wage and capital rent for each sector in each country.

The algorithm to solve this new version of the model is similiar to the main algorithm with some changes. We start by guessing a wage and capital rent vector fot each country: $\hat{w}_s^n$ and $\hat{R}_s^n$. Each vector has the size of the number of sectors. By iterationg on the quations of price and unit cost, we calculate the price indexes corresponding to the current values of wages and capital

rents.

Equation (1.33) can then used to calculate the proportional changes in sectoral expenditure. We set all the values of $\hat{L}_t^j$ to 1 and use the current values of wage to calculate expenditure changes. These values will be used to check the consistency of equation (1.29). If this equation doesn't hold, we update all the values of labor and capital and return to the first step and redo eveything.

The results of model estimation with immobile labor and capital across sectors are shown in tables 1.7 and 1.8. The difference between these results and the freely mobile factor model shows the importance of intersectoral factor reallocation in determining the welfare changes.

In the case of a 10% productivity shock to the largest exporter in each sector, table 1.7, we realise that in most of the sectors, the positive welfare gain for the home country is higher for the case of freely mobile factors. This means that in the short run, only part of the welfare gains are realised and rest of the gains are achieved in the long run when labor and capital are reallocated across sectors. As capital and labor move form other sector to the sector that has gained productivity, welfare gains increase.

Other interesting result is the opposite sign of the welfare impact on the rest of the world for the cases of mobile and immobile factors. In the comparative advantage sectors of the rest of the world and in the short run, when factors are immobile, positive procutivity shock in Portugal has a positive welfare impact on the rest of the world. The negative welfare impacts are realized in the long run, when factors move away from these comparative advantage sectors.

We see similar results for the experiment of firm exit. There are smaller welfare decreases after a firm's exit with immobile factors. Rest of the negative

impact of firm exit is realised when factors move from that sector to other sectors. In the comparative advantage sectors of the rest of the world and in short run, when factors are immobile, the welfare impact are negative but as factors move from other sectors to this sector, welfare impact becomes positive.

1.5 Conclusion

In this paper, we presented a framework that allows us to quantify the welfare value of individual firms. Using exact hat algebra, we match our model to sector level data from the world and firm level data from Portugal in 2004. Quantitative analysis shows that large firms are important for the welfare of consumers and idiosyncratic shocks to firm could significantly change the welfare at home and foreign countries. Our results confirm international trade's role in transmitting idiosyncratic shocks across countries.

Our results show that beside domestic and foreign market shares of the firm, firm's sector and patterns of comparative advantage are very important in determining the value of each firm. Policymakers need to consider these facts when implementing laws to protect certain groups of firms or when allocating funds to bail out certain firms.

Accuracy of our results are limited to the modeling assumptions like fixed number of firms, market structure, production function form and also to the accuracy of parameter estimations. Despite these limitations, our model provides a first step for understanding the value of firms in an economy and welfare impact of their shocks.

For future work, we are planning to use firm level data over multiple years and observe the firms that enter and exit the market to estimate the welfare

impact of firm entry and exit. We can also use a panel data to estimate the dynamic welfare impacts of actual, observed firm level shocks in an open economy. These estimates have been so far done mostly in closed models, but our framework shows that international trade and patterns of comparative advantage have huge impact on how firm level shocks affect aggregate welfare.

1.6 Tables

Number	Sector	σ_s
1	Agriculture, Forestry & Fishing	3.01
2	Mining and Quarrying	4.08
3	Food, Beverages and Tobacco	4.77
4	Textiles and Textile Products	2.99
5	Leather, Leather and Footwear	2.78
6	Wood, Products of Wood, Cork	3.89
7	Pulp, Paper and Publishing	2.21
8	Coke, Petroleum, Nuclear Fuel	4.57
9	Chemicals, Chemical Products	2.73
10	Rubber and Plastics	2.50
11	Other Non-Metallic Mineral	2.06
12	Basic Metals, Fabricated Metal	2.58
13	Machinery, Nec	2.69
14	Electrical, Optical Equipment	2.70
15	Transport Equipment	2.99
16	Manufacturing, Nec; Recycling	2.89
17	Non-tradables	5.18

Table 1.1: Elasticities of Substitution

		Largest Firm		Median Firm	
Sector	Category	Portugal	Rest of World	Portugal	Rest of World
1	Export	-0.00152%	+0.0000201%	-0.0000007%	+0.000006%
	Domestic sale	+0.00176%	+0.0000169%	+0.00002%	+0.000006%
2	Export	+0.0954%	-0.000431%	+0.00165%	-0.0000131%
	Domestic sale	+0.0554%	-0.000248%	+0.00316%	-0.0000199%
3	Export	+0.0205%	+0.0000235%	+0.00100%	+0.000005%
	Domestic sale	+0.0480%	-0.000008%	+0.000205%	+0.000006%
4	Export	+0.00424%	-0.000003%	+0.0000380%	-0.00000304%
	Domestic sale	+0.00576%	-0.000007%	+0.0000514%	-0.0000049%
5	Export	+0.0337%	-0.000142%	+0.000535%	-0.0000081%
	Domestic sale	+0.0216%	-0.0000888%	+0.000133%	-0.00000631%
6	Export	+0.0725%	-0.000277%	+0.000611%	-0.00000805%
	Domestic sale	+0.0666%	-0.000236%	+0.000758%	-0.00000871%
7	Export	+0.0779%	-0.000212%	+0.00183%	-0.0000091%
	Domestic sale	+0.0779%	-0.000212%	+0.0000851%	-0.00000593%
8	Export	+0.000917%	-0.0000093%	+0.000917%	-0.0000093%
	Domestic sale	+0.000917%	-0.0000093%	+0.000917%	-0.0000093%
9	Export	+0.146%	-0.000519%	+0.00716%	-0.0000293%
	Domestic sale	+0.146%	-0.000519%	+0.000558%	-0.00000769%
10	Export	+0.176%	-0.000712%	+0.00101%	-0.00000962%
	Domestic sale	+0.176%	-0.000712%	+0.000409%	-0.00000727%
11	Export	+0.0143%	-0.0000331%	+0.000105%	-0.00000599%
	Domestic sale	+0.0395%	-0.0000551%	+0.00005%	-0.0000078%
12	Export	+0.0257%	-0.000061%	+0.00119%	-0.00000815%
	Domestic sale	+0.0155%	-0.000036%	+0.000129%	-0.00000601%
13	Export	+0.0699%	-0.000267%	+0.000278%	-0.00000683%
	Domestic sale	+0.0699%	-0.000267%	+0.000400%	-0.00000732%
14	Export	+0.101%	-0.000325%	+0.000715%	-0.00000818%
	Domestic sale	+0.189%	-0.000612%	+0.000286%	-0.00000683%
15	Export	+0.416%	-0.00146%	+0.0207%	-0.000082%
	Domestic sale	+0.0405%	-0.000153%	+0.00159%	-0.0000112%
16	Export	+0.0466%	-0.000175%	+0.000156%	-0.0000064%
	Domestic sale	+0.0112%	-0.0000410%	+0.000095%	-0.0000061%

Table 1.2: Welfare gain from 10% firm productivity shock

		Largest Firm		Median Firm	
Sector	Category	Portugal	Rest of World	Portugal	Rest of World
1	Export	+0.00742%	-0.0000747%	+0.000086%	-0.000007%
	Domestic sale	-0.00819%	-0.0000594%	-0.000015%	-0.0000064%
2	Export	-0.265%	+0.00118%	-0.00488%	+0.0000274%
	Domestic sale	-0.160%	+0.000702%	-0.00927%	+0.0000465%
3	Export	-0.0449%	-0.0000636%	-0.00229%	-0.000005%
	Domestic sale	-0.108%	-0.000004%	-0.000446%	-0.000006%
4	Export	-0.0199%	-0.0000209%	-0.000171%	-0.0000001%
	Domestic sale	-0.0274%	+0.0000120%	-0.000232%	+0.00000505%
5	Export	-0.175%	+0.000707%	-0.00299%	+0.0000179%
	Domestic sale	-0.118%	+0.000457%	-0.000819%	+0.00000888%
6	Export	-0.220%	+0.000815%	-0.00198%	+0.0000127%
	Domestic sale	-0.209%	+0.000716%	-0.00244%	+0.0000152%
7	Export	-0.539%	+0.00112%	-0.0151%	+0.0000332%
	Domestic sale	-0.539%	+0.00112%	-0.000849%	+0.00000729%
8	Export	-0.00229%	+0.0000145%	-0.00229%	+0.0000145%
	Domestic sale	-0.00229%	+0.0000145%	-0.00229%	+0.0000145%
9	Export	-0.676%	+0.00214%	-0.0400%	+0.000137%
	Domestic sale	-0.676%	+0.00214%	-0.00322%	+0.0000164%
10	Export	-0.907%	+0.00341%	-0.00674%	+0.0000309%
	Domestic sale	-0.907%	+0.00341%	-0.00279%	+0.0000157%
11	Export	-0.133%	+0.000247%	-0.00117%	+0.00000792%
	Domestic sale	-0.387%	+0.000478%	-0.000546%	+0.00000631%
12	Export	-0.150%	+0.000302%	-0.00747%	+0.0000203%
	Domestic sale	-0.0957%	+0.000190%	-0.000912%	+0.00000761%
13	Export	-0.372%	+0.00136%	-0.00170%	+0.0000121%
	Domestic sale	-0.372%	+0.00136%	-0.00240%	+0.0000147%
14	Export	-0.488%	+0.00137%	-0.00417%	+0.0000191%
	Domestic sale	-0.952%	+0.00266%	-0.00173%	+0.0000114%
15	Export	-1.036%	+0.00209%	-0.0994%	+0.000369%
	Domestic sale	-0.193%	+0.000698%	-0.00768%	+0.0000321%
16	Export	-0.221%	+0.000779%	-0.000883%	+0.00000894%
	Domestic sale	-0.0573%	+0.000186%	-0.000570%	+0.00000763%

Table 1.3: Welfare gain from firm exit

Sector	Labor Portugal	Labor ROW
Agriculture, Forestry & Fishing	1.0043	0.9999
Mining and Quarrying	1.0329	0.9999
Food, Beverages and Tobacco	1.0137	0.9999
Textiles and Textile Products	1.0153	0.9998
Leather, Leather and Footwear	1.0162	0.9997
Wood, Products of Wood, Cork	1.0182	0.9999
Pulp, Paper and Publishing	1.0057	0.9999
Coke, Petroleum, Nuclear Fuel	1.0151	0.9999
Chemicals, Chemical Products	1.0144	0.9999
Rubber and Plastics	1.0118	0.9999
Other Non-Metallic Mineral	1.0032	0.9999
Basic Metals, Fabricated Metal	1.0113	0.9999
Machinery, Nec	1.0160	0.9999
Electrical, Optical Equipment	1.0148	0.9999
Transport Equipment	0.7349	1.0006
Manufacturing, Nec; Recycling	1.0096	0.9999
Non-tradables	1.0003	0.9999

Table 1.4: Proportional sectoral labor changes after the exit of the largest exporter in sector 15

Sector	Sector 10	Sector 15
Agriculture, Forestry & Fishing	1.0032	1.0048
Mining and Quarrying	1.0128	1.0181
Food, Beverages and Tobacco	1.0029	1.0079
Textiles and Textile Products	1.0082	1.0160
Leather, Leather and Footwear	1.0094	1.0191
Wood, Products of Wood, Cork	1.0077	1.0107
Pulp, Paper and Publishing	1.0069	1.0104
Coke, Petroleum, Nuclear Fuel	1.0048	1.0074
Chemicals, Chemical Products	1.0095	1.0171
Rubber and Plastics	0.8666	1.0152
Other Non-Metallic Mineral	1.0060	1.0066
Basic Metals, Fabricated Metal	1.0090	1.0135
Machinery, Nec	1.0098	1.0202
Electrical, Optical Equipment	1.0091	1.0175
Transport Equipment	1.0103	0.7354
Manufacturing, Nec; Recycling	1.0053	1.0122
Non-tradables	0.9992	1.0002

Table 1.5: Proportional sectoral labor changes in Portugal after the exit of the largest exporter in sectors 10 and 15. We set $\sigma_s = 3.2$ for all sectors so elasticities don't affect the results

	Constant Markups		Variable Markups	
Sector	Portugal	Rest of World	Portugal	Rest of World
9	+0.3112%	-0.001111%	+0.3098%	-0.001105%
10	+0.3697%	-0.001503%	+0.3697%	-0.001503%
14	+0.2148%	-0.0006909%	+0.2151%	-0.0006916%
15	+0.9495%	-0.003432%	+0.9503%	-0.003434%

Table 1.6: Welfare gain from 20% firm productivity shock to the largest exporter of some sectors for constant and Variable markups

	Mobile factors		Immoblie factors	
Sector	Portugal	Rest of World	Portugal	Rest of World
1	-0.00152%	+0.0000201%	-0.00764%	+0.00000388%
2	+0.0954%	-0.000431%	+0.00210%	+0.00000006%
3	+0.0205%	+0.0000235%	+0.0309%	-0.0000119%
4	+0.00424%	-0.000003%	+0.00482%	+0.0000065%
5	+0.0337%	-0.000142%	+0.00364%	+0.0000061%
6	+0.0725%	-0.000277%	+0.0157%	-0.0000003%
7	+0.0779%	-0.000212%	+0.0335%	+0.0000639%
8	+0.000917%	-0.0000093%	+0.000136%	-0.000334%
9	+0.146%	-0.000519%	+0.0416%	+0.000025%
10	+0.176%	-0.000712%	+0.0231%	+0.000036%
11	+0.0143%	-0.0000331%	+0.00811%	+0.0000118%
12	+0.0257%	-0.000061%	+0.0138%	+0.0000145%
13	+0.0699%	-0.000267%	+0.0159%	+0.0000046%
14	+0.101%	-0.000325%	+0.0362%	+0.0000385%
15	+0.416%	-0.00146%	+0.103%	+0.000124%
16	+0.0466%	-0.000175%	+0.00832%	+0.0000120%

Table 1.7: Welfare gain from 10% firm productivity shock to the largest exporter in each sector

	Moble factors		Immobile factors	
Sector	Portugal	Rest of World	Portugal	Rest of World
1	+0.00742%	-0.0000747%	+0.0363%	-0.0000173%
2	-0.265%	+0.00118%	-0.00571%	-0.0000093%
3	-0.0449%	-0.0000636%	-0.0722%	+0.0000267%
4	-0.0199%	-0.0000209%	-0.0231%	-0.0000321%
5	-0.175%	+0.000707%	-0.0195%	-0.0000363%
6	-0.220%	+0.000815%	-0.0501%	-0.00000177%
7	-0.539%	+0.00112%	-0.269%	-0.000634%
8	-0.00229%	+0.0000145%	-0.000335%	+0.0000005%
9	-0.676%	+0.00214%	-0.234%	-0.000197%
10	-0.907%	+0.00341%	-0.145%	-0.000348%
11	-0.133%	+0.000247%	-0.0767%	-0.000116%
12	-0.150%	+0.000302%	-0.0845%	-0.000095%
13	-0.372%	+0.00136%	-0.0913%	-0.0000319%
14	-0.488%	+0.00137%	-0.210%	-0.000248%
15	-1.036%	+0.00209%	-0.490%	-0.000968%
16	-0.221%	+0.000779%	-0.0415%	-0.0000714%

Table 1.8: Welfare gain from the exit of the largest exporter in each sector

CHAPTER 2

TAX COMPETITION AND MULTINATIONAL PRODUCTION

2.1 Introduction

Multinational production (MP) has been rising rapidly in the past few decades. Firms are increasingly producing their products away from their country of origin and export them to multiple destinations. There are multiple factors that determine the choice of production locations of firms.

Multiple empirical studies have shown that the corporate tax rate is an important factor in determining firms' location choice. Barrios et al. (2012) utilize a large international firm-level data set and estimate that the impact of both host and parent country tax rates are negative on the location of new foreign firm subsidiaries. Devereux and Griffith (1998) study a panel of US firms locating in the European market and show that the effective average tax rate significantly impacts the choice between locations.

However, there aren't many general equilibrium quantitative studies on the impact of taxes on the location choice of multinationals and how this choice affects the welfare and other aggregate outcomes in the host country. Most of the related studies consider tax or subsidy competition across different regions in a country or study the movement of capital across different countries.

In this paper, we develop a multi-country general equilibrium framework to quantify the aggregate impact of corporate tax rate changes in any country.

In the model, firms choose their location of production to maximize their profits based on cost of production, trade and MP costs and tax rates in each country. We'll show how changes in tax rates affect the overall profits in each country and how they lead to changes in wages, prices and welfare of the consumers.

Results confirm that when a country unilaterally reduces its corporate tax rates, it attracts more multinational products and it improves the welfare of its population at the expense of other countries. The main mechanism at work here is agglomeration. As tax rates of a country decline and firms open more affiliates there, consumers benefit from lower price index in that country. Domestic firms also benefit from this lower price index by using cheaper intermediate goods.

This paper is related to several strands of literature. There is a large and vibrant literature focused on quantitatively modeling trade and MP and estimating the welfare gains from them. Irarrazabal et al. (2013) present a quantitatively estimable expansion of Helpman et al. (2004) paper to study the proximity-concentration trade-off between exporting and MP. Their model incorporates both fixed costs of exporting and MP and as a result, equations can't be aggregated and solved easily for the purpose of our study. Ramondo and Rodríguez-Clare (2013) extend the Ricardian trade model of Eaton and Kortum (2002) to add multinational production. Their model allows counter-factual analysis in a multi-country setup but it's not appropriate for our analysis as firms have a profit of zero in a perfect competition environment. Arkolakis et al. (2017) take this model to a parametrized monopolistic competition setup of Melitz (2003). In their model, countries endogenously specialize in innovation or production and this specialization is important in determining the gain or loss of each country from MP. By replacing the

plant-level fixed cost with export fixed costs, they have been able to create a tractable multi-country model with equations that easily aggregate. However, because of absence of MP fixed costs, their model generates too many affiliates that are smaller compared to data. Tintelnot (2017) adds the fixed cost of establishing plants and estimates the model using numerical methods. As a result of addition of the plant-level fixed costs, the equations in his model can't be aggregated easily.

Our paper is also related to regional fiscal competition papers. Fajgelbaum et al. (2018) develop a quantitative economic geography model to study state taxes as a potential source of spatial misallocation in the United States. They find that difference in state tax rates lead to aggregate losses and study the impact of recent tax reforms. Ossa (2018) constructs a similar quantitative economic geography model to study subsidy competition among US states. He solves for the Nash equilibrium of the non-cooperative and cooperative games of subsidy competition and estimates welfare gains of subsidizing firm location by a state at the expense of others.

There is also a large literature on tax competition that study the movement of capital across countries or regions. While they only focus on outflow of capital, the insights of their analysis can be used for an analysis considering multinational firms. Building on the classic models of Zodrow and Mieszkowski (1986) and Wilson (1986), Keen and Konrad (2013) present a static, multi-country tax competition model where capital is the mobile factor. Mendoza and Tesar (2005) explain why the capital integration of European union in 1980 didn't result in a race to bottom. They use a dynamic, neoclassical general equilibrium model of tax competition.

2.2 International Tax System

Countries use one of the two methods for taxation of income earned abroad: The worldwide method and the territorial method. Under the territorial method, income earned by multinational affiliates abroad is wholly or partially exempt from home country taxation. Under the worldwide system, multinational firms need to pay home country taxes on the income earned abroad, once it's repatriated. A credit is usually given for taxes paid to foreign governments (PWC (2013)). Under this system, companies have incentive to keep profits abroad to avoid paying taxes to the home country upon repatriation.

Since from the beginning of this century, many countries have switched from the worldwide method to the territorial method and exempt 95-100% of the profit earned by affiliates in some or all of the foreign countries. Most notably, UK and Japan adopted the territorial system, with exemption applied to all countries, in 2009. As of 2012, 28 of 34 OECD countries use territorial system and US recently switched to this system as well.

In this paper, to make the analysis more straight forward and to focus on desired economic forces, we only consider and include countries with territorial tax system and assume they exempt 100 percent of foreign income. Including countries with worldwide method would complicate the equations and we would lose tractability and also, the issue of profit repatriation would require a two-period or dynamic model instead of our current static model.

We also abstract from the issue of profit shifting. As shown in Zucman (2014), large multinational firms increasingly use transfer pricing to shift profits to foreign tax havens to reduce their tax bill. These tax havens include European countries like Ireland or Luxembourg and also Bermuda and

other Caribbean islands.

There are several empirical studies on the issue of profit shifting to tax havens. Harris et al. (1993) and Hines Jr and Rice (1994) show evidence of profit shifting to tax havens. Clausing (2003) provides evidence of transfer mis-pricing for the purpose of profit shifting from US multinational data. Hebous and Johannesen (2015) use data from German multinationals to show they use trade in services to shift profit to tax havens. In a similar study, Liu et al. (2017) use UK tax system change of 2009 from worldwide to territorial to exhibit that British multinationals manipulate transfer prices to shift profits to tax havens.

However, not all firms engage in these tax haven operation. As shown in Desai et al. (2006), tax haven profit shifting is mostly done by larger firms. According to Gumpert et al. (2016), reallocation of taxable income to tax havens is difficult and only 20.4% of German multinationals have tax haven affiliates. Not accounting for profit shifting to tax haven by manipulating transfer prices and other means is an important limitation of our analysis. When multinational firms have the option of avoiding taxes by shifting profits to tax havens, they will not be as responsive to tax rate changes in countries as predicted by our model. However, as noted above, these operations are available only to certain and limited number of firms and industries and not including them in the model doesn't discredit the result. Adding profit shifting to tax havens to our models will be an important issue for future research.

2.3 Model

We develop a model of trade and multinational production that is suitable for analyzing the impact of corporate tax rates on firm location choice and aggregate outcomes. We assume a market structure of monopolistic competition as in Melitz (2003) and Chaney (2008).

There are N countries in the world indexed by i, l or n. Each country has fixed and exogenously given measures of firms, M_i, and workers, L_i. There is a continuum of goods, $\omega \in \Omega$ and each good is produced by a single firm. We assume standard CES preferences with the price index given by:

$$P_i = \left(\int_{\omega \in \Omega} p_i(\omega)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{2.1}$$

where σ is the elasticity of substitution and $p_i(\omega)$ is the price of good ω in country i.

Each firm uses two factors of production: labor and intermediate goods. Productivity of a firm consists of a core productivity component, ϕ, and a vector of location-specific productivity shifters, $\mathbf{z} = (z_1, ..., z_N)$. The production function of a firm from country i producing in country l can be written as:

$$q_{il}(\omega) = \phi z_l \left(\frac{l^l(\omega)}{\beta_l} \right)^{\beta_l} \left(\frac{i^l(\omega)}{1-\beta_l} \right)^{1-\beta_l} \tag{2.2}$$

where l^l is the labor and i^l is the intermediate goods used in country l.

We assume ϕ is drawn from a pareto distribution:

$$\phi \sim 1 - \left(\frac{b_i}{\phi} \right)^{\kappa} \tag{2.3}$$

with the restriction that $\kappa + 1 - \sigma > 0$. z_l for the firm is drawn from Frechet distribution with parameter θ:

$$z_l \sim e^{-z^{-\theta}} \tag{2.4}$$

Each country's only tax is a proportional tax on the profits of the firms located in that country. Government will use these tax revenues to provide a public good to consumers. Using these simple proportional taxes as opposed to distortionary taxes keeps the model simpler and more tractable. Proportional taxes won't affect the mark-up of firms and firm will continue to charge the standard CES mark-up of $\sigma/(\sigma - 1)$. However, taxes will still affect firm's location choice by impacting the effective cost that firm faces in each country to produce.

2.3.1 Firm's problem

To simplify the analysis, we assume firms don't face any fixed cost of establishing a plant in the home country or abroad and they don't face any marketing fixed cost of exporting either. Each firm will optimally choose a country to produce its product and sell it in all countries.

Consider a firm from country i that locates in country l and sells to all countries from there. The revenue of this firm from selling its product to country n is $(p_{iln}/P_n)^{1-\sigma} X_n$, where p_{iln} is the price of selling in country n and X_n is the total expenditure in country n. The overall profit of this firm is:

$$\pi_{il}(\phi z_l) = (1 - t_l) \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} \sum_{n=1}^{N} P_n^{\sigma-1} \frac{X_n}{\sigma} \frac{\phi^{\sigma-1} z_l^{\sigma-1}}{(\tau_{ln} c_l \gamma_{il})^{\sigma-1}} \tag{2.5}$$

where t_l is the proportional tax on the profit of a firm producing in country l as in Krautheim and Schmidt-Eisenlohr (2011), $c_l = w_l^{\beta_l} P_l^{1-\beta_l}$ is the cost of the cost-minimizing bundle of factors and w_l is the wage in country l. τ_{ln} is the iceberg trade cost with $\tau_{ll} = 1$. γ_{il} is the iceberg bilateral MP cost with $\gamma_{ll} = 1$. These MP iceberg costs capture variety of costs a firm incurs when producing in a foreign country from legal and communication costs to technology transfer cost.

Firm decides to locate in country l, if l maximizes this profit function over all potential production locations. Since z_l has a Frechet distribution with parameter θ, (2.5) shows that firm profit is also Frechet-distributed with the parameter $\theta/(\sigma - 1)$.

From the properties of Frechet distribution, we know that it is a max stable distribution, meaning that the maximum of Frechet-distributed random variables is also Frechet-distributed. As a result, $\max_l \pi_{il}$ is Frechet-distributed as well.

Using above results, we conclude that probability of a firm form i locating in l, or ψ_{il} is given by:

$$\psi_{il} = \frac{\left(\sum_{n=1}^{N} P_n^{\sigma-1} \frac{X_n}{\sigma} \frac{1-t_l}{(\tau_{ln} c_l \gamma_{il})^{\sigma-1}}\right)^{\frac{\theta}{\sigma-1}}}{\Psi_i} = \left(\frac{\Pi_{il}}{\Psi_i}\right)^{\frac{\theta}{\sigma-1}} \tag{2.6}$$

where,

$$\Psi_i^{\frac{\theta}{\sigma-1}} = \sum_{j=1}^{N} \left(\sum_{n=1}^{N} P_n^{\sigma-1} \frac{X_n}{\sigma} \frac{1-t_j}{(\tau_{jn} c_j \gamma_{ij})^{\sigma-1}}\right)^{\frac{\theta}{\sigma-1}} = \sum_{l=1}^{N} \Pi_{il}^{\frac{\theta}{\sigma-1}} \tag{2.7}$$

Here, Π_{il} is proportional to the expected profit of a firm from i located in l and Ψ_i is proportional to the expected profit of a firm originated from i that chooses the production location to maximize the total profits. ψ_{il} can also

be considered as the ratio of the firms from i that locate in l. As evident from above equations, tax rates have important roles in the location choice of each firm and countries can attract more firms by lowering their corporate tax rates.

2.3.2 Aggregation

Similar to heterogeneous firm trade literature, we define an average productivity measure in each country. As firms select the location of their production, we can assume there is a single representative firm located country l and originated from country i with productivity $\tilde{z}_{il}$ given by:

$$\tilde{z}_{il} = \psi_{il}^{-\frac{1}{\theta}} \tag{2.8}$$

This relationship can be combined with equation (2.1) to write down the price index in country n as:

$$P_n^{1-\sigma} = \sum_{i=1}^{N} \sum_{l=1}^{N} M_i \psi_{il} p_{iln}(\tilde{z}_{il})^{1-\sigma} \tag{2.9}$$

where $p_{iln}(\tilde{z}_l)$ is the price of sales from l to n by firms originated from i assuming they all have productivity $\tilde{z}_{il}$.

Using above results and integrating over all values of ϕ, we can calculate the total sales of firms from i to n through country l:

$$X_{iln} = M_i \psi_{il} (p_{iln}(\tilde{z}_{il})/P_n)^{1-\sigma} X_n \tag{2.10}$$

As in Arkolakis et al. (2017), we use these values to construct trade and MP shares for each country so we can take the model to data. Trade shares are

given as the share of expenditure on a country spent on good imported from another country:

$$\lambda_{ln}^{T} = \frac{\sum_i X_{iln}}{X_n} \tag{2.11}$$

MP shares are defined as share of production in a country from firms originated in another country:

$$\lambda_{il}^{M} = \frac{\sum_n X_{iln}}{\sum_{i,n} X_{iln}} \tag{2.12}$$

Letting Π_{iln} be the profits associated with sales X_{iln}, from standard CES properties, we get:

$$\Pi_{iln} = (1 - t_l)\frac{X_{iln}}{\sigma} \tag{2.13}$$

Summing over countries, total profit of firms from i located in l, can be written as: $\Pi_{il} = (1 - t_l)\sum_n X_{iln}/\sigma$.

2.3.3 Government and Workers

The Government of each country taxes the profits of all firms located in that country. It uses this revenue to supply a public good, G, to the consumers in that country. Total revenue of the government can be written as:

$$R_l = P_l G_l = t_l \sum_i \widetilde{\Pi}_{il} \tag{2.14}$$

where $\widetilde{\Pi}_{il}$ is the gross total profit of firms from i producing in l, before taxes. We assume there is a representative worker at each country that supplies all the labor and owns all the firm originated from that country. Utility of the representative worker is a Cobb-Douglas function of a consumption good, C,

and the public good provided by the government:

$$v_n = u_n G_n^{\alpha_n} C_n^{1-\alpha_n} \tag{2.15}$$

where u_n capture natural and general characteristics of each country that affect the utility of anyone living there. α_n is the Cobb-Douglas coefficient that changes country by country.

2.3.4 General Equilibrium

To close the model and solve for its general equilibrium, we first write down the goods market clearing condition. The final aggregate good, Q_n, produced in each country can be either consumed by workers, C_n, or used by firms as intermediate goods, I_n, or by governments to provide the public good, G_n:

$$Q_n = C_n + I_n + G_n \tag{2.16}$$

Multiplying both sides with the price index, we can get an equation for the total expenditure in country n, X_n:

$$X_n = P_n C_n + P_n I_n + P_n G_n \tag{2.17}$$

To obtain the labor market clearing equation, we should only consider the labor used for production in each country as there are no fixed costs of marketing or establishing a plant:

$$w_l L_l = \frac{\sigma - 1}{\sigma} \beta_l Y_l \tag{2.18}$$

where Y_l is the total value production in country n and it's equal to $\sum_{i,n} X_{iln}$. Finally, consumers budget constraint will be written as:

$$P_i C_i = \sum_l \Pi_{il} + w_i L_i + \Delta_i \tag{2.19}$$

where Δ_i is the exogenous international transfer to consumers as in Dekle et al. (2008b). These transfers account for total trade and MP imbalance for each country.

Combining this equation and the equation for government expenditure, we can write the total expenditure in country n as:

$$X_i = \sum_l \Pi_{il} + \frac{1}{\beta_i} w_i L_i + t_i \sum_j \widetilde{\Pi}_{ji} + \Delta_i \tag{2.20}$$

2.3.5 General Equilibrium in proportional changes

To solve the model for an actual or counter-factual change in tax rates, we write the general equilibrium equations in proportional changes. Proportional change in any variable x, will be written as $\hat{x} = x'/x$, where x' is the counter-factual value of the variable and x is its initial value. Starting from a set of tax rates in different countries, $\{t_l\}_{l=1}^N$, tax rates could change to a new set of rates, $\{t'_l\}_{l=1}^N$, and we would like to calculate how aggregate variables, and especially welfare, respond to these changes.

First, using the expression for the cost of cost-minimizing bundle of goods, we write it in relative changes:

$$\hat{c}_l = \hat{w}_l^{\beta_l} \hat{P}_l^{1-\beta_l} \tag{2.21}$$

The price index, after using equations (2.9) and (2.10), can be written in relative changes too:

$$\hat{P}_n^{1-\sigma} = \sum_i \sum_l \frac{X_{iln}}{X_n} \hat{\psi}_{il}^{\frac{\theta+1-\sigma}{\theta}} \hat{c}_l^{1-\sigma} \tag{2.22}$$

where, after applying hat algebra to (2.6), $\hat{\psi}_{il}$ will be specified as:

$$\hat{\psi}_{il} = \left(\frac{\hat{\Pi}_{il}}{\hat{\Psi}_i} \right)^{\frac{\theta}{\sigma-1}} \tag{2.23}$$

To proceed, we note that from (2.7):

$$\hat{\Psi}_i^{\frac{\theta}{\sigma-1}} = \sum_l \psi_{il} \hat{\Pi}_{il}^{\frac{\theta}{\sigma-1}} \tag{2.24}$$

Starting from the equation $\Pi_{il} = (1 - t_l) \sum_n X_{iln}/\sigma$, we obtain:

$$\hat{\Pi}_{il} = \frac{1 - t_l'}{1 - t_l} \sum_n \hat{X}_{iln} \frac{X_{iln}}{\sum_n X_{iln}} \tag{2.25}$$

To complete the above equation, hat algebra needs to be applied to (2.10):

$$\hat{X}_{iln} = \hat{\psi}_{il}^{\frac{\theta+1-\sigma}{\theta}} \hat{c}_l^{1-\sigma} \hat{P}_n^{\sigma-1} \hat{X}_n \tag{2.26}$$

We also write down equations (2.18) and (2.20) in relative changes:

$$\hat{X}_i = \sum_l \frac{\Pi_{il}}{X_i} \hat{\Pi}_{il} + \frac{1}{\beta_i} \frac{w_i L_i}{X_i} \hat{w}_i + \frac{t_i'}{1 - t_i'} \sum_j \frac{\Pi_{ji}}{X_i} \hat{\Pi}_{ji} + \frac{\Delta_i}{X_i} \tag{2.27}$$

$$\hat{w}_l = \hat{Y}_l = \sum_i \lambda_{il}^M \sum_n \hat{X}_{iln} \frac{X_{iln}}{\sum_n X_{iln}} \tag{2.28}$$

To calculate the change in welfare we need changes in the consumption good and also public good:

$$\hat{P}_i\hat{C}_i = \sum_l \frac{\Pi_{il}}{P_iC_i}\hat{\Pi}_{il} + \hat{w}_i\frac{w_iL_i}{P_iC_i} + \frac{\Delta_i}{P_iC_i} \tag{2.29}$$

$$\hat{P}_l\hat{G}_l = \hat{t}_l\frac{1-t_l}{1-t'_l}\frac{\sum_i \hat{\Pi}_{il}\Pi_{il}}{\sum_i \Pi_{il}} \tag{2.30}$$

Finally, the proportional change in the welfare of the consumer is obtained as:

$$\hat{v}_n = \hat{G}_n^{\alpha_n}\hat{C}_n^{1-\alpha_n} \tag{2.31}$$

Above equations can be solved once we calibrate the values of needed parameters and obtain the trade and MP share as well as labor expenditure in each country. For any exogenous change in tax rates, changes in all aggregate outcomes, and especially welfare, will be obtained.

2.4 Data and Calibration

We limit the analysis to 13 countries that use territorial system for the taxation of international income, as in 2012, and we can find reliable multinational production data for them: Italy, Germany, France, Spain, UK, Austria, Portugal, Sweden, Canada, Belgium, Finland, Norway, Czech Republic.

Country level trade, expenditure and labor income data is acquired from world input-output tables, Timmer et al. (2015). Multinational production data is obtained from OECD AMNE Database Activity of Multinational Enterprises and Eurostat Foreign Affiliate Statistics database for 2012. We have compared the values from these two sources and used the average of values, if there is any discrepancy between them, however, for countries in

our analysis, most of the values match. This dataset is used to created the MP shares, λ_{il}^{M}, and also trade shares, λ_{ln}^{T}. These shares will be directly used in equations and will also be used to calibrate the values of X_{iln} with a procedure similar to the one in Arkolakis et al. (2017).

Even though many papers have used the MP data provided in Ramondo et al. (2015), we have decided to construct a new MP dataset for 2012 from aforementioned sources . The main reason is that the dataset in Ramondo et al. (2015) is constructed as an average dataset over 1996-2001, when most countries were still using the worldwide international tax system.

As a result of using the values in relative changes, we don't need to estimate some parameters like trade and MP iceberg costs, τ_{ln} and γ_{il}. This approach puts restrictions on these iceberg costs so that the predicted values for trade and MP shares exactly match the observed values from data.

There are a few parameters that need to be calibrated. We estimate the share of labor and intermediate input, β_n, from the world input-output tables for all countries. For each country, α_n is calibrated as R_n/GDP_n or the share of tax revenues to GDP for country n. These values are obtained from the world bank datasets.

Like most of the literature, we set $\sigma = 4$ to get a markup of 33% for firms. As in Tintelnot (2017), we set the shape parameter of Frechet distribution of productivities to $\theta = 7$. This value is close to the median value for the shape parameter of productivity distribution in Eaton and Kortum (2002).

Given the values of these calibrated parameters and trade and MP shares from data, we can solve equations (2.21) to (2.31) using an iterative procedure to get relative changes in welfare and other aggregate outcomes.

2.5 Simulations and Results

Our frameworks can be used to estimate the impact of actual or counterfactual changes in the tax rates of one or multiple countries. In the section, we show the results and their interpretation for a few scenarios. We use the calibrated value of parameters mentioned in the previous section.

Table 2.1 shows the top combined corporate tax rates of the list of our countries in 2012 from PWC (2013). We use these tax rates as the proportional tax rates on profits in our analysis. All these countries use territorial tax system in 2012 and exempt 95 or 100% of the income earned abroad from home country taxation.

2.5.1 UK corporate tax rate cut

In 2012, it was announced by the British chancellor of exchequer that corporate tax rate will be cut to 21% by April 2014 from its 2012 level of 24%. This tax cut was made to close the gap with some European tax havens like Ireland and Luxembourg and to reduce the amount of tax avoidance by multinational firms who would shift profits to these tax havens.

Table 2.2 demonstrates the results of this tax rate cut in UK according to our model. This table shows the percentage change for each country in welfare, $\hat{v}_n$, in real expenditure, $\hat{X}_n/\hat{P}_n$, and in real wage, $\hat{w}_n/\hat{P}_n$.

In this analysis, other countries keep their 2012 taxes and nothing else changes, so we can isolate the impact of British tax cuts. As expected, after this tax cut, UK gains at the expense of most of other countries by attracting more firms and production to its land. Extra economic activity more than enough compensates for lower tax rates and increases the total revenue of UK government.

When UK cuts tax rates, according to our model, the probability of multinational firms choosing UK as the location of production, or ψ_{il}, increases. This increase in the number of firms located in UK results in more varieties produced at home which reduces the price index that its citizens face.

Since we are assuming labor force is fixed for each country and can't move across borders, increased demand for labor in UK, resulted from increased production, will put upward pressure on wages. Increased wages will improve the welfare of UK consumers by increasing their real consumption and also improving UK's terms of trade.

Results show that the impact of UK tax cuts on other countries depends on the how much they trade with UK. Most of the countries see a reduction in their welfare as UK attracts more multinational firms at their expense. However, countries who trade more with UK, benefit from lower UK price index through their imports and from larger demand in UK through their exports compared to countries that trade less with UK.

As it could be seen in table 2.2, Germany and Belgium are the only countries whose welfare doesn't decline as a result of this change and that's because of the large size of their trade with UK with respect to the size of their economy. Rest of the countries' welfare and real wages decline.

2.5.2 Swedish corporate tax rate cut

Swedish government cut their corporate tax rates in 2012 from 26.3% to 22% to absorb investment and improve their competitiveness and job growth, Thomann (2014). This tax cut followed multiple reports indicating that Swedish tax base is suffering from large amounts of profit shifting by multinational firms to low tax countries.

Table 2.3 shows the aggregate effects of this tax cut in Sweden and rest of the countries. Results bear a lot of similarities to the results of tax cut in UK. Sweden gain around 0.5% in welfare and most of the other countries lose, except for Norway and Finland who have large trade volumes with Sweden compared to the size of their economies.

2.6 Conclusion

In this paper, we quantify the impact of corporate tax rates on the location choice of multinational firms and aggregate outcomes including the welfare of consumers. We create a multi-country general equilibrium model of trade and multinational production where each country applies a proportional corporate tax on the profit of firms producing there.

We calibrate the model for 2012 and use it to quantify the effects of actual tax cuts in UK and Sweden. These tax cuts attract more firms and economic activity to these countries and improve the welfare of consumers by up to 0.5% at the expense of other countries. These results show that tax cuts benefit these countries significantly.

Like any other analysis, ours comes with limitations. We obtain these results from a theoretical framework and their accuracy is limited by the modeling assumptions and simplifications that we have made. We are also abstracting from other taxes that each government collects from firms and individuals, like sales and income taxes. Including these taxes could impact our results to some extent.

Also, as mentioned earlier, we are abstracting from the issue of profit shifting of large firms to tax havens by manipulating their transfer price or other methods. This issue could impact the accuracy of our results as firms don't

necessarily keep their profit in the same place as their productions. By establishing tax haven operations, firms could reduce their foreign tax payments, so the corporate tax rates and their changes may not matter for them as much.

For future research, the list of countries could get limited to European union countries, so labor movement in response to tax rate changes could be included in the model. This movement of labor across countries can have important implications for the model and change the results significantly. We could also add a tax haven with zero tax rate to the list of the countries and give firms the option of profit shifting to this tax haven with certain costs. This will significantly enrich the current model and address the limitation mentioned above.

2.7 Tables

Country	**Corporate tax rate**
Italy	27.5%
France	34.4%
Germany	30.2%
Spain	30.0%
UK	24.0%
Austria	25.0%
Portugal	31.5%
Sweden	26.3%
Canada	26.1%
Belgium	34.0%
Finland	24.5%
Norway	28.0%
Czech Republic	19.0%

Table 2.1: Corporate tax rates in 2012

Country	Welfare	Real Expenditure	Real Wage
Italy	-0.02%	-0.1%	-0.01%
France	-0.01%	-0.09%	-0.01%
Germany	+0.01%	-0.01%	+0.008%
Spain	-0.02%	-0.07%	-0.01%
UK	+0.41%	+0.39%	+0.27%
Austria	-0.15%	-0.23%	-0.1%
Portugal	-0.15%	-0.25%	-0.1%
Sweden	-0.05%	-0.15%	-0.02%
Canada	-0.06%	-0.14%	-0.02%
Belgium	+0.002%	-0.04%	+0.001%
Finland	-0.14%	-0.21%	-0.05%
Norway	-0.13%	-0.21%	-0.09%
Czech Republic	-0.17%	-0.24%	-0.1%

Table 2.2: Effect of UK's tax cut in 2012 from 24% to 21%. Values are in proportional changes.

Country	Welfare	Real Expenditure	Real Wage
Italy	-0.08%	-0.1%	-0.05%
France	-0.04%	-0.06%	-0.02%
Germany	+0.001%	-0.001%	-0.001%
Spain	-0.07%	-0.09%	-0.05%
UK	-0.02%	-0.03%	-0.01%
Austria	-0.14%	-0.11%	-0.09%
Portugal	-0.12%	-0.13%	-0.1%
Sweden	+0.53%	+0.37%	+0.29%
Canada	-0.1%	-0.14%	-0.05%
Belgium	-0.05%	-0.04%	-0.02%
Finland	+0.04%	+0.01%	+0.01%
Norway	+0.04%	+0.01%	+0.01%
Czech Republic	-0.15%	-0.19%	-0.06%

Table 2.3: Effect of Sweden's tax cut in 2012 from 26.3% to 22%. Values are in proportional changes.

CHAPTER 3

FIRM ENTRY AND EXIT DURING A CRISIS: EVIDENCE FROM PORTUGUESE FINANCIAL CRISIS OF 2010-14

3.1 Introduction

A growing number of theoretical and empirical studies have been trying to understand the cyclical behavior of firm entry and exit. In this paper, we analyze the value of firms that enter and exit over the business cycle using firm level data from Portugal over the period of 2010-2014 Portuguese financial crisis.

This crisis was a result of Portugal not being able to repay its government debt after the great recession. Portugal's economy contracted 5.3% from 2010 to 2012 and unemployment rate rose to 16% in 2012. Eventually, IMF and European union agreed to a bailout worth 78 million Euros and Portugal underwent an adjustment program which included austerity measures and structural reforms (Reis (2015), Portugal (2015) and Gurnani (2016)). In this paper, we'll focus on the firm level aspects of this crisis.

We will use the methodology developed in Dias and Sarhangian (2018) to estimate the welfare value of each firm that enters or exits. According to this approach, the value of each firm is defined as the welfare loss in the home country after the firm exits the market for exogenous reasons. We can apply this method to firms that enter and exit to measure how much the firms that exit are worth compared to those that enter at different points of the business cycle. One advantage of this method is that it includes a general-

equilibrium, multi-country international trade structure and different sectors of the economy. As a result, the revenue share of the firm in both domestic and export markets, firms sector and patterns of comparative advantage all determine the value of the firm.

We find that, on average, firms that exit during the height of the crisis in 2010-12 are more valuable than firms who enter during these years and also they are more valuable than firms who exit during the recovery years. These result indicate that crises push more valuable firms out compared to the regular years.

There are many papers analyzing the cyclicality of entry and exit rates and also the characteristics of entering and exiting firms. Campbell (1998) shows that entry rates are correlated positively with output growth in US, meaning that they are pro-cyclical, but exit rates are counter-cyclical. Moreira (2016) finds that firms entering during recessions are not only smaller, they also remain smaller during their life cycle. Lee and Mukoyama (2015) use US Annual Survey of Manufactures to show that exit rates are almost equal for good and bad years, but entry rates are pro-cyclical and they decline significantly during recessions. They also observe that the relative productivity of entrants is higher in recessions compared to boom times, even though the relative productivity of exiting firms is almost constant over the business cycle.

Some other papers model the entry and exit dynamics. Clementi and Palazzo (2016) study the effect of entry and exit on the aggregate dynamics and find that they amplify and propagate the effects of aggregate shocks. They point out that entry rate is pro-cyclical, as opposed to exit rate that is counter-cyclical. Lee and Mukoyama (2008) include a cyclical entry cost in a general equilibrium dynamic model to explain entry and exit patterns in data. A

similar framework is build in Bilbiie et al. (2012) which includes an endogenous entry cost.

Our paper also relates to studies of crises in different countries. Sandleris and Wright (2014) for the Argentine Crisis of 2001 and Oberfield (2013) for the Chilean crisis of 1982 are two examples of these papers. They mostly focus on the decline of growth factor productivity in these countries and major contributors to this decline, while we study the value of firms pushed out of the market during crisis and the value of entering firms.

Since Melitz (2003), the extensive margin of trade and firm entry-exit has received a lot of attention in international trade literature. Recently, in a working paper, Hsieh et al. (2016) estimate that gains from entry-exit or "new" gains from trade for Canadian firms was negative after Canada-US Free Trade Agreement in 1980s. Our paper is related to this paper in the sense of having an international trade structure and considering welfare impacts of firm entry and exit, however we don't estimate the trade gains from entry-exit but welfare value of each entering or exiting firm.

3.2 Data

We use firm level data from Portugal between 2010 and 2015. Our dataset contains balance sheet variables, domestic and foreign sales and the value of domestic and foreign inputs used by the firms. Table 3.1 shows the number of firms entering and exiting the market and the rates of entry and exit. To calculates these statistics, we have omitted the firms that have zero sales.

Our statistics are in line with the results of literature, for example Clementi and Palazzo (2016). Entry rates are pro-cyclical, they decline during the

Year	Number of Entry	Number of Exit	Entry rate	Exit rate
2010	19303	21104	6.05%	6.62%
2011	22971	23164	7.24%	7.30%
2012	19849	20670	6.41%	6.68%
2013	24312	17310	7.87%	5.60%
2014	25114	16378	7.96%	5.19%
2015	25039	17073	7.76%	5.29%

Table 3.1: Entry and Exit statistics

crisis years of 2010-2012 and increase at the recovery years of 2014-2015, whereas the exit rates are counter-cyclical, they are higher during the crisis years and decline after the recovery starts.

3.3 Welfare Analysis

In this section, we estimate the welfare value of entering and exiting firms for each year in Portugal and rest of the world. According to the methodology developed in Dias and Sarhangian (2018), we estimate the value of each firm by calculating the percentage change in the welfare of consumers, if that firm's productivity drops to zero for exogenous reasons.
Table 3.2 exhibits the welfare value of all firms that enter or exit in each year. The absolute value of the entry and exit numbers show how much the welfare of consumers will decline if all the firms, entering or exiting, are removed and their factors of production are reallocated to other firms in the same sector and other sectors.

All numbers for Portugal, entry and exit, are negative indicating that overall value of both entering and exiting firms has been positive for Portugal every year and their removal will reduce the welfare of consumers. However, we see some positive numbers on the exit column of the rest of the world. These

Year	Entry Portugal	Exit Portugal	Entry ROW	Exit ROW
2010	-0.2369236	-0.8726862	-0.0002025	+0.00062980
2011	-0.2188702	-0.9899928	-0.0003386	+0.00063309
2012	-0.1650697	-0.5005393	-0.0004411	-0.00013802
2013	-0.1894232	-0.4066929	-0.0006636	-0.00013642
2014	-0.2641372	-0.2824458	-0.0004085	-0.00035653
2015	-0.2081749	-0.3741266	-0.0006155	+0.000002826

Table 3.2: Entry and Exit Welfare

numbers mean that the exit of these firms in Portugal increases the welfare in the rest of the world during some of the years. This happens because during these years most of the exiting firms are in comparative disadvantage sectors of Portugal and their exit increases the comparative advantage of the rest of world compared to Portugal. As a result, the welfare in the rest of world slightly increases in some of the years.

To adjust for the different entry-exit rates, we divide the welfare numbers by the number of entering or exiting firms in Portugal. Table 3.3 shows the number of entering firms, number of exiting firms, average welfare value of entering firms and average welfare value of exiting firms in Portugal for each year.

Year	# of Entry	# of Exit	Average value: Entry	Average value: Exit
2010	19303	21104	-1.22739E-05%	-4.13517E-05%
2011	22971	23164	-9.52811E-06%	-4.27384E-05%
2012	19849	20670	-8.31627E-06%	-2.42157E-05%
2013	24312	17310	-7.79135E-06%	-2.34947E-05%
2014	25114	16378	-1.05175E-05%	-1.72454E-05%
2015	25039	17073	-8.31403E-06%	-2.19133E-05%

Table 3.3: Average Entry and Exit Welfare

Our results, both total and average welfare values, show that the welfare value of entering firms is almost constant over the business cycle. However, the welfare value of exiting firms is higher during the height of the crisis, 2010-2012, compared to recovery years of 2014-2015. We also realize that

the welfare value of exiting firms is higher compared to the value of entering firms every year. This difference is much more emphasized in the years of 2010-2012 when crisis was affecting the economy much more negatively.

To gain more insight on the quality of entering and exiting firms, we calculate the share of the value added of entering and exiting firms in the total value added of all firms. Results are shown in table 3.4.

Year	Incumbents	Entrants	Survivors	Exiters
2010	99.53%	0.47%	98.82%	1.18%
2011	99.44%	0.56%	98.76%	1.24%
2012	99.58%	0.42%	99.37%	0.63%
2013	99.35%	0.65%	99.55%	0.45%
2014	99.22%	0.78%	99.50%	0.50%
2015	99.35%	0.65%	99.45%	0.55%

Table 3.4: Value added Shares

As shown in the table, exiting firms carry a larger share of total value added of all firm in 2010-2012 compared to later years when recovery starts. This is in line with the welfare table results where the exiting firms have larger welfare value at the height of the crisis. The value added share of exiting firms declines as recovery gradually starts from 2013.

The correlation coefficient that we obtain over time between the value added share and welfare value of exiting firm is 0.98. It shows that the value added share and welfare value of exiting firms are highly correlated and they are both higher in the crisis years. We find a much smaller correlation coefficient of 0.57 for entry.

3.4 Conclusion

Financial crisis of 2010-14 caused high unemployment, negative growth rates and high budget deficits in Portugal. In this paper, we use the methodology in Dias and Sarhangian (2018) and analyze the welfare value of firms that enter and exit during the crisis and estimate how much they are worth to the consumers.

We find that, on average and overall, firms that exit during the crisis time are worth more to the consumers compared to firms that exit during after the recovery starts. The welfare value of firms who exit during the crisis years is much higher than firms who enter, however these values are much closer during the recovery years. These results show that more valuable firms are pushed out during the downturns.

Since our framework includes a multi-sector international trade structure, our measure of firm's welfare value is affected by the sector of the firm and its export activities. Basically, revenue is not the only determinant of the welfare value of each firm, but where the firm sells to is also very important. Therefore, our analysis provides a more reliable measure of firm value than just using its revenue or productivity. However, in future research, a dynamic model can be developed to better measure how valuable the firms that exit during the downturns are for the consumers. This will help us better understand the negative impacts of economic crises.

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