10.14754/CEU.2018.12

THREE ESSAYS IN INTERNATIONAL TRADE

by

Franklin Okechukwu Maduko

Submitted to
Central European University
Department of Economics and Business
in partial fulfillment of the requirement for the degree of Doctor of Philosophy

Advisor: Miklós Koren

Budapest, Hungary

10.14754/CEU.2018.12
10.14754/CEU.2018.12

CENTRAL EUROPEAN UNIVERSITY
DEPARTMENT OF ECONOMICS AND BUSINESS

The undersigned hereby certify that they have read and recommend to the Department of Economics and Business for acceptance a thesis entitled **"Three Essays in International Trade"** by **Franklin Maduko**.
Dated: December 10, 2018

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
Chair of the Thesis Committee:

Botond Koszegi

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
Advisor:

Miklos Koren

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
Internal Examiner:

Gabor Bekes

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
External Examiner:

Harald Fadinger

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
External Member:

Balazs Murakozy

10.14754/CEU.2018.12

CENTRAL EUROPEAN UNIVERSITY
DEPARTMENT OF ECONOMICS AND BUSINESS

Author: **Franklin Okechukwu Maduko**
Title: **Three Essays in International Trade**
Degree: **Ph.D.**
Date: **December 10, 2018**

Hereby, I testify that this thesis contains no material accepted for any other degree at any other institution and that it contains no material previously written and/or published by another person except when the appropriate acknowledgement is made.

Signature of the author: ....

10.14754/CEU.2018.12

Abstract

This thesis consists of three single-authored chapters. Each chapter employs both theoretical and empirical methodologies to investigate a particular aspect of international trade.

Chapter 1

In this chapter, I study the effects of the reduction in import tariffs charged on EU imports in Hungary during the periods (1996-2003) on the efficiency of Hungarian manufacturing firms. Since, I do not observe firm-level output quantity, I propose a structural framework that enables me estimate quantity productivity from revenue data. This framework involves integrating the demand systems faced by a firm in both the foreign and domestic markets with the firm's production function, and by this, I derive a new structural estimable equation that estimates quantity productivity. Using a matched firm-product level datasets and product tariffs, and applying the structural methodology, I find that a 10 percentage point reduction in average tariffs faced by a firm raises firm level quantity productivity by 0.97 percent and revenue productivity by 2.1 percent. This large differences between revenue and quantity productivity implies that revenue productivity overstates the effects of trade liberalization and calls for re-evaluations of numerous studies that have attributed large efficiency gains to trade liberalization. In addition, I offer a more general framework that can be easily applied in estimating firm-level physical productivity from revenue data when firms sell in both domestic and export markets.

Chapter 2

In this chapter, I use a matched firm-product-destination dataset for manufacturing firms in Hungary and exploit the exogenous variations in the foreign demand addressed to a firm using an instrumental variable approach and a structural methodology to study the relationship between a firm's domestic and foreign sales while controlling for the firm's supply determinants. I find that a 10 percent exogenous increase in foreign sales leads to approximately 1.6 percent decrease in domestic sales. This finding suggests the presence of an increasing marginal cost of production, contrary to the assumption of constant marginal costs in most trade models. To shed some lights on the implications of our findings for aggregate welfare, I introduce an increasing marginal cost technology into a traditional "new" trade model, and show that liberalizing trade results to a new channel of reductions in potential welfare gains not accounted for in previous studies. Thus, it implies that constant marginal cost assumption in trade models is not innocuous. As increasing marginal costs is a consequence of capacity constraints at the firm level (Ahn

and McQuiod 2016), the findings provide support for concurrent policies that reduces trade barriers and eases capacity constraints in order to ensure the full realization of gains from trade.

Chapter 3

In this chapter, I ask the following questions: How does US exports in high technology sector react to a change in intellectual property rights (IPR) reforms in destination countries? What determines the industry sensitivity of exports to IPR reforms? To answer these questions, I build a partial equilibrium model where a profit maximizing firm in the North has acquired patents on its output and then, decides when and which countries to export. Countries are heterogeneous in their level of IPR regulation, imitation risk and economic size. The firm faces a trade-off between market expansion and market power. By exporting to all countries, the firm increases its sales and profit but faces the risk of imitation on its output which robs it of its market power. The model predicts that: strengthening IPR laws in countries in the South leads to increased exports especially in sectors with relatively longer product life-cycle length. However, this relationship is non-monotonic as products in sectors at the topmost distribution of product life-cycle length are less sensitive to stricter IPR reforms compare to sectors at the median. I use yearly panel datasets (1989-2006) consisting of US product-destination data, country-level IPR index and cross-sectional product life-cycle length data to test the predictions of the model. I find our empirical results is consistent with the predictions of the model. The results point to the importance of IPR policies in determining sectoral patterns of trade flows between countries.

10.14754/CEU.2018.12

Acknowledgements

This has been a long journey of five years and I am grateful to God and number of people who has made this work a reality. Firstly, I wish to thank my thesis supervisor Miklós Koren for his exceptional mentorship and guidance in all the projects I embarked upon during my doctoral studies. His assistance at availing me with some datasets, and his constructive feedback and suggestions made this thesis a reality. I am also eternally grateful to the my examiners, Gábor Békés and Harald Fadinger, for their prompt and very useful feedback and comments. I learnt a lot by reading and thinking through some of the comments. For this I say, thank you so much. I also wish to thank Attila Rátfai, Róbert Lieli, Ádám Szeidl, Alessandro de Chiara, and Arieda Muço for individual feedback I received from them after my presentation at the department's brownbag seminar. My academic visit to UCLA helped me at improving the first chapter of this thesis. For, this I am grateful to Nico Voigtländer for hosting me and providing me with valuable comments. To Central European University Budapest Foundation, I am very thankful for the research, summer school and travel grants awarded to me. These grants were instrumental to the completion of my thesis.

I am very indebted to my professors at the economics and business department of Central European University. Through several interactions with you all, classroom and research seminars, I became a more knowledgeable version of myself. I learnt how to decipher a good research question and how to proceed with providing answers to such questions. Special thanks to the administrative staff at the department most especially the former and current PhD coordinators (Katalin Szimler and Veronika Orosz) for their exceptional assistance at numerous times I reached out for clarifications and also for organizing the doctoral defense. To my PhD colleagues (too numerous to mention), thank you so much for the insightful discussions and feedback. I am grateful to Andras Vereckei for his help with prompt provision of micro datasets I used in some parts of this thesis and also for his willingness to assist in understanding the variables. István Szabó assisted me a couple times during my early days with data programming. I learned a lot from him, and for this, I am thankful.

I wish to express my sincere gratitude to Vladimir Mikhailov, Nóra Tatai, Surparna Das, Williams Iheme, Chinyelumdu Nwosu, Sanford Mba, and friends from CEU Christian fellowship for their encouragements. You were more like family than friends to me, and I am so grateful that I could count on you all. Last but not the least, I owe a lot to my parents and siblings for their inspiration, patience, kind prayers and best wishes towards the completion of my thesis. You are the best family I can ever wish for, and I am constantly overwhelmed by your love and support.

10.14754/CEU.2018.12

Contents

10.14754/CEU.2018.12

10.14754/CEU.2018.12

Chapter 1

Quality-Adjusted Productivity and The Effect of Trade Liberalization on Productivity

1.1 Introduction

This paper studies one of the central questions in the field of international trade: Does trade liberalization generate economic gains at the firm level? We focus on the impact of the gradual reduction of import tariffs charged on European Union (EU) imports in Hungary on Hungarian manufacturing firms' productivity during the periods (1996-2003) leading to Hungary's accension into the EU .

While a number of empirical literature (Fernandes (2007), Topalova and Khandelwal (2011), Trefler (2004) etc) have examined a similar question using data from a different setting, these papers typically rely on productivity estimates from a revenue production function as sales quantity is unobserved. In these studies, sales variable is deflated using an industry price index and then, used as the dependent variable in the productivity estimation. The main concern here, is that productivity estimates from deflated revenue have two shortcomings especially in industries with a large scope of product differentiation (Levinsohn and Melitz, 2002 and De Loecker, 2011). First, the coefficients of the inputs may be biased if the price error defined as the difference between a firm's price and the industry's price index is correlated with any production input. This price error is expected to be larger in industries with larger scope of product differentiation. Second, even if the biased is absent, the productivity estimates will reflect true productivity and components of unobserved prices and demand conditions which may over- or underestimate true productivity. These complexities casts some doubts on the preciseness of existing findings and thus, suggests the need for re-evaluations of papers that rely on productivity estimates from sales revenue data.

Our paper makes two contributions to this literature. First, we propose a novel productivity estimation framework that estimates quantity productivity from revenue data, thus overcoming the drawbacks from revenue productivity. The main difference between our framework and the one proposed in De Loecker (2011) is that we integrate both the domestic and foreign markets to the supply side. This is driven by the observation that over 40 percent of firm's in our data exports in each year. With an increase in import competition from the EU, firms may become more productive and simultaneously reduce their prices in the domestic market, resulting to lower revenue productivity[1]. This could go the other way since Hungarian firms also faced preferential export tariffs reduction with the EU during this period. This drop in variable trade costs could have increased the demand faced by Hungarian exporters, propelling them to raise their prices[2]. The consequence of this, is that revenue productivity will be overstated[3]. Thus, our framework suggests that integrating the domestic market while ignoring the export markets, as in De Loecker (2011), may overstate firm-level productivity. Second, we apply our methodology to study the effects of reduction in import tariffs[4] on EU imports on manufacturing firms' productivity in Hungary between the period 1996-2003. We estimate both revenue and our quantity productivity measure which we call *quality-adjusted productivity (QA productivity)* and study the impact of trade liberalization on these two measures of productivity. We find that a 10 percentage point reduction in import tariffs increases firm-level quantity productivity by 0.97 percent and revenue productivity by 2.1 percent (see column (3) and (7) in Table 1.5). Clearly, revenue productivity overstates the impact of trade liberalization on firm-level efficiency. Another key difference between our paper and existing studies is that we exploit the disaggregated nature of our dataset by mapping a firms' product to the import tariffs the product faces in the domestic market. We average the product tariffs faced by a firm across all products in each year. This average firm-level tariffs captures the import competition addressed to a firm in each period between 1996 to 2003. This unique feature of our data allows us to capture variations in average tariffs at the firm-level instead of industry-level variation commonly seen in the literature. Thus, we are able to control for industry-year fixed effects in our estimation. This is necessary in our setting for two reasons. First, since export and import tariffs are likely correlated at the industry-level (Trefler, 2004), the industry-year fixed effects, controls for the industry-level export and import tariffs at the 2-digit level. Second, It is possible that some industries were protected due to political lobbying or other unobserved considerations. Thus, our approach enables us control for

[1]Marin and Voigtländer (2013) finds that Chilean firms reduces their prices after the became more efficient.

[2]Firms could raise their prices due to increasing marginal costs, or simply because their average cost is lower than their competitors abroad. So firms would still be competitive with slightly higher prices.

[3] Marin and Voigtländer (2013) argues that the productivity gains from exporting around the period leading to Slovenia entry into the EU (De Loecker, 2007) may be due to increasing markups

[4]By import tariffs, we imply the tariffs faced by a manufacturing firm on its output. This tariff captures the import competition faced by a firm in its domestic market. This is different from the import tariffs on the imported inputs used in production by a firm.

unobserved time-varying industry effects which may bias our results.

Our new structural estimation equation consists of conventional variables (labour, capital, material inputs) and a proxy for unobserved firm-level prices- *domestic market share in its industry*. Before proceeding further with the analysis, we compare the productivity estimates from both measures across several trade tariffs episodes. Figure (1.2) shows a graph of the ratio of weighted-average revenue to quantity productivity for the period 1993-2007. Clearly, revenue productivity grows faster than quantity productivity during periods of massive trade liberalization. The slope of this ratio is slightly decreasing in periods (1993-1995) prior to the tariff reduction which implies an increase in quantity productivity, steeper in periods (1996-2003) during the tariffs reductions and steepest in periods after entry into the European union (2004-2007). The rising revenue productivity during periods of massive trade liberalization may reflects rising markups and not necessarily true efficiency gain or a combination of both. We also verify that our price proxy replicates similar pattern in studies that observe firm-level prices. In the spirit of Foster et al. (2008), we examine the correlation between our price proxy, revenue productivity and quality-adjusted productivity. While we find a strong positive correlation between our proxy for prices and revenue productivity, the correlation between the proxy and quality-adjusted productivity is negative, consistent with Foster et al. (2008) in their study for the US.

The mechanisms through which trade liberalization may affect productivity are numerous. First, increased competition from imports may force firms to be creative in eliminating inefficiencies and use inputs efficiently. However, it may reduce demand for domestic high-end output and thus impede the amount of domestic learning spillovers which may negatively affect productivity growth (Lucas Jr, 1993, Young, 1991, Stokey, 1991). Second, trade liberalization reduces the cost of imported inputs and may result to increased use of such inputs which obviously increases productivity (Halpern et al., 2015, Goldberg et al., 2010 etc). Third, liberalization may incentivise firms to invest in technologies that enhances productivity (Bustos, 2011, Goh, 2000). However, it may reduce these incentives if liberalization reduces the market share of firms.

We begin our analysis in section 1.2 where we present our simple empirical setup and derive a structural econometric equation for the estimation of quantity productivity from revenue data. We consider the demand side of a two country world - *home and foreign* with a representative consumer in each that faces a standard CES utility function and choose varieties to consume subject to a budget constraint. The usual demand system for each variety emerges which depends negatively on the price and positively on quality of the variety. On the supply side, we consider a firm which produces with a Cobb-Douglas technology, sells in the domestic market and then decides whether to export. The firm's problem is to choose prices in domestic and export markets (if it exports). We derive the total revenue that emerges in equilibrium and show how to recover physical productivity. Our physical productivity estimate is the conventional revenue productivity adjusted with the domestic market share of the firm within its industry. For industries where products are homogeneous (large elasticity of substitutiton which we denote by σ), our estimation equation collapses to revenue productivity equation.

In section 1.3, we present our data and discuss several cleaning procedures and restrictions on our sample. We use Hungarian manufacturing firm-level panel data which comes from three sources: (1) balance sheet data for the period 1993-2003 from Hungarian Tax Authority (APEH), (2) trade data for the period 1993-2003 assembled by Hungarian customs[5], (3) Product level import tariff data charged on imports from the EU for the period 1996-2003 from Hungarian trade ministry. The balance sheet data consist of firms classified at the NACE 2-digit industry level, and contains firm-level yearly variables such as total sales, exports, capital, labour and material inputs etc. The trade data consist of firm-level exports and import shipments to and fro specific countries at 10-digit combined nomenclature (CN-10). Our interests here is to identify products produced by each exporting firm. So we drop imports and exports information and redefine products at the HS 6-digit level. The tariff data with the EU is at the CN-10 digit level which we average to the HS6-digit level[6]. We also provide a detailed descriptive statistics on each of our datasets in the relevant subsections.

In section 1.4, we estimate our quality-adjusted and revenue productivity using standard proxy methods pioneered by Olley and Pakes (1996) and extended in Levinsohn and Petrin (2000) and Ackerberg et al. (2015) (henceforth OP, LP and ACF respectively). We recover the elasticity of substitution for each industry and perform a number of comparative analysis between quantity productivity and traditional revenue productivity estimates as already discussed above.

In section 1.5, we estimate the effect of the reduction in import tariffs charged on EU imports on the efficiency of Hungarian manufacturing firms. One of the main strengths of our methodology is that we construct variations in tariffs at the firm-level. By doing this, we are able to control for possible unobserved time-varying industry (NACE 2 digits) effects that jointly affect average industry tariffs and productivity. However, our analysis

[5] Hungary joined the EU in 2004, so we do not have access to firm-level import and export starting after 2003.

[6] We do this because the CN-10 classification for both exports and tariff is noisy in the sense that in some years, we do not observe some CN-10 tariffs which was observed in the previous year. In some cases, we observe new CN-10 not in the previous years. Also, firms often switch their main export product at the 10-digit level; this happens infrequently at 6 digits. This inconsistency is the main reason for aggregating at the HS-6. Békés et al. (2011) shows that CN-6 is equivalent to HS-6 using same Hungarian manufacturing firms data.

in this section poses three potential shortcomings. First, we focus on exporting firms as we do not observe the specific products sold by non-exporters. Nonetheless, we do not consider this a major concern since exporter's sales represent over 91% of the total sales of all firms in each year. Therefore, our findings could generalise to a case where the entire manufacturing firms are observed. Second, we only observe products sold in the export markets and are agnostic about whether exporters have different product mix in the export and domestic markets. If such patterns exist, we expect it to be more pronounced at a highly disaggregated level (CN-8 and above)[7]. Therefore, we match every HS6 product exported by a firm to its corresponding tariffs. Third, while our main framework was developed for single-product firms, we apply it to multi-product firms. This will likely overestimate productivity for multiproduct firms if productivity is strongly associated with producing multiple products[8]. Internalizing these potential shortcomings, we proceed with our analysis by restricting our data to periods between 1996-2003 as this was the period Hungary entered a gradual tariffs reduction agreement with the EU. We identify the tariffs faced by an exporter by computing the simple average of the tariffs on products the firm produced at each time period. We employ two empirical strategies. The first strategy is a direct method as in Fernandes (2007) where we estimate the effect of tariffs on productivity directly in a single production function estimation[9]. The second strategy which we called the two-step approach follows a non-parametric form where we start with estimating the productivity as residuals from a production function estimation (similar to section 4) and then we project the productivity estimates on tariffs while controlling for some variables of interest as discussed later. Our aim in this exercise are twofolds. First, we want to evaluate the effect of lowering tariffs on firm-level productivity and secondly, to show that this effects is over-estimated when using revenue productivity measures.

We sum up the discussions in section 1.6 and provide additional information and results in the appendix.

[7]According to the European commision webpage (ec.europa.eu/taxation_customs/business/calculation-customs-duties/what-is-common-customs-tariff/combined-nomenclature_en), HS-2 product "18" is described as *"Cocoa and Cocoa Preparations"*; HS-4 product "1806" is *"Chocolate and other food preparations containing cocoa"*, HS-6 "1806 10" is *Cocoa powder, containing added sugar or sweetening matter* and for CN-8 "1806 10 15" is *Containing no sucrose or containing less than 5 % by weight of sucrose ("including invert sugar expressed as sucrose) or isoglucose expressed as sucrose "*. Our point here is that peoduct mix across markets if it exists maybe be more pronouced at a finer level of disaggregation due to taste preferences across markets.

[8]In the appendix, we extend our framework to multiproduct firms. This introduces an additional parameter to the estimation equation (see equation 1.A.3) which captures the number of varieties in each period. We do not observe the number of varieties at the firm level in each period.

[9]For more details on motivation and identification, we refer the reader to Fernandes (2007).

1.1.1 Literature Review

We build on the vast and growing literature on production function estimation at the plant level. Starting with Olley and Pakes (1996) (OP) which shows how to control for the simultaneity bias when estimating production functions by relying on investments as proxy for unobserved productivity. Given the lumpy nature of investment data, Levinsohn and Petrin (2000) (LP) showed that material inputs (which are less lumpy) could be used as proxy for productivity in the Olley and Pakes (1996) framework. Their work have been extended by Ackerberg et al. (2015) (ACF) which argued that the coefficient of labor cannot be identified in the first stage of OP and LP framework and shows how to identify labor in the second stage. Other literatures have proposed an adjustment to this framework. For example, Bond and Söderbom (2005) have shown (for the Cobb-Douglas production function) that under the scaler unobservable assumptions in the LP and OP framework, using gross output function cannot identify coefficients of perfectly variable inputs without input price variation except further assumptions are imposed. Thus, they propose estimation of a value-added production function. De Loecker (2013) suggests including lagged export dummy in the productivity process of the OP and LP procedure as lag of export status may be correlated with lag of productivity. These literatures typically relies on deflating sales revenue with industry price index which poses a threat to identification of production inputs and may bias productivity estimates in industries with high scope of product differentiation. Relative to these literatures, we propose a new production function estimation equation that controls for unobserved prices and demand shifters.

Our paper is not the first to integrate the demand-side of the economy to the supply-side in estimating a production function. Klette and Griliches (1996) developed the framework to integrate the demand-side with the supply-side of the economy, thus, addressing the problems caused by deflated sales proxy for firm-level production function estimation in differentiated products. Their focus was on estimating the returns to scale and not productivity. Levinsohn and Melitz (2002) builds on this framework, to obtain and interpret credible estimates of productivity. They show that productivity estimates based solely on sales revenue is bias as it reflects price and demand shifters, however they offer no application to their procedure. De Loecker (2011) is the first to apply this methodology in the study of the effect of quota reduction on efficiency of Belgian textile manufacturers. Their estimating equation is a reduced form expression of deflated sales revenue on production inputs (capital, labour and materials), industry output, unobserved demand shifter and productivity. They recover the elasticity of substitution from the coefficient of industry output which they use to back-out quantity productivity from their reduced-form estimates of productivity. Their framework assumes that the unobserved demand shifter can be summarised by a product and sector fixed effect, a proxy for prices and an unobserved error term which they assume to be exogoneous. They exploit the multi-products nature of their data and constructs a proxy for prices which reflects the extend to which a firm is exposed to the rapid easing of quotas in the EU during the period 1994 to 2002. They find that their methodology predicts weaker effect of trade liberalization on firm-level productivity. Our paper offers a simpler framework similar to theirs. Unlike their framework, ours do not rely on estimates of the industry elasticity of substitution or precise observation of industry output variable to back out firm-level productivity. A key difference in deriving our structural equation is that we integrate the export market into our framework since most firms exports to markets with non-zero tariffs [10]. In a special case where we assume all firms are non-exporters, we show that our estimating equation is similar to De Loecker (2011). However, by allowing for exporting, we show that our estimating equation collapses to De Loecker (2011) with an additional term which reflects the firms' export intensity.

Our paper is also related to Rho and Rodrigue (2016). The main similarity is that both papers estimate a model-consistent productivity under the assumption that firms endogenously responds to idiosyncratic demand shocks in the foreign market. While their paper focuses on understanding the impact of investment on exporting, we focus on how increased import competition faced by firms affect firm-level quantity productivity. While theirs normalize domestic demand shocks to one, we assume it to be differential across firms and time. This is particularly important in our setting since our objective is to study the relationship between firm-level variation in domestic demand shocks addressed to them on their productivity. Demidova et al. (2012) uses a similar production function estimation as ours. While their paper introduces export demand shocks nonparametrically in their material function, we provide a structural model that incorporates both differential exports and domestic demand shocks addressed to a firm to its production function with the objective of estimating quantity productivity from revenue data. Besides, our focus is different from theirs. While they study the effects of the interaction between productivity and country-specific export demand shocks on a firm's export destination, we are interested in how import competition impacts productivity.

Our paper is also related to Foster et al. (2008) which investigates the distinction between quantity and revenue productivity. In their framework, they observed both physical output and sales revenue at the firm level in addition to input variables. They estimate quantity and revenue productivity and perform a number of comparative analysis be-

[10] This may not be a concern in De Loecker (2011) if Belgium textile manufacturers are not export-oriented

tween their estimates. One finding that emerges from their study is that the correlation between plant prices and revenue productivity is positive with a correlation coefficient of 0.16, however this correlation with physical productivity is negative with a coefficient of -0.54. The findings in our paper is consistent with theirs. Our proxy for prices is negatively correlated with quality-adjusted productivity and positively correlated with revenue productivity. The similarity between both findings support the notion that revenue productivity may reflect rising firm-level prices and also implies that domestic market shares of a firm within its industry is strongly correlated with unobserved prices.

A number of new and growing literature have proposed a new measure of firm-level productivity in an environment with very rich data. For example, Marin and Voigtländer (2013) constructs marginal costs of products within a plant using the methodology proposed in De Loecker and Warzynski (2012) and test for efficiency gains from exporting. Atkin et al. (2017) constructs different measures of productivity from a field experiment on rug manufacturers in Egypt. Relative to these papers, our measure provides a credible alternative in an environment without such rich data.

This paper is also related to the vast and growing literature studying the impact of trade liberalization on productivity of firms (Topalova and Khandelwal (2011)- Indian firms, Fernandes (2007)- Colombian firms, Lileeva and Trefler (2010)-Canadian firms, Bustos (2011)-Argentine firms, De Loecker et al. (2016) - Indian firms, Trefler (2004)-Canadian firms, among many). Most of these papers use either revenue productivity (Topalova and Khandelwal, 2011, Fernandes, 2007) or labor productivity (Trefler, 2004) and finds a positive effect of trade liberalization on productivity. We argue that using revenue productivity may overestimate the effect of trade liberalization and we introduce a methodology that corrects for this potential bias.

This work is also related to Khandelwal (2010). Both papers use market shares as proxy for quality conditional on prices[11] and investigates different questions. To our knowledge, this paper is the first to provide a general framework for estimating quantity productivity from sales revenue data in an environment where firms exports.

1.2 Empirical Framework

In this section, I start with a model of demand and supply side, derive the estimating equation of interest for single producers and discuss the advantages of my framework. In the appendix, I also show an extension of the framework for multiproduct producer

[11] Khandelwal (2010) assumes that firms produce choosing price and quality, while our setup assumes that firms are endowed with quality and choose price to maximize its profit, consistent with Johnson (2012) .

under some restrictive assumptions.

1.2.1 Demand

Consider a world consisting of two countries home h and foreign f and a representative industry with many firms producing differentiated goods. Our analysis is focused on firms in the home country. Consumers in both countries have the constant elasticity of substitution (CES) preferences with same industry elasticity of substitution between varieties denoted by $\sigma > 1$. Consumers in country $i = \{h, f\}$ spends R_i in nominal terms on varieties in the industry. A representative consumer in each country i maximizes its utility given by:

$$U_i = \left[\int_{\omega \in \Omega} \tilde{q}_i(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \quad \text{for } \; i \in \{H, F\} \tag{1.1}$$

We assume U_i to be differentiable and quasi-concave. The quantity of each consumed variety is denoted by $\tilde{q}_i(\omega)$ which is measured in units of utility. For each industry, I assume that all varieties are measured in similar physical units such that $\tilde{q}_i(\omega)$ can be seperated into a demand shifter $\zeta_h(\omega)$ which we call *quality* and physical units $q_i(\omega)$ such that $\tilde{q}_i(\omega) = \zeta_h(\omega) q_i(\omega)$. The product quality $\zeta_h(\omega)$ can be seen as a single dimensional metric of the representative consumer's valuation of product characteristics in one physical unit of the product (Johnson, 2012). Thus, product quality acts as a demand shifter for physical quantities. Changes in $\zeta_i(\omega)$ across time could result from either changes in the quality embodied from the good or changes in consumer's relative valuation of the product. For foreign consumers, we assume $\zeta_f(\omega) = \zeta_h(\omega)\nu_f$ such that $\nu_f \geq 0$ is the foreign demand shock. This allows for changes in idiosyncratic preferences for product ω across countries. Consumers in both countries are subject to the budget constraint: $\int_{\omega \in \Omega} p_i(\omega) q_i(\omega) d\omega = R_i$. Where $p_i(\omega)$ and R_i are the price of variety ω and income in country i respectively . This setup generates the usual demand system faced by each firm i as :

$$q_i(\omega) = \zeta_i(\omega)^{\sigma-1} \chi_i p_i(\omega)^{-\sigma} \tag{1.2}$$

Where $\chi_i = P_i^{\sigma-1} R_i$ is the aggregate level of demand in the sector in country i , this can be interpreted as the position of the demand curve common to all firms and $P_i = [\int_{w \in \Omega} \zeta_i(\omega)^{\sigma-1} p_i(\omega)^{1-\sigma} d\omega]^{\frac{1}{1-\sigma}}$ is a summary of the prices of all available varieties in an industry in country i. We assume that firms are small relative to the industry the belong so they have no power to exert any influence on this industry price index P_i and take it as given.

1.2.2 Supply

We assume that all firms j are heterogenous in their productivity levels A_j and produces a single variety j under monopolistic competition. To avoid the abuse of notations we henceforth denote j in place of ω such that $q_i(\omega) \equiv q_{ij}$. Firms produce with a Cobb-Douglas technology using labor L_j, physical capital K_j and material inputs M_j. We follow the literature and assume that labor L_j and capital K_j are predetermined (Halpern et al., 2015) and material is a perfectly variable input[12] and can be freely adjusted at any point in time. Firm $j's$ production function in the current period is:

$$q_j = A_j K_j^{\alpha_k} L_j^{\alpha_l} M_j^{\alpha_m}$$

where $A_j = exp(a_j + \mu_j)$ and μ_j is the measurement error and idiosyncratic shock to production. Our assumption on M_j implies that the total variable cost is given by :

$$TVC_j = q_j^{\frac{1}{\alpha_m}} A_j^{-\frac{1}{\alpha_m}} K_j^{-\frac{\alpha_k}{\alpha_m}} L_j^{-\frac{\alpha_l}{\alpha_m}}$$

Note here that we do not assume any specific marginal cost structure. Firms may export some of their output to the foreign market by paying a fixed export costs f_F which reflects additional cost incurred by doing business abroad. We assume that the price which exporters receive is different from that paid by foreign consumers such that $p^*_{jf} = p_{jf}\tau_j$, where $\tau_j > 1$ is the import tariff or shipping cost. Firm's problem is to maximize profits choosing prices in both domestic and foreign markets subject to the demand curve in equation (1.2). We can rewrite this problem as:

$$\max_{q_{jh}q_{jf}} \left\{ q_{jh}^{\frac{\sigma-1}{\sigma}} (\zeta_{jh}^{\sigma-1}\chi_h)^{\frac{1}{\sigma}} + \frac{q_{jf}^{\frac{\sigma-1}{\sigma}} (\zeta_{jf}^{\sigma-1}\chi_f)^{\frac{1}{\sigma}}}{\tau_j} - \frac{(q_{jh}+q_{jf})^{\frac{1}{\alpha_m}}}{A_j^{\frac{1}{\alpha_m}} K_j^{\frac{\alpha_k}{\alpha_m}} L_j^{\frac{\alpha_l}{\alpha_m}}} - f_h - f_f \right\} \tag{1.3}$$

This yields the price equation:

$$p_{jh} = \left(\frac{\sigma}{\sigma-1}\right)^V \left[\frac{1}{\alpha_m}(A_j K_j^{\alpha_k} L_j^{\alpha_l})^{-\frac{1}{\alpha_m}}\right]^V \zeta_{jh}^{1-\frac{V}{\alpha_m}} (\chi_h + \tau^{-\sigma}\nu_f\chi_f)^{\frac{V(1-\alpha_m)}{\alpha_m}} \tag{1.4}$$

Where $V = \frac{\alpha_m}{\alpha_m - \sigma(\alpha_m - 1)}$. Provided $\alpha_m \neq 1$, a change in the demand shifter has an effect on prices. We derive the firm-level domestic, foreign and total revenue that emerges from

[12] In literature on production function estimations, materials have been assumed as a perfectly variable input. See Ackerberg et al. (2015) and Levinsohn and Petrin (2000) for more details

this framework (see appendix) respectively below:

$$R_{jh} = Z^{V(\sigma-1)}(A_j K_j^{\alpha_k} L_j^{\alpha_l})^{\frac{V(\sigma-1)}{\alpha_m}} \zeta_{jh}^{\frac{V(\sigma-1)}{\alpha_m}} \chi_h(\chi_h + \tau_j^{-\sigma}\nu_{jf}^{\sigma-1}\chi_f)^{\frac{V}{\alpha_m}-1} \tag{1.5}$$

$$R_{jf} = Z^{V(\sigma-1)}(A_j K_j^{\alpha_k} L_j^{\alpha_l})^{\frac{V(\sigma-1)}{\alpha_m}} \zeta_{jh}^{\frac{V(\sigma-1)}{\alpha_m}} \chi_f \nu_{jf}^{\sigma-1}\tau_j^{-\sigma}(\chi_h + \tau_j^{-\sigma}\nu_{jf}^{\sigma-1}\chi_f)^{\frac{V}{\alpha_m}-1} \tag{1.6}$$

$$R_{jT} = \begin{cases} Z^{V(\sigma-1)}(A_j K_j^{\alpha_k} L_j^{\alpha_l})^{\frac{V(\sigma-1)}{\alpha_m}} (\zeta_{jh}^{\sigma-1}\chi_h)^{\frac{V}{\alpha_m}} & \text{if firm sells at home} \\ Z^{V(\sigma-1)}(A_j K_j^{\alpha_k} L_j^{\alpha_l})^{\frac{V(\sigma-1)}{\alpha_m}} \zeta_{jh}^{\frac{V(\sigma-1)}{\alpha_m}} (\chi_h + \tau_j^{-\sigma}\nu_{jf}^{\sigma-1}\chi_f)^{\frac{V}{\alpha_m}} & \text{if firm sells in both} \end{cases} \tag{1.7}$$

where T denotes total and $Z = (\frac{\sigma-1}{\sigma})\alpha_m$. Our aim in this exercise is to derive a production function equation which estimates quantity productivity from total revenue data. There are 3 unobservable variables in equation (1.7b) - $\zeta_{jh},\ \tau_j\ and\ \nu_{jf}$. We can reduce the unobservables by dividing equation (1.5) by (1.6)

$$\nu_{jf}^{\sigma-1}\tau_j^{-\sigma} = \frac{R_{jf}\chi_h}{R_{jh}\chi_f} = \frac{R_{jf}/P_{sf}^{\sigma-1}R_{sf}}{R_{jh}/P_{sh}^{\sigma-1}R_{sh}} \tag{1.8}$$

Equation (1.8) can be interpreted as the competitiveness of a firm in the export market relative to the domestic market. This relative competitiveness can be increasing due to either a decrease in the tariffs faced by a firm or an increase in the export demand. We substitute equation (1.8) in (1.7) and simplify to obtain:

$$\frac{(R_{jh} + R_{jf})}{P_{sh}} = A_j K_j^{\alpha_k} L_j^{\alpha_l} M_j^{\alpha_m} \zeta_{jh} \left(\frac{R_{jh}}{R_{sh}}\right)^{\frac{1}{|\sigma-1|}} \tag{1.9}$$

Denote $D_{jh} = \frac{R_{jh}}{R_{sh}}$ the domestic market share of the firm within its industry; $\frac{1}{|\sigma-1|}$ yields an estimate of the industry elasticity of demand. Taking logs of equation 1.9 and including a time subscript we derive:

$$\tilde{r}_{jt} = \alpha_l l_{jt} + \alpha_k k_{jt} + \alpha_m m_{jt} + \beta d_{jt} + ln\zeta_{jht} + a_{jt} + \mu_{jt} \tag{1.10}$$

Equation (1.10) is our new production function estimation equation, where $\beta = \frac{1}{|\sigma-1|}$ and all lower-case variables are in log terms. The demand shifter ζ_{jh} is unobserved, but positively correlated with domestic market shares d_{jt}[13]. Therefore, part (but not all) of

[13]Domestic market share is derived as: $\frac{r_h(\omega)}{R_h} = \zeta_h(\omega)^{\sigma-1}P_h^{\sigma-1}p_i(\omega)^{1-\sigma}$. This can be re-expressed as $ln\left(\frac{r_h(\omega)}{R_h}\right) = (\sigma-1)ln(\zeta_h(\omega)) + (\sigma-1)ln(P_h) + (1-\sigma)\left(Vln\left(\frac{\sigma}{\sigma-1}\right) + Vln\left[\frac{1}{\alpha_m}(A_j K_j^{\alpha_k} L_j^{\alpha_l})^{-\frac{1}{\alpha_m}}\right] + \left(1-\frac{V}{\alpha_m}\right)ln(\zeta_h(\omega)) + \left(\frac{V(1-\alpha_m)}{\alpha_m}\right)ln(\chi_h + \tau^{-\sigma}\nu_f\chi_f)\right)$. Taking the first-order condition with respect to $\zeta_h(\omega)$, we obtain $dln(D_{jh})/d\zeta_h(\omega) = [(\sigma-1) + (1-\sigma)(1-V/\alpha_m)]\zeta_h(\omega)^{-1} > 0$ for $0 < \alpha_m < 1$.

the variation in ζ_{jh} is captured by variations in the domestic market shares (d_{jt}). In addition, d_{jt} also captures variation in prices not related to product quality[14]. Note, α_l, α_k and α_m are structural parameters of the production function and the industry elasticity of substitution can be recovered from $\beta = \frac{1}{|\sigma-1|}$. In the following subsections, we compare our estimating equation 1.10 with standard revenue productivity equation and De Loecker (2011) quantity productivity equation.

1.2.3 Relationship with Revenue Productivity

We show here that the revenue-based measure of productivity is a special case of our measurement of productivity. In other words, our estimating equation (1.10) nests revenue-based productivity under the assumption of perfect substitution between varieties within an industry. As $\sigma \to \infty$, β tends to zero, so equation (1.10) can be re-written as:

$$\tilde{r}_{jt} = \alpha_l l_{jt} + \alpha_k k_{jt} + \alpha_m m_{jt} + \omega_{jt} + \mu_{jt} \tag{1.11}$$

where productivity $\omega_{jt} = a_{jt} + ln\zeta_{jht}$ is the revenue productivity. Clearly ω_{jt} is a combination of physical productivity and the demand shifter. Equation (1.11) implies that in an homogeneous goods sector, firms facing high demand can be misinterpreted to be more productive than firms facing low demand, consistent with Foster et al. (2016) that use firm-level data from an homogeneous goods industry in the US and finds that older firms face high demand but are less productive compared to younger firms that face low demand. This suggests that even in homogeneous goods sector, controlling for the demand shifter is imperative in estimating physical productivity.

1.2.4 Relationship with De Loecker (2011)

We also show the relationship between our framework and De Loecker (2011). From equations (1.5, 1.6 and 1.7), our estimating equation (1.10) can be expressed as:

$$\tilde{r}_{jt} = \underbrace{\beta_l l_{jt} + \beta_k k_{jt} + \beta_m m_{jt} + \beta_s q_{st} + \varepsilon^*_{jt} + a^*_{jt}}_{\text{de Loecker (2011)}} + \frac{1}{\sigma} ln\left(1 + \frac{R_{jf}}{R_{jh}}\right) + u_{it} \tag{1.12}$$

For exports sales equal to zero ($R_{jf} = 0$), we obtain equation (4) in De Loecker (2011). That is:

$$r_{jt} = \beta_l l_{jt} + \beta_k k_{jt} + \beta_m m_{jt} + \beta_s q_{st} + a^*_{jt} + \varepsilon^*_{jt} + u_{it}$$

[14] The price proxy d_{jt} reflects both output prices and quality, consistent with Khandelwal (2010) that instruments quality with market shares conditional on prices.

where $\beta_q = \frac{\sigma-1}{\sigma}\alpha_q$ for $q = \{l, k, m\}$; $\beta_s = \frac{1}{\sigma}$; $a^*_{jt} = a_{jt}\frac{\sigma-1}{\sigma}$ and $\varepsilon^*_{jt} = \frac{\sigma-1}{\sigma}\zeta_{jt}$. The variable $(1+\frac{R_{jf}}{R_{jh}})$ captures the competitiveness of a firm in the foreign market relative to its home market. If not controlled may overstate productivity for high export-oriented firms. Note that equation (1.10) is isomorphic to equation (1.12), we choose the functional form in (1.10) because of two reasons. First, we do not observe industry output quantity, and the second is its ease to estimate as we need not rely on estimates of the industry elasticity of substitution.

Before moving to the estimation procedure, I discuss the data sets and cleaning specifics, together with some descriptive statistics in the next section.

1.3 Data

In this section, we describe our data sources, cleaning procedure and present some descriptive statistics.

1.3.1 Data

Our data comes from 3 datasets. The first is production data which is a panel of the universe of Hungarian firms' balance sheet data for the period 1993-2003. The second is a panel of exports data consisting of firm-product and export destination information for the period 1993-2003[15]. The third is a bilateral product-level tariff data between Hungary and the EU for the period 1996-2003. We also complement this with data on producer price index by industry publicly available at the online database of Hungarian statistical office.

Production Data

The production dataset comes from Hungarian Tax Authority (APEH) and include balance sheet and income statement information such as net value of sales and exports, fixed assets, wage bills, costs of goods and material inputs, and average annual employment, among others. For the purpose of this paper, we focus on manufacturing firms[16] with at least one employee and delete observations from non-manufacturing firms and manufacturing firms with less than one employee. We drop observations for which total export sales is greater than total sales as we consider this a reporting error and we are unsure about how to treat these observations. We merge this data with industry producer price index (PPI) at the 2-digit NACE identifier and create new variables for deflated total

[15]Hungary joined the EU in 2004, and so we could not observe exports and destination data.

[16]In appendix, I describe the sectors we considered in this work.

sales, exports sales and material inputs using the PPI. We construct domestic sales by substracting exports from total sales. In the appendix, we discuss a number of data cleaning procedure and treatment of missing values for sales, capital, employment and material inputs. After the cleaning, the manufacturing sectors consist of 58550 unique firms and 269454 firm-year observations. Out of these, approximately 40% of firms exported at least once throughout our sample period. We classify these firms as exporters. Table (1.1) shows some descriptive statistics of the production data. We observe an increasing pattern for total sales, exports and material inputs thoughout the sample period. The fraction of exporters ranges between 0.42 to 0.54, however these exporter's share of total sales lies between 93% to 96% of total sales. This suggests that the impact of trade liberalization on exporting firms can be generalised to all firms considering the weight of exporter's sales in aggregate output. In column (9), we show that the average annual growth of wage per worker increased over the time period studied with mild decline in some periods. Overall, the observed patterns are consistent with existing studies.

Since the domestic market share of a firm within its industry is crucial in this work, we describe the patterns of this variable over time. We proceed by computing the fraction of domestic sales within an industry attributed to the top 1%, 5% and 10% of firms in each year. We then summarise its distribution across industries in table (1.2). For example under Top 1%, in 1993, the minimum across industries for the fraction of domestic market sales attributed to the top 1% of firms within an industry is 20%, the maximum is 38.5% and the median is 29%. This implies that in the median industry, the top 10%, 5% and 1% of firms contributed 73.5%, 60.5% and 29% of total domestic sales in 1993. This pattern is consistent across the years in our data. The results implies that the domestic sales within an industry is heavily concentrated in very few number of large firms - *superstar firms* using the parlance in Mayer and Ottaviano (2008). The efficiency of such firms may be overstated if revenue productivity is used as our measure of firm-level efficiency[17].

Trade Data

This dataset comes from Hungarian statistical Office. It is assembled from customs declarations filled out when exporting or importing. It consists of a complete set of firm-level transactions on export and import shipments in Hungary at a highly disaggregated level (Combined Nomenclature-10). That is, we observed the range of products exported by a firm, the export destination, quantity and sales value . We also observe firm-level imports, the source country, quantity and purchase value for same period. The total

[17]By using quantity productity as the measure of efficiency, Foster et al. (2016) showed that older firms have higher demand but are less productive when compared with younger firms which typically have lower demand.

Table 1.1: Summary Statistics of Production Data

Year	Average Employment	Total Sales	Exporters Share	Total Exports	No. of Firms	Ratio of Exporters	Material Input	Wage Growth%
1993	53	10.71	0.94	2.44	13185	0.44	1.06	-
1994	54	12.19	0.94	2.91	15810	0.43	1.37	-4.03
1995	39	13.07	0.94	3.53	17668	0.42	1.93	-14.55
1996	34	10.12	0.93	3.28	19681	0.42	2.21	-10.28
1997	33	10.97	0.93	4.11	20982	0.43	2.91	-1.07
1998	32	12.01	0.93	4.83	23493	0.42	3.78	0.23
1999	31	15.29	0.95	5.52	24283	0.42	4.42	6.25
2000	30	16.15	0.96	6.39	25414	0.43	5.71	5.11
2001	38	14.76	0.95	6.84	19094	0.54	6.69	37.76
2002	36	19.90	0.96	8.03	20136	0.53	7.47	18.36
2003	34	21.51	0.96	9.27	21154	0.52	8.24	2.15

Total sales, exports and materials are aggregate in trillions of HUF. Exporters share is the fraction of of total sales attributed exporters. Wages growth is the year-by-year growth of average wage/worker expressed in percentages.

number of observations is 12,117,483. Since we are not interested in imports, we keep only the data on exports which amounts to 2,466,408 observations[18]. Table (1.3) show a summary statistics of the trade data. We see that the largest fraction of Hungarian manufacturing exports goes to the EU during the period covered in our data. This is also true for Hungarian imports (Békés et al., 2011). Between 73% to 79% of Hungarian manufacturing export destination is the EU. This implies that the EU is Hungary's biggest trading partner during the period 1996-2003. The second export destination are a group of countries consisting mainly of central and eastern european countries (see table notes below the table).

Tariff Data

Our tariffs dataset comes from Hungarian trade office. The data consists of raw files of a highly disaggregated (CN-10) product tariffs charged on EU imports, bilateral product tariffs with members of Central European Free Trade Association (CEFTA) and, tariffs charged on other Central European countries including Israel and Turkey during the period 1996-2003. This tariffs capture the differential exposure of Hungarian products to different tariffs with the EU and other countries. I aggregate the tariffs with the EU by taking simple averages at the HS-6 level for each year. Column (6) of table (1.3) shows the average import tariffs charged on EU imports. Clearly, tariffs are reducing during the period leading to Hungary's entry into the EU. Average tariffs fell by over 75% between

[18]We follow the basic cleaning detailed Békés et al. (2011). Detailed stylized facts about both datasets are contained in their paper.

Table 1.2: Summary Statistics For Domestic Market Share

	Distribution of Domestic Market Shares								
	Top 1%			Top 5%			Top 10%		
Year	Min	Med	Max	Min	Med	Max	Min	Med	Max
1993	0.201	0.291	0.385	0.439	0.605	0.786	0.591	0.735	0.871
1994	0.217	0.274	0.485	0.459	0.635	0.818	0.595	0.746	0.888
1995	0.216	0.300	0.568	0.518	0.632	0.787	0.649	0.766	0.889
1996	0.208	0.310	0.541	0.475	0.630	0.786	0.625	0.759	0.881
1997	0.180	0.302	0.607	0.480	0.618	0.830	0.630	0.753	0.899
1998	0.233	0.345	0.604	0.505	0.617	0.816	0.644	0.754	0.889
1999	0.211	0.317	0.565	0.511	0.593	0.782	0.657	0.734	0.875
2000	0.161	0.335	0.728	0.485	0.585	0.857	0.625	0.713	0.912
2001	0.168	0.310	0.493	0.449	0.543	0.794	0.625	0.713	0.912
2002	0.170	0.310	0.479	0.474	0.558	0.763	0.623	0.687	0.864
2003	0.167	0.304	0.465	0.480	0.552	0.775	0.633	0.696	0.860

Notes: This table shows the distribution of domestic market shares across periods in our data. In each industry and in each year, I construct the fraction of total domestic sales attributed to the Top 1%, 5% and 10% firms. For each year, I show the range (min and max) and median of this value across industry for top 1%, 5% & 10% firms

1996-2003[19]. In figure (1.1) we plot the average import tariffs (in percentages) with the EU and Group 2 countries. The figure shows a strong positive co-movements between both tariffs. It also suggests that any of these tariffs can be used as a measure of trade liberalization. Since Hungary's biggest trading partner is the EU, we choose the tariffs with the EU in our analysis.

Data Merging

We use our data in the following order:

Step 1: We estimate a variant[20] of the quality-adjusted and revenue productivity for each NACE-2 digit industry level using the balance sheet data for the entire period[21] and save the estimated productivity measures and industry elasticities. We then conduct a number of comparative analysis between the quality-adjusted and traditional revenue productivity measures.

Step 2: In the second part of the paper, we study the effect of trade liberalization on the productivity of exporting firms[22]. We start by aggregating the trade data at the

[19] Hungary joined the EU in 2004 so tariff drop to zero. However we do not observe the exports to any destinations and so we restrict the second part of the analysis to period between 1996-2003

[20] See section 4 for the estimation strategy and motivation

[21] We purposely extend the balance sheet data to 2007 to show some patterns after Hungary's entry in the EU. See Figure (1.2) and the following discussions.

[22] Our focus on exporting firms is because we do not observe the products sold by non-exporting firms

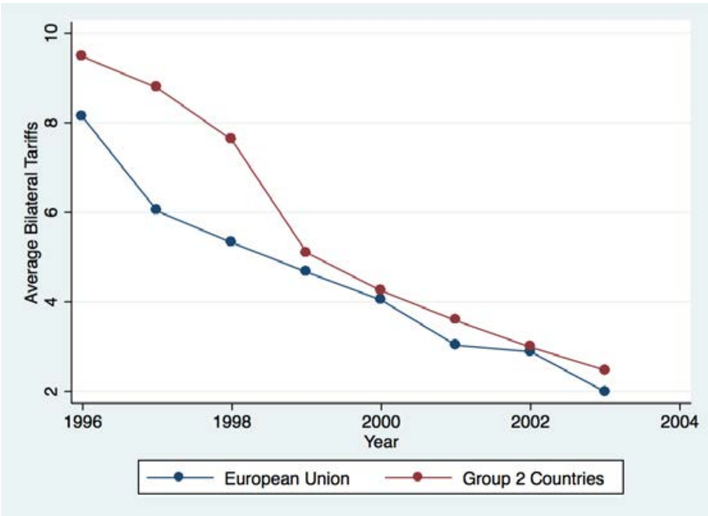
10.14754/CEU.2018.12

Table 1.3: Share of Hungarian Exports Across Different Destinations

Year	European Union	Group 2 Countries	United States	Other Countries	MeanTariff with EU(%)
1996	0.73	0.12	0.04	0.15	8.13
1997	0.76	0.10	0.03	0.13	6.03
1998	0.77	0.10	0.05	0.12	5.32
1999	0.79	0.09	0.06	0.09	4.67
2000	0.78	0.08	0.05	0.07	4.04
2001	0.78	0.09	0.05	0.08	3.03
2002	0.79	0.09	0.04	0.08	2.89
2003	0.77	0.11	0.03	0.09	1.99

This table shows the shares of Hungarian manufacturing exports across several destinations. European Union includes all countries that were part of the EU between the period 1996-2003 including Norway, Switzerland and Liechtenstein. Group 2 countries consist of the following: Czech Republic, Slovakia, Slovenia, Romania, Israel, Turkey, Estonia, Bulgaria, Latvia, Lithuania, Croatia and Poland. Other countries consist of every other countries not listed here.

Figure 1.1: Bilateral Tariffs



See notes below Table (1.3) for a list of countries under Group 2

HS-6 digit level and then, we merge our data in step 1 (using unique firm-year identifiers) with the trade data containing products and export destinations. Our interest here is to identify the products produced and exported by a firm. So I drop the destination information. Some firms have zero exports in the balance sheet data and positive exports in the trade data. These firms are assumed to

and so we cannot match our tariff data to these firms. We also do not think that our results will be largely sensitive to this data limitation if we had observe products from non-exporting firms because exporting firms account for over 95% of total sales in the economy during the periods of trade liberalization between Hungary and the European Union.

be intermediaries (Ahn et al., 2011) that help other firms to facilitate trade. There are other firms with positive exports in the balance sheet data but do not appear in the trade data. These are likely to be firms that use intermediaries for exporting. We drop these two types of firms.

Step 3: In the tariff data, we consider only import tariffs charged on EU imports. Since the tariff data starts from 1996, I dropped years between 1993 to 1995 in the merged data in Step 2 and merge it with our tariff data using year and HS-6 product code identifiers. Our new data ranges from 1996-2003 . We compute the tariffs faced by each exporting firm in each year by taking averages of the tariffs of each products it exports in a given year. Finally, we average over the number of HS-6 digit products in each given year for each firm. This leaves us with 39128 observations and 11038 unique firm identifiers. Each observation in this new data represents a firm in a given year , its average tariffs with the EU and other firm level characteristics.

Step 4: During the late nineties, a large number of firms were part of the supply chain for large firms in the EU, thus domestic sales may not matter to them. These export platforms are pronounced in the auto manufacturing industry and may have little presence in other industries . Since we do not observe these firms in the data, and in order to address this potential concern, we create a sub-sample from the sample described in Step 3 by excluding firm's in *Motor vehicles, trailers and semi-trailers* and *Other transport equipments* industries (NACE 2 industry 34 and 35), and firms with over 70% of export share from our sample. This new subsample consists of 27829 observations and 9071 unique firm identifiers. This will be our main sample. We also report the results for the full sample in the appendix.

1.4 Estimation Strategy

In this section, I describe the estimation procedure and identification that provides estimates of productivity, industry elasticity and coefficients of the production function. Our procedure relies on the proxy methods developed in Olley and Pakes (1996) and extended by Levinsohn and Petrin (2000) and Ackerberg et al. (2015). The main estimating equation is given by:

$$\tilde{r}_{jt} = \alpha_l l_{jt} + \alpha_k k_{jt} + \alpha_m m_{jt} + \beta d_{jt} + a_{jt} + ln\zeta_{jht} + \mu_{jt} \tag{1.13}$$

All variables are as defined in section 1.2. Our goal here is to obtain consistent estimates of the firm-level productivity. Since we do not observe the demand shifter ζ_{jht}, we need to construct a variable which approximates for ζ_{jht}. We argue that the variation in demand addressed to a product will depend on availability of substitutes. Since trade liberalization increases the net number of varieties in an industry (Melitz, 2003), ζ_{jh} will reflect a firm's exposure to the prevailing trade policy[23]. We follow similar reasoning as in De Loecker (2011) by approximating ζ_{jh} with an industry dummy α_s, year dummy α_t, average tariffs faced by a firm $\bar{\tau}_{jt}$ and an unobservable firm-specific demand shock $\tilde{\zeta}_{jht}$ which I assume to be independent and identically distributed (iid) across firms over time. That is:

$$\zeta_{jht} = \alpha_s + \alpha_t + \rho\bar{\tau}_{jt} + \tilde{\zeta}_{jht}$$

The highly disaggregated multi-product nature of our export data makes it possible to construct each producer's exposure to trade policy in each time period. Import tariffs might be correlated with export tariffs addressed to a firm in the EU market, thus violating our distributional assumption on $\tilde{\zeta}_{jht}$ and introducing some bias to our results. To address this concern, we control for industry-time dummies in some specifications instead of a separate industry and time fixed effects. This controls for any time-variant industry effects that maybe correlated with firm level characteristics. This includes average industry export tariffs, endogeneity from trade policy etc. We then rewrite our main estimating equation as:

$$\tilde{r}_{jt} = \alpha_l l_{jt} + \alpha_k k_{jt} + \alpha_m m_{jt} + \beta d_{jt} + a_{jt} + \alpha_s + \alpha_t + \rho\bar{\tau}_{jt} + \mu^*_{jt} \tag{1.14}$$

To study the effect of trade liberalization on productivity, we can estimate equation (1.14) directly or we employ a two-step method where we estimate $\tilde{r}_{jt} = \alpha_l l_{jt} + \alpha_k k_{jt} + \alpha_m m_{jt} + \beta d_{jt} + a_{jt} + \mu_{jt}$ and recover the productivity estimates a_{jt} in a first step and then regress the recovered productivity on average tariffs $\bar{\tau}_{jt}$ whilst controlling for some covariates in the second step. We provide a detailed discussion on this in section 5.

One of our interests in this paper is to compare the estimated quality-adjusted productivity with revenue productivity across several periods prior to joining the EU and after entry. However, our data poses some restrictions to using equation (1.14) for this purpose. As already mentioned, we do not observe firm-level products for the period prior to the trade policy (1993-1995) and subsequent periods to entry into the EU (2004-2007) for all the firms. This makes it impossible to estimate productivity from equation (1.14) for the entire dataset. For the sake of a comparative analysis of quality-adjusted productivity

[23] This reasoning is consistent with De Loecker (2011) that approximates the unobserved demand shifter with a product dummy, a product group dummy, average exposure of a producer to EU quotas and an i.i.d. demand shock

with revenue productivity across several trade policy eras, we estimate quality-adjusted productivity from the equation: $\tilde{r}_{jt} = \alpha_l l_{jt} + \alpha_k k_{jt} + \alpha_m m_{jt} + \beta d_{jt} + a_{jt} + \mu_{jt}$ and revenue productivity from $\tilde{r}_{jt} = \alpha_l l_{jt} + \alpha_k k_{jt} + \alpha_m m_{jt} + a_{jt} + \mu_{jt}$. This estimation is the first step of the two-steps method. We estimate a separate production function for each NACE 2-digit manufacturing sector borrowing insights from Ackerberg et al. (2015)[24].

Our dependent variable is the firm-level sales revenue data deflated by NACE 2-digit industry-specific price indices[25] and we also deflate other nominal variables using same price indices. Similar to Ackerberg et al. (2015) procedure, I specify an endogenous process for productivity which depends on lagged productivity[26]. The law of motion of productivity is assumed to follow a first-order markov process as defined below:

$$a_{jt} = f(a_{jt-1}) + \xi_{jt} \tag{1.15}$$

where ξ_{it} is the innovation term. This specification ensures that we control for any time-invariant effects that may be correlated with unobserved productivity and inputs. The innovation term ξ_{it} is by OP/LP assumption uncorrelated with the firm's lagged choice variables.

We commence by assuming that materials m_{it} is directly related to unobserved productivity, labor input and our proxy for price and demand shifter- *domestic market shares.* Specifically, as assumed in OP/LP, capital in period t is determined through its choice of investment in period $t-1$(i.e. k_{it}=g(k_{it-1}, i_{it-1})), and as in ACF, l_{jt} is chosen either in period t, $t-q$ (such that $0 < q < 1$) or t. The crucial thing here is that material inputs is chosen conditional on l_{it}. What is new here is that we introduce a new variable to the ACF framework by assuming that the firm observes its domestic demand in either period

[24] As already discussed in the literature review of this paper, Ackerberg et al. (2015) is an extension of OP/LP procedure. Specifically, they argue that labor elasticity can be identified in the first stage of OP/LP under 3 restrictive data generating process (DGP) namely: (1) a case where i.i.d. optimization error in l_{it} (after m_{it} or i_{it} have been choosen) and not in m_{it} or i_{it} (2) a case where i.i.d. shocks to the price of labor or output after i_{it} or m_{it} is chosen but before l_{it} is chosen, (3) in the case of OP procedure, labor is non-dynamic and chosen at $t-q$ $(0 < v < 1)$ as a function of productivity in period $t-v$ ω_{it-v} while i_{it} is chosen at t. Their main contribution is to identify labor in the second stage of OP/LP.

[25] In unreported specifications, I test for the robustness of our results by estimating a value-added production function where m_{jt} do not enter the estimating equation. This is because Bond and Söderbom (2005) have shown (for the cobb-douglas function) that under the scalar unobservable assumption, the procedure in ACF, LP and OP using the gross output production function cannot identify coefficients of perfectly flexible inputs without input price variation except further assumptions are imposed. Infact, Gandhi et al. (2011) shows that both the gross output production function and value-added production function could still suffer from these identification issues and have proposed a new identification strategy that solves this problem.

[26] We highlight that De Loecker (2013) emphasis the importance of including exporting in the endogenous productivity process if the aim is to estimate efficiency gains from exporting. They also suggest inclusion of investment and the interaction between investment and exporting. We are not interested in efficiency gains from exporting and our data do not contain variables on investment.

t or $t-q$ before choosing its material inputs. In otherwords, material inputs is chosen conditional on $k_{jt}, l_{jt}, d_{jt}, a_{jt}$ [27]. This gives rise to the function of material inputs as:

$$m_{jt} = g_t(k_{jt}, l_{jt}, d_{jt}, a_{jt}) \tag{1.16}$$

This relies on the assumption that input demand is monotonically increasing in productivity under monopolistic competition [28]. With the monotonicity assumption, I can invert equation (1.16) and derive a function that proxies for productivity as:

$$a_{jt} = g_t^{-1}(k_{jt}, l_{jt}, d_{jt}, m_{jt}) = h_t(k_{jt}, l_{jt}, d_{jt}, m_{jt}) \tag{1.17}$$

The estimation consists of two stages as in Ackerberg et al. (2015) except for the fact that I obtain both demand and supply parameters in the second stage. In the first stage of the procedure, we estimate the equation of the form:

$$\tilde{r}_{jt} = \phi_t(k_{jt}, l_{jt}, d_{jt}, m_{jt}) + \mu_{it}$$

where $\phi_t(k_{jt}, l_{jt}, d_{jt}, m_{jt}) = \alpha_k k_{jt} + \alpha_l l_{jt} + \alpha_m m_{jt} + \beta d_{jt} + h_t(m_{jt}, k_{jt}, l_{jt}, d_{jt})$. In principle, none of the input variables can be identified in the first stage. We compute $\hat{\phi}_t(.)$ from first stage estimation where $h_t(m_{jt}, k_{jt}, l_{jt}, d_{jt})$ is proxied by a third-order polynomial function of its components.

In the second stage, we provide moments to identify the parameters of interest after obtaining the innovation term. We commence by using $\hat{\phi}_t(.)$ and together with initial guess of the coefficient vector $\boldsymbol{\alpha_z} = \{\alpha_k, \alpha_l, \alpha_m, \beta\}$ and for any other candidate vector of $\tilde{\boldsymbol{\alpha}}_{\boldsymbol{z}}$, productivity is computed as:

$$a_{jt}(\tilde{\boldsymbol{\alpha}}_{\boldsymbol{z}}) = \hat{\phi}_t(.) - (\tilde{\alpha_k} k_{jt} - \tilde{\alpha_l} l_{jt} - \tilde{\alpha_m} m_{jt} - \tilde{\beta} d_{jt})$$

We use our productivity process (equation 1.15) to recover the innovation term ξ_{jt} by a non-parametric regression of $a_{jt}(\tilde{\boldsymbol{\alpha}}_{\boldsymbol{z}})$ on its own lag $a_{jt-1}(\tilde{\boldsymbol{\alpha}}_{\boldsymbol{z}})$. We define the moment condition below and iterate over candidate vector $\tilde{\boldsymbol{\alpha}}_{\boldsymbol{z}}$

$$\boldsymbol{E}\left\{ \xi_{jt}(\tilde{\alpha_k}, \tilde{\alpha_m}, \tilde{\alpha_m}, \tilde{\beta}) \begin{pmatrix} k_{jt} \\ l_{jt-1} \\ m_{jt-1} \\ d_{jt-1} \end{pmatrix} \right\} = 0 \tag{1.18}$$

[27] We also checked for the case where market shares are identified in the first stage of Ackerberg et al. (2015), and we obtained similar estimates

[28] De Loecker (2011) verifies that this assumption hold for the case where the demand side is integrated in the production function estimation

Thus equation (1.18) states that for the optimal $\tilde{\boldsymbol{\alpha}}_{\boldsymbol{z}}$, the innovation term ξ_{it} is uncorrelated with our instruments $(k_{jt}\ l_{jt-1}\ m_{jt-1}\ d_{jt-1}\ )'$. With the estimates of the coefficients for every industry, I compute the firm-level productivity as $\hat{a}_{jt}$:

$$\hat{a}_{jt} = \tilde{r}_{jt} - (\hat{\alpha_l} l_{jt} + \hat{\alpha_k} k_{jt} + \hat{\alpha_m} m_{jt} + \hat{\beta} d_{jt}) \tag{1.19}$$

Table (1.9) in the appendix shows the parameter estimates for each manufacturing industry in our sample. We easily recover the elasticity of substitution of each industry from $\hat{\beta} = \frac{1}{|\sigma - 1|}$ and report them in Table (1.9). We also estimate revenue productivity using similar procedure as above. The only difference with our previous estimation procedure is the exclusion of domestic market shares in the productivity estimation. Table (1.10) in the appendix shows the parameter estimates for this case.

From Table (1.9) and (1.10), we find that in most industries, the coefficients of l_{jt}, k_{jt} and m_{jt} are smaller for quantity productivity estimates when compared to that for revenue productivity. For example in NACE-2 sector 16, the coeffficient of l_{jt}, k_{jt} and m_{jt} for quantity productivity estimation is 0.656, 0.185 and 0.034 respectively. Compared to revenue productivity, we obtain 0.988, 0.307 and 0.145. This is not surprising, since domestic market shares is likely to be positively correlated with both inputs and outputs, thus overstating the input coefficient[29]. Our framework suggests that revenue productivity estimating equation is misspecified. However, if our specification is misspecified, then the market share is upwards bias and input coefficient are downwards bias.

1.4.1 Properties of the Productivity Estimates

In this section, we conduct two comparative analysis between our estimated quality-adjusted productivity and revenue productivity to highlight differences and similarities between these two measures. Our main objective here is to show that firm-level domestic market shares within its industry provides a good proxy of unobserved prices and would replicate similar patterns as prices. It thus, suggests the importance of controlling for unobserved prices and demand shifters in productivity estimation.

Comparison Between Quality-Adjusted and Revenue Productivity

Equation (1.9) suggests that rising firm-level prices may overstate revenue productivity. Increasing firm-level prices is likely to occur in our data during the period we study for two reasons. First, we found in Chapter 2, the prevalence of increasing marginal cost

[29] Assuming α_m^{True} is an unbiased estimate of the material input, and if d_{jt} is unobserved and positively correlated with material inputs m_{jt} and output r_{jt}, then our estimated coefficient for material inputs in revenue production function can be expressed as: $\alpha_m = \alpha_m^{True} + \beta \frac{cov(d_{jt}, m_{jt})}{var(m_{jt})}$. Clearly, $\alpha_m > \alpha_m^{True}$.

structure. This implies that scaling up production to address foreign demand comes at a cost of higher marginal cost of production, which is reflected in the prices. Second, even if the marginal cost structure was constant, firms may scale up their prices in the EU market and still be competitive due to lower labor cost in Hungary compared to the EU. Therefore, one would expect revenue productivity to increase faster than quality-adjusted measure during the periods Hungary entered the tariff easing agreement with the EU and fastest when it joined the EU. This implies that during periods of trade liberalization, revenue productivity maybe overstated[30]. We compare the ratio (denoted by R_t) of weighted-average revenue productivity to the quality-adjusted productivity across the periods in our data. We proceed by defining this ratio as:

$$R_t = \frac{\sum_s F_{st}\omega_{st}^C}{\sum_s F_{st}\omega_{st}^N} \tag{1.20}$$

Where $\omega_{st}^i = \sum_j F_{jst}\omega_{jst}^i$ for $i = \{C, N\}$, $F_{jst} = \frac{sales_{jst}}{sales_{st}}$ is the weight of a firm's total sales within its industry at a given time and $F_{st} = \frac{\text{industry sales}}{\text{total sales}}$ is the ratio of industry to total sales in period t. Here s, j, t, C, N denotes sector, firm, time, revenue and quality-adjusted productivity respectively. We extend our data slightly to span between 1993-2007, to highlight the specific patterns in R_t after Hungary's entry into the EU[31]. Figure (1.2) shows the graph of R_t across the periods between 1993 to 2007. We create 3 partitions on the graph in order to elucidate the evolution of R_t over 3 major trade policy episodes. The first partition is the period 1993-1995 prior to the tariff easing agreement. During this period, we observe that this ratio is slightly decreasing which suggests that productivity growth was driven by physical productivity and not demand factors. The second partition are the periods between 1996- 2003 for which Hungary entered a pre-accession agreement with the EU which involved a reduction in trade tariffs. We observe a sharp rise in this ratio, which may imply that average revenue productivity grew faster than quality-adjusted productivity. One possible explanation is that firms raised prices during this period leading to a steeper rise in revenue productivity than quality-adjusted productivity. The third partition are the periods between 2004-2007 for which Hungary joined the EU and tariffs were set to zero. We observed a much steeper rise in this ratio, which we argue is due to rising demand/prices from zero tariffs in the EU market. We also show that the observed slope is significant by running a trend regression of this ratio across the periods in our data. We report this estimate in the appendix Table (1.12).

[30]This argument is consistent with De Loecker (2011), that studies the effect of quota protection on productivity for Belgian textile manufacturers. They find that abolishing all quotas increases revenue productivity by 8% as against 2% for their corrected productivity.

[31]This extension is only for this comparative analysis. We apply the estimation method already decribed on this extended sample.

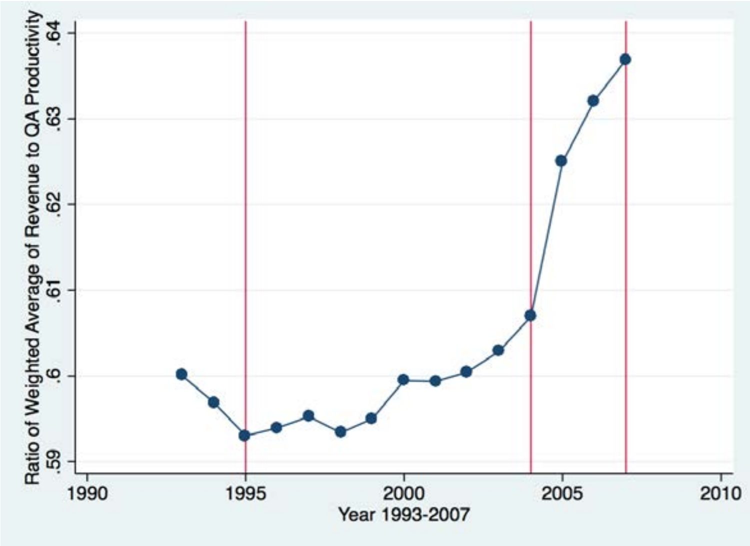


Figure 1.2: Graph of Ratio Revenue/Quality-Adjusted TFP Across Periods

Overall, these patterns are not surprising since revenue productivity reflects unobserved demand/prices conditions. In section (5), we focus on the periods between 1996-2003 of which we have product-specific information of each firm and the tariffs faced by these products in the EU, we then study the effects of trade liberalization on both measures of productivity.

Additional Properties of the Estimates

We now test for additional relationship of our estimates to confirm that our measures replicate existing patterns in the literature. We focus on correlations and standard deviation. Table (1.4) presents the summary statistics for quality-adjusted productivity, revenue productivity, domestic market share (our proxy for price), sales revenue and capital. We remove industry-year fixed effects from each variable in this summary statistics to ensure that aggregate industry intertemporal movements do not drive our results[32]. The first important point to note is that the two productivity measures are strongly correlated and exhibits high dispersion within industry-year. Unsurprisingly, revenue TFP has a higher dispersion than our Quality-Adjusted TFP measure. This is because the former is a combination of the later and firm-level prices. Firms may have responded to decreased trade barriers with the EU differently through changes in their prices, thereby causing more dispersion in revenue productivity than quantity productivity.

We also observe, a strong positive correlation between revenue productivity and domestic market share (price proxy). This is not surprising because prices are expected to

[32]Our results are also consistent to the case where we do not control for industry-time FE (see Table 1.13)

Table 1.4: Summary Statistics For Productivity Measures, Sales and Capital

	Correlations				
	Quality-Adjusted Productivity	Revenue Productivity	Sales Revenue	Capital	Domestic Market Shares
Quality-Adjusted Prod.	1.00				
Revenue Productivity	0.59**	1.00			
Sales Revenue	0.22**	0.41**	1.00		
Capital	0.01**	0.08**	0.74**	1.00	
Domestic Market Shares	-0.07**	0.39**	0.90**	0.64**	1.00
	Standard Deviations				
	0.58	0.98	1.97	2.31	1.93

Notes: This table shows the correlation and standard deviations of our firm-level variables using the truncated samples (1993 - 2003). All variables are in logs. We remove sector-year fixed effects from each variable prior to computing the statistics. $**$, $*$ and † are 1%, 5% and 10% significant levels respectively.

have a strong positive correlation with revenue productivity. Interestingly, we observe a negative correlation between our quality-adjusted productivity and domestic market shares, consistent with more productive firms having lower marginal costs and charging lower prices. This results are consistent with the findings in Foster et al. (2016) for the United States. By comparing large and small firms, their paper reports that older firms have larger demand (thus market shares) and lower physical productivity when compared with younger firms which typically have lower demand. The strength of the negative correlation is weaker than that in Foster et al. (2008). This is either because our price proxy is noisy and does not perfectly capture variations in prices or because we use different datasets.

Finally, we observe that sales has a stronger correlation with revenue TFP than it has with quality-adjusted TFP consistent with Foster et al. (2008) which is unsurprising since revenue TFP reflects prices and demand conditions. In Table (1.13) in the appendix, we repeat the same exercise in Table (1.4) for same variable but without removing the sector-year fixed effects. We find the results to be very similar. In conclusion, by using firm-level datasets for Hungary and a model-driven proxy for prices, our results are similar to existing findings for the US.

1.5 Effects of Trade Liberalization on Productivity

In this section, we study the impact of reduction in tariffs charged on imports from the EU on firm level productivity during the period between 1996 and 2003[33]. Due to some data limitations, we focus on firms that exported directly at least twice during the period

[33]Hungary joined the EU in 2004 and from this period, all tariff was set to zero.

studied. We merge the tariff data to the products exported by each firm at the HS-6 level and construct a measure of tariffs faced by each firm for each year during the period of our study by taking simple averages of the tariffs on the products exported by the firm. Our data limitation poses three potential shortcomings. First, we do not observe the product mix of non-exporters so we cannot match our tariff information to non-exporters. However, we do not consider this an issue as total sales attributed to exporting firms ranges between 93% to 96% of total sales attributed to all firms during the period 1996-2003 studied (see table 1.1)[34]. Second, we observe products exported by exporting firms but we do not know whether exporters have different product mix in the domestic and foreign markets. This is clearly not a concern if products mix in domestic and foreign markets are different at a very disaggregated level (HS-6 and above)[35]. If firms sell different product (at HS-4 or below) mix in the export and domestic markets, then our measure of firm-level exposure to trade liberalization with the EU may be bias. Third, while the framework we developed in section 2 is for single product firms, we apply it to also multiproduct firms. Though we showed how our framework extends to multiproduct firms under some restrictive but standard assumptions (See appendix A), we do not apply this extension due to the limitations on our data as we do not observe the number of varieties in a firm across time. This will likely overestimate productivity for multi-product firms. Thus, we remind the reader about these caveats in the interpretation of our results. We compare the impact of trade liberalization on quality-adjusted and revenue productivity and examine whether foreign-owned firms benefit more or less from trade liberalization compared to domestic firms.

1.5.1 Estimation Strategy

As already discussed in Section 4„ I employ two estimation strategies- *two-steps strategy* and *direct method*. In what follows, I describe these strategies in detail. In the first step of the two-steps strategy, I seperately estimate the quality-adjusted and revenue productivity using the methods described in Section 4. The key difference is that I pull all firms from every industry together into a single estimation and control for industry and time fixed effects. Industry dummies control for any industry specific components that maybe jointly correlated with production inputs and output, and time dummies controls for aggregate demand components that may affect material demand. I also control for

[34]Some of these exporters use intermediaries for exporting since we observe some of these exporters in the Balance sheet data but do not observe them in the trade data (Ahn et al. (2011) and Bai et al. (2017)). We drop these set of firms since we do not observe their product mix in the export market.

[35]For example if a firm sells HS-8 product 66022021 in the domestic market and product 66022022 in the international market and if both tariffs varies, this is obviously not an issue because both tariffs are the same at our level of aggregation HS-6.

importers dummy as being an importer may be jointly correlated with material inputs and productivity.

In the second step, I project the recovered productivity estimates against the tariffs faced by each firm. While the quality-adjusted productivity allows the productivity response to be isolated from the demand response, the revenue productivity does not since it captures both price and demand variations. If prices are rising during trade liberalization, it is natural to expect productivity gains to be higher in revenue productivity. Before proceeding to the regression equation, we remind the reader about the underlying assumption that the tariff setting process is exogenous to the firm. This assumption is plausible given that the chances of a single firm in Hungary to influence trade decisions at the EU level is quite slim.

The second stage involves a regression of the form:

$$\omega^i_{jt} = k + \rho\bar{\tau}_{jt} + \alpha_{st} + \beta X_{jt} + \epsilon_{jt}, \quad i \in \{C, N\} \tag{1.21}$$

where we now denote productivity by ω^i_{jt}, α_{st} is an industry time fixed effect, $\bar{\tau}_{jt}$ is average tariffs, and X_{jt} are controls such as lagged productivity or ownership dummy. Our main coefficient of interest is ρ which measures the effects of tariff cuts on productivity. Since $\omega^C_{jt} = \omega^N_{jt} + (p_{jt} - P_{sht} - \zeta_{jht})$, equation (1.21) implies that regressing revenue productivity on tariffs relies on the strong assumption that firm-level tariffs are uncorrelated with prices. This clearly overstates the effect of tariffs on revenue productivity[36] and sheds some light on the importance of integrating the demand system in production function estimation if quantity data is unobserved. We include industry-year dummies to control for any industry-level time-variant heterogeneity that are simultaneously correlated with tariffs charged on imports from EU and productivity. Such heterogeneity may include industry level tariffs charged on Hungarian exports in the EU market, or endogeneity from organized industry lobbying for preferential protection etc. In the estimation, we use either contemporaneous or lagged tariff variables.

The second estimation strategy involves a direct method similar to Fernandes (2007) where we pool data across all industries and estimate the effects of tariffs cuts on productivity in a single estimation equation. We reintroduce the demand shifter ζ_{jht} into the productivity equation and treat it non-parametrically by approximating it by industry

[36] To see this more clearly, by using revenue productivity in 1.21, the estimating equation takes the form:

$$\omega^N_{jt} + (p_{jt} - P_{sht} - \zeta_{jht}) = k + \rho\bar{\tau_{jt}} + \alpha_{st} + \beta X_{jt} + \underbrace{\gamma(p_{jt} - P_{sht} - \zeta_{jht}) + \epsilon^*_{jt}}_{\epsilon_{jt}}$$

Therefore $\rho = \rho^{true} + \gamma\frac{cov(\bar{\tau}_{jt}, p_{jt})}{var(\bar{\tau}_{jt})}$. Since $cov(\bar{\tau}_{jt}, p_{jt}) < 0$ and ρ^{true} is expected to be negative, then we clearly see that ρ overstates the effects of tariffs on productivity.

dummies α_s, year dummies α_t and average tariffs $\bar{\tau}_{jt}$, faced by a firm in each year and an i.i.d. exogenous demand shock $\tilde{\zeta}_{jt}$ such that the productivity equation becomes:

$$\tilde{r}_{jt} = \alpha_l l_{jt} + \alpha_k k_{jt} + \alpha_m m_{jt} + \beta d_{jt} + a_{jt} + \alpha_s + \alpha_t + \rho\bar{\tau}_{jt} + \mu^*_{jt} \tag{1.22}$$

where $\mu^*_{jt} = \mu_{jt} + \tilde{\zeta}_{jt}$ is the zero-mean shocks that are uncorrelated with the regressors. Export tariffs faced by Hungarian firms in EU markets may be correlated with import tariffs and may bias our estimate of ρ. Since, we do not observe such export tariffs, we control for industry-time fixed effects in some specifications. By doing this, we implicitly assume that the industry-time dummies capture the industry-level export tariffs in the EU market, and that this tariff approximates for firm-level export tariffs. It is also possible that importing intermediate inputs is correlated with material demand or firms that imports more faces lower tariffs. Since importing is strongly correlated with productivity (Halpern et al., 2015), we control for importers dummy non-parametrically to ensure that this channel does not contaminate our estimates.

To estimate revenue productivity, we exclude the domestic markets share in a similar equation as equation (1.22). Estimation is similar to the procedure described in Section (4) and proceed in the usual two steps. The only difference is that the material demand function depends on an addtional term $\bar{\tau}_{jt}$. That is, $m_{jt} = g_t(k_{jt}, l_{jt}, d_{jt}, a_{jt}, \bar{\tau}_{jt})$ and increases monotonically with productivity conditional on k_{jt}, l_{jt}, d_{jt} and $\bar{\tau}_{jt}$. Thus, we can express productivity as an inverse function of the observables as $a_{jt} = h_t(k_{jt}, l_{jt}, d_{jt}, m_{jt}, \bar{\tau}_{jt})$ and our revenue equation takes the form:

$$\tilde{r}_{jt} = \phi_t(k_{jt}, l_{jt}, d_{jt}, m_{jt}, \bar{\tau}_{jt}) + \alpha_s + \alpha_t + \mu_{jt}$$

where $\phi_t(.) = \alpha_l l_{jt} + \alpha_k k_{jt} + \alpha_m m_{jt} + \beta d_{jt} + \bar{\tau}_{jt} + h_t(k_{jt}, l_{jt}, d_{jt}, m_{jt}, \bar{\tau}_{jt})$ is approximated by a third order polynomial in k_{jt}, l_{jt}, d_{jt}, m_{jt}, $\bar{\tau}_{jt}$ in the first step estimation. In the second step we use similar markov process for productivity as in equation (1.15) and moment conditions in equation (1.18) to identify the coefficients of capital, labor, material inputs and domestic market shares and augment it with an additional moment condition $E(\xi_{jt}(.)|\bar{\tau}_{jt-1}) = 0$ since tariffs is assumed to be exogenous.

1.5.2 Estimation Results

We present our findings for Table (1.5), (1.6) and (1.7) using both contemporaneous and lagged average tariffs. It is important to note that the expected sign of ρ is negative if trade liberalization with the EU increases productivity. We present the results for the direct approach for both quality-adjusted and revenue productivity in Table (1.5).

Columns (1) to (4) presents the estimates for QA productivity, and columns (5) to (8) presents that for revenue productivity. Our preferred specification is column (3) and (7) where we control for year, industry and importer's dummies. Our results imply that a 10 percentage point reduction in tariffs is associated with an increase in firm-level productivity by 0.97 percent when QA productivity is used. However, same 10 percentage point reduction in tariffs is associated with revenue productivity by 2.1 percent. This pattern is consistent even when we control for industry-time dummies (columns 2 and 6), foreign ownership dummy (columns 4 and 8) and when we do not control for importers dummy (columns 1 and 5). Our findings is inline with the results in De Loecker (2011), that while trade liberalization increases physical productivity, its effect is overstated when revenue productivity is used as the measure of efficiency.

We present the results from the two-steps approach (equation (1.21)) in Table (1.6) and (1.7) for QA and Revenue Productivity respectively. We use both contemporaneous (columns 1-2) and lagged tariffs (columns 3-7). In our preferred specification (column 5 of Table (1.6)), the estimates suggest that a 10 percentage points reduction in tariffs is associated with a rise in quality-adjusted productivity by 0.53 percent. This estimated effect rises to 0.68 percent if revenue productivity was used instead (column 5 of Table 1.7), a rise by over 20 percent. If firms are eliminating internal inefficiency as a result of increased competition, we should expect higher efficiency gains from domestic firms than from foreign firms. This is because foreign firms are already exposed to foreign competitions and may have eliminated most inefficiencies prior to the trade policy. In column 6 of both Table 1.6 and 1.7 , we interact tariffs with a dummy that takes the value of 1 if the firm is a foreign firm and 0 if otherwise. Our estimates in column 6 of Table (1.6) implies that a 10 percentage points reduction in tariffs is associated with an increase in QA productivity by 0.59 percent for domestic firms, and 0.13 percent for foreign firms. Column 6 of Table (1.7) presents the same analysis using revenue productivity, the estimates imply that a 10 percentage points reduction in tariffs is associated with an increase in revenue productivity by 0.76 percent for domestic firms and 0.20% for foreign firms. This results suggests that efficiency gains from trade liberalization is weaker for foreign-owned firms compared to domestic firms. Similar to the previous cases, we observe this effect to be stronger. Overall, our estimates are highly significant and similar in magnitudes to the ones reported in Topalova and Khandelwal (2011) and Fernandes (2007).

We conduct a number of robustness checks to test the sensitivity of our results to a slightly modified specification and data restrictions. In the previous analysis (Table 1.6, 1.7) robust standard errors were clustered at the industry level. So, we repeat the analysis with robust standard errors clustered at the firm level and report the result in the appendix Table (1.14), we find our results to be similar. Second, we drop the importer's

dummy in the first-step estimation of the two-step approach, and our results remain unchanged as reported in Table (1.16) of the appendix. Finally, we use the full sample which contains firms in the automobile industry and firms with over 70% share of exports in their total sales, and report the estimates in the appendix Table 1.15. The results remains unchanged and consistent with our two-step approach results.
In summary, our results suggest the presence of true efficiency gains from trade liberalization and that standard measures overstates productivity response to trade liberalization. This indicates that controlling for unobserved prices result to closer measures of true efficiency gains from trade liberalization.

Table 1.5: Estimating the Effects of Trade Liberalization on Productivity

	Direct Method							
Dep. var:	QA Productivity				Revenue Productivity			
Log Sales	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Capital	0.040***	0.038***	0.038***	0.035***	0.048***	0.047***	0.047***	0.044***
	(0.000)	(0.002)	(0.001)	(0.002)	(0.000)	(0.001)	(0.001)	(0.001)
Log Labor	0.117***	0.115***	0.117***	0.122***	0.161***	0.162***	0.161***	0.165***
	(0.004)	(0.004)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)
Log Materials	0.483***	0.456***	0.477***	0.468***	0.837***	0.836***	0.833***	0.830***
	(0.000)	(0.004)	(0.000)	(0.000)	(0.001)	(0.004)	(0.001)	(0.005)
Tariffs	-0.109***	-0.140***	-0.097***	-0.064***	-0.219***	-0.235***	-0.211***	-0.187***
	(0.001)	(0.007)	(0.002)	(0.005)	(0.000)	(0.005)	(0.002)	(0.005)
Log Domestic MS	0.429***	0.460***	0.431***	0.435***				
	(0.000)	(0.001)	(0.000)	(0.000)				
Importers dummy			0.079***	0.067***			0.059***	0.051***
			(0.000)	(0.000)			(0.001)	(0.000)
Foreign-Owned				0.104***				0.079
				(0.000)				(0.001)
Year FE	Yes	No	Yes	Yes	Yes	No	Yes	Yes
Industry FE	Yes	No	Yes	Yes	Yes	No	Yes	Yes
Industry Year FE	No	Yes	No	No	No	Yes	No	No
Observations	27829	27829	27827	27807	27829	27829	27827	27807

Notes: This table reports the results of the effect of tariff reductions on firm-level productivity employing the direct approach. Foreign is a dummy that takes the value 1 if a firm is over 50% foreign owned and 0 if otherwise. I exclude firms in industry 34 and 35. (That is: "Motor vehicles, trailers and semi-trailers" and Other transport equipments) and firms with export sales greater than 70% of total sales to ensure that our results are not driven by export platform firms. Bootstrap standard errors are reported in parentheses. $*$, $**$ and $***$ indicates 10%, 5% and 1% significance. MS=market share

1.6 Conclusion

In this paper, we provide new evidence on the effect of trade liberalization on manufacturing firm's productivity in Hungary. By exploiting the import tariff reduction charged on imports from the EU during the periods (1996-2003) leading to Hungary's EU accession, we make important contributions to the literature.
First, we propose a new structural econometric equation for estimation of quantity productivity from sales revenue data. Our framework integrates the demand-system in the domestic and foreign market with the supply-side, which makes it possible to estimate the impact of tariff reduction on quantity productivity of Hungarian manufacturing firms.

Table 1.6: Estimating the Effects of Trade Liberalization on Productivity

Dependent Variable:	Quality-Adjusted Productivity						
	Two-Steps Approach						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariffs	-0.115***	-0.129***					
	(0.012)	(0.015)					
Lagged Tariffs			-0.108***	-0.050*	-0.053*	-0.059**	-0.026***
			(0.016)	(0.029)	(0.026)	(0.027)	(0.008)
Lagged Productivity				0.646***	0.644***	0.644***	0.102***
				(0.017)	(0.017)	(0.017)	(0.011)
Foreign x Lag Tariffs						0.046***	
						(0.014)	
Importers dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	No	No	No	Yes
Industry-Year FE	No	Yes	No	No	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	No	No	No
Industry FE	Yes	No	Yes	Yes	No	No	No
Observations	27827	27827	19442	19442	19442	19433	19442
R-squared	0.132	0.163	0.093	0.532	0.546	0.546	0.275

Notes This table reports the results of the effect of tariffs cut on firm-level productivity. Foreign is a dummy that takes a value=1 if firm is foreign-owned and 0 if domestic or state-owned. I excluded firms in industry 34 and 35 (i.e. "Motor vehicles, trailers and semi-trailers" and Other transport equipments) and firms with export sales more than 70% of its total sales to ensure that our results are not driven by export platform firms. In column 1-7 robust standard errors are clustered at the industry level in parentheses. $*$, $**$ and $***$ indicates 10%, 5% and 1% significant levels.

Table 1.7: Estimating the Effects of Trade Liberalization on Productivity

Dependent Variable:	Revenue Productivity						
	Two-Steps Approach						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariffs	-0.164***	-0.177***					
	(0.012)	(0.015)					
Lagged Tariffs			-0.160***	-0.065**	-0.068**	-0.076**	-0.029***
			(0.018)	(0.030)	(0.027)	(0.029)	(0.010)
Lagged Productivity				0.638***	0.635***	0.635***	0.101***
				(0.018)	(0.018)	(0.018)	(0.012)
Foreign x Lag Tariffs						0.057***	
						(0.018)	
Importers dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	No	No	No	Yes
Industry-Year FE	No	Yes	No	No	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	No	No	No
Industry FE	Yes	No	Yes	Yes	No	No	No
Observations	27827	27827	19442	19442	19442	19433	19442
R-squared	0.138	0.168	0.096	0.519	0.533	0.533	0.280

Notes This table reports the results of the effect of tariffs cut on firm-level productivity. Foreign is a dummy that takes a value=1 if firm is foreign-owned and 0 if domestic or state-owned. I excluded firms in industry 34 and 35 (i.e. "Motor vehicles, trailers and semi-trailers" and Other transport equipments) and firms with export sales more than 70% of its total sales to ensure that our results are not driven by export platform firms. In column 1-7 robust standard errors are clustered at the industry level in parentheses. $*$, $**$ and $***$ indicates 10%, 5% and 1% significant levels.

We introduce this framework to overcome some potential estimation bias associated with estimating productivity from sales revenue because we do not observe output in our data. We also compare our productivity estimates across several trade policy eras and show that revenue productivity grew faster than physical productivity during periods of massive trade liberalization in Hungary.

Our highly disaggregated datasets enable us overcome potential endogeneity concerns (such as unobserved industry lobbying[37] or domestic policies) in similar studies. While most related studies identify tariffs faced by a firm at the 3- or 4-digits industry level, our unique dataset ensures that we identify tariffs at the firm-level. Therefore, we control for time-varying industry characteristics while exploiting the variation in average firm-level tariffs on productivity. This is particularly important for identification in our setting because the tariffs cuts is part of the prerequisites to join the EU. It is likely that industry-specific domestic policies that are correlated with productivity were simultaneously implemented.

Second, our results imply that tariff reduction has a strong and negative effects on firm productivity, even after controlling for unobserved firm-fixed effect, time-varying industry effects and general economic conditions that affects all firms. This effect is stronger when we use revenue productivity as our measure of efficiency compared to when quality-adjusted productivity is used. In addition, we find that this effect is weaker for foreign firms when using quality-adjusted productivity compared to when revenue productivity is used. The intuition is that foreign firms have experience with international competitions and may have eliminated internal inefficiencies prior to trade liberalization. Therefore, tariff reductions may have induced rising markups rather than true productivity gains for foreign-owned firms. Overall, this suggests that revenue-based measure of productivity overstates the impact of trade liberalization, consistent with the literature (De Loecker, 2011).

Our proxy for unobserved prices in the production function equation is the firm's domestic market share. We show that this proxy exhibits some of the empirical properties of prices in studies that observed firm level prices. For example, we find that our price proxy has a strong positive correlation with revenue productivity and a negative correlation with quality-adjusted productivity, consistent with Foster et al. (2008) that finds similar patterns of correlation for observed firm-level prices, quantity and revenue productivity using data from the US. This correlation also suggests that firms with large demand are less productive than firms with smaller demand. Thus, revenue productivity leads to a misinterpretation of this relationship, consistent with Foster et al. (2016) that

[37]See Mitra et al. (2002) and Goldberg and Maggi (1999) for empirical findings on industry lobbying for trade protection in a developing and developed country respectively. See Grossman and Helpman (1994) for theoretical findings

finds that older firms face larger demand than younger firms and these older firms are less productive than younger firms when quantity productivity is used.

We do not investigate the underlying mechanisms behind the productivity gains due to trade liberalization, but existing studies points to the direction of imported inputs (Halpern et al., 2015), imported machinery (Koren and Csillag, 2017), and managerial strategy (Bloom et al., 2015). Further work on firm-level mechanisms would be an interesting direction to explore.

Appendix

Appendix 1.A Extension to Multiproduct Producers

Our aim in this subsection is to show how our framework can be extended to a multi-products setting. In the previous section, we assumed that each firm produces a single product. We will now consider an additional channel - *multiproducts* - besides productivity and markups which could explain the dispersion in firm sizes. We show how our framework extends to the case where firms produce more than one product since we anticipate this to be the case in most firms[38]. By relying on the following restrictive but standard assumptions in the literature (Foster et al. (2008), De Loecker (2011), Levinsohn and Melitz (2002)): (1) identical production functions across products; (2) equal proportion of inputs are used in producing each product; (3) the number of varieties produced by a firm is constant; we show the relationship between a given product k of firm j q_{jkt} to its total input usage as[39]:

$$q_{jkt} = (\rho_{jkt} L_{jt})^{\alpha_l} (\rho_{jkt} K_{jt})^{\alpha_k} (\rho_{jkt} M_{jt})^{\alpha_m} A_{jt} \tag{1.A.1}$$

where ρ_{jkt} is defined as the share of product k in firm j's total input use. I further assume that inputs are spread across products in exact proportion to the number of products produced. So $\rho_{jkt} = S_j^{-1}$, where S_j is the number of products produced by firm j . The total variable cost is:

$$TVC_{jkt} = q_{jkt}^{\frac{1}{\alpha_m}} L_{jt}^{-\frac{\alpha_l}{\alpha_m}} K_{jt}^{-\frac{\alpha_k}{\alpha_m}} A_{jt}^{-\frac{1}{\alpha_m}} S_j^{\gamma}$$

Where $\gamma = \frac{\alpha_l + \alpha_k}{\alpha_m}$. On the demand side, for simplicity, we assume the consumer valuation is embodied on the brand and not the specific product so ζ_{ijt} (where $i = \{h, f\}$) is the

[38] We do not observe the number of products produced by a firm in the balance sheet data, but the export data shows that approximately 79.2 percent of exporting firms export at least 2 or more products at the CN-9 digit level. The remaining 20.8 percent may be multiproduct firms if the sell different product mixes at home and abroad. Aggregating at the HS-6 digit level, we see that approximately 77% of exporting firms export at least two products

[39] We suppress the country subscript since we are dealing with only firms in the home country

same for every product of a firm. The demand for each product can be derived as:

$$q_{ijkt} = p_{ijkt}^{-\sigma}\zeta_{ijt}\chi_{st} \tag{1.A.2}$$

In similar steps as the single product case, firm's maximize profit by choosing prices p_{ijkt} for each product in both the foreign and domestic market subject to demand system in equation(1.A.2). The price that emerges for each variety is similar to equation (1.4) with an additional term (S_j^V). This implies that by keeping quality fixed and splitting inputs over the production of more products, firms can increase the price of its unit output (Levinsohn and Melitz, 2002). This enables us to generate a system of product specific revenue in both foreign and domestic markets. The firm total revenue is derived by summing over the revenue for each of its product $R_{jt} = \sum_{k\in S_j} R_{jkt}$. Taking logs the estimating equation is:

$$\tilde{r}_{jt}^v = \alpha_l l_{jt} + \alpha_k k_{jt} + \alpha_m m_{jt} + \beta d_{jt} + a_{jt} + ln(\zeta_{jh}) + s_j^* + \mu_{jt} \tag{1.A.3}$$

This estimating equation is similar to equation (1.10). The only difference is the presence of the additional term $s_j^* = (1 + \alpha_m(1+\gamma))ln(S_j)$. For a single product firm $s_j^* = 0$, but for a multi-product firm it is some positive number which is constant over time. The derivation follows very closely from derivation of equation (1.10). Since we do not observe the varieties produced at the firm level, we are unable to control for the number of varieties in the estimation. Our aim in this subsection is to show how our framework can be extended to a multi-products setting.

Appendix 1.B Model Solution

1.B.1 Detailed Derivation of Revenue Equations

The first order condition of the profit maximization equation (1.3) yields:

$$\left(\frac{\sigma-1}{\sigma}\right) q_{jh}^{-\frac{1}{\sigma}} (\zeta_{jh}^{\sigma-1}\chi_h)^{\frac{1}{\sigma}} = \frac{(q_{jh}+q_{jf})^{\frac{1-\alpha_m}{\alpha_m}}}{\alpha_m (A_j K_j^{\alpha_m} L_j^{\alpha_l})^{\frac{1}{\alpha_m}}} \tag{1.B.1}$$

$$\frac{1}{\tau_j}\left(\frac{\sigma-1}{\sigma}\right) q_{jf}^{-\frac{1}{\sigma}} (\zeta_{jf}^{\sigma-1}\chi_f)^{\frac{1}{\sigma}} = \frac{(q_{jh}+q_{jf})^{\frac{1-\alpha_m}{\alpha_m}}}{\alpha_m (A_j K_j^{\alpha_m} L_j^{\alpha_l})^{\frac{1}{\alpha_m}}} \tag{1.B.2}$$

Recalling that $q_{jh} = \zeta_{jh}^{\sigma-1}\chi_h p_j^{-\sigma}$ and $q_{jf} = \zeta_{jf}^{\sigma-1}\chi_f(p_j\tau_j)^{-\sigma}$ and substituting in equation 1.B.1 we obtain

$$q_{jh}^{-\frac{1}{\sigma}} = \left(\frac{\sigma}{\sigma-1}\right)(\zeta_{jh}^{\sigma-1}\chi_h)^{-\frac{1}{\sigma}}\alpha_m^{-1}(A_jK_j^{\alpha_m}L_j^{\alpha_l})^{-\frac{1}{\alpha_m}}(\zeta_{jh}^{\sigma-1}\chi_h + \zeta_{jf}^{\sigma-1}\chi_f\tau^{-\sigma})^{\frac{1-\alpha_m}{\alpha_m}}(p_{jt}^{-\sigma})^{\frac{1-\alpha_m}{\alpha_m}} \tag{1.B.3}$$

We know that $(p_{jt}^{-\sigma})^{\frac{1-\alpha_m}{\alpha_m}} = q_{jh}^{\frac{1-\alpha_m}{\alpha_m}}(\zeta_{jh}^{\sigma-1}\chi_h)^{\frac{\alpha_m-1}{\alpha_m}}$ and substituting in equation 1.B.3 we have

$$q_{jh} = Z^{\sigma V}\zeta_{jh}^{\sigma-1}\chi_h(A_jK_j^{\alpha_k}L_j^{\alpha_l})^{\frac{\sigma V}{\alpha_m}}(\zeta_{jh}^{\sigma-1}\chi_h + \zeta_{jf}^{\sigma-1}\chi_f\tau^{-\sigma})^{\frac{(\alpha_m-1)\sigma V}{\alpha_m}} \tag{1.B.4}$$

Where $Z = \frac{(\sigma-1)\alpha_m}{\sigma}$ and $V = \frac{\alpha_m}{\alpha_m-\sigma(\alpha_m-1)}$. Recall revenue is $R_{jh} = p_jq_{jh} = q_{jh}^{\frac{\sigma-1}{\sigma}}\zeta_{jh}^{\frac{\sigma-1}{\sigma}}\chi_h^{\frac{1}{\sigma}}$. We already have the expression for q_{jh} in equation (1.B.4) so we can write

$$R_{jh} = Z^{V(\sigma-1)}\zeta_{jh}^{\sigma-1}\chi_h(A_jK_j^{\alpha_k}L_j^{\alpha_l})^{\frac{V(\sigma-1)}{\alpha_m}}(\zeta_{jh}^{\sigma-1}\chi_h + \zeta_{jf}^{\sigma-1}\chi_f\tau_j^{-\sigma})^{\frac{V}{\alpha_m}-1} \tag{1.B.5}$$

Similarly, substituting $q_{jh} = \zeta_{jh}^{\sigma-1}\chi_h p_j^{-\sigma}$ and $q_{jf} = \zeta_{jf}^{\sigma-1}\chi_f(p_j\tau_j)^{-\sigma}$ in equation (1.B.2) we have

$$q_{jf}^{-\frac{1}{\sigma}} = \left(\frac{\sigma}{\sigma-1}\right)(\zeta_{jf}^{\sigma-1}\chi_f)^{-\frac{1}{\sigma}}\alpha_m^{-1}\tau_j^{-\frac{1}{V}}(A_jK_j^{\alpha_m}L_j^{\alpha_l})^{-\frac{1}{\alpha_m}}(\zeta_{jh}^{\sigma-1}\chi_h+\zeta_{jf}^{\sigma-1}\chi_f\tau^{-\sigma})^{\frac{1-\alpha_m}{\alpha_m}}((\tau_jp_{jt})^{-\sigma})^{\frac{(1-\alpha_m)}{\alpha_m}} \tag{1.B.6}$$

We know that $(\tau_jp_{jt})^{\frac{\sigma(\alpha_m-1)}{\alpha_m}} = (q_{jf}(\zeta_{jf}^{\sigma-1}\chi_f)^{-1})^{\frac{1-\alpha_m}{\alpha_m}}$ and substituting in 1.B.6

$$q_{jf} = Z^{\sigma V}\zeta_{jf}^{\sigma-1}\chi_f\tau_j^{-\sigma}(A_jK_j^{\alpha_k}L_j^{\alpha_l})^{\frac{\sigma V}{\alpha_m}}(\zeta_{jh}^{\sigma-1}\chi_h + \zeta_{jf}^{\sigma-1}\chi_f\tau_j^{-\sigma})^{\frac{(\alpha_m-1)\sigma V}{\alpha_m}} \tag{1.B.7}$$

In a similar as above we can derive export sales as:

$$R_{jf} = Z^{V(\sigma-1)}\zeta_{jf}^{\sigma-1}\chi_f\tau^{-\sigma}(A_jK_j^{\alpha_k}L_j^{\alpha_l})^{\frac{V(\sigma-1)}{\alpha_m}}(\zeta_{jh}^{\sigma-1}\chi_h + \zeta_{jf}^{\sigma-1}\chi_f\tau_j^{-\sigma})^{\frac{V}{\alpha_m}-1} \tag{1.B.8}$$

Summing up equation (1.B.5 and 1.B.8) and reminding the reader that $\zeta_{jf} = \zeta_{jh}\nu_{jf}$ obtain out total sales in equation(1.7).

$$R_{jT} = \begin{cases} Z^{V(\sigma-1)}(A_jK_j^{\alpha_k}L_j^{\alpha_l})^{\frac{V(\sigma-1)}{\alpha_m}}(\zeta_{jh}^{\sigma-1}\chi_h)^{\frac{V}{\alpha_m}} & \text{if firm sells at home} \\ Z^{V(\sigma-1)}(A_jK_j^{\alpha_k}L_j^{\alpha_l})^{\frac{V(\sigma-1)}{\alpha_m}}\zeta_{jh}^{\frac{V(\sigma-1)}{\alpha_m}}(\chi_h + \tau_j^{-\sigma}\nu_{jf}^{\sigma-1}\chi_f)^{\frac{V}{\alpha_m}} & \text{if firm sells in both} \end{cases} \tag{1.B.9}$$

Recall price equation is $p_{jt} = q_{jh}^{-\frac{1}{\sigma}}(\zeta_{jh}^{\sigma-1}\chi_h)^{\frac{1}{\sigma}}$. Substituting equation (1.B.1) into this equation, we can express price as:

$$p_{jt} = \frac{\sigma}{\sigma-1}\frac{1}{\alpha_m}(A_jK_j^{\alpha_k}L_j^{\alpha_l})^{-\frac{1}{\alpha_m}}(q_{jh} + q_{jf})^{\frac{1-\alpha_m}{\alpha_m}}$$

So,

$$R_{jT}^{-\alpha_m} = (p_{jt}q_{jT})^{-\alpha_m} = Z^{\alpha_m}(A_jK_j^{\alpha_k}L_j^{\alpha_l})(q_{jh}+q_{jf})^{-1}$$

$$R_{jT}^{-\alpha_m} = Z^{\alpha_m}M_{jt}^{-\alpha_m} \implies Z^{\alpha_m} = M_{jt}^{\alpha_m}R_{jT}^{-\alpha_m} \tag{1.B.10}$$

To derive the estimation equation, we can substitute equation (1.8) and 1.B.10 into 1.B.9 rearrange and obtain the estimating equation.

1.B.2 Comparison with De loecker (2011)

To derive De Loecker (2011) version of our estimating equation, we substitute equation (1.8) into 1.B.9 and we obtain:

$$R_{jT} = Z^{V(\sigma-1)}(A_jK_j^{\alpha_k}L_j^{\alpha_l})^{\frac{V(\sigma-1)}{\alpha_m}}\zeta_{jh}^{\frac{V(\sigma-1)}{\alpha_m}}\chi_h^{\frac{V}{\alpha_m}}\left(1+\frac{R_{jf}}{R_{jh}}\right)^{\frac{V}{\alpha_m}}$$

Raise both sides of the equation to the power $\frac{\alpha_m}{V}$ We obtain:

$$R_{jT}^{\frac{\alpha_m}{V}} = Z^{\alpha_m(\sigma-1)}(A_jK_j^{\alpha_k}L_j^{\alpha_l})^{\sigma-1}\zeta_{jh}^{\sigma-1}\chi_h\left(1+\frac{R_{jf}}{R_{jh}}\right)$$

Substitute Z^{α_m} in equation (1.B.10) into the above equation, rearrange and we get:

$$R_{jT}^{\frac{\alpha_m}{V}}R_{jT}^{\alpha_m(\sigma-1)} = (A_jK_j^{\alpha_k}L_j^{\alpha_l}M_j^{\alpha_m})^{\sigma-1}\zeta_{jh}^{\sigma-1}P_{sh}^{\sigma}Q_{sh}\left(1+\frac{R_{jf}}{R_{jh}}\right)$$

$$\left(\frac{R_{jT}}{P_{sh}}\right)^{\sigma} = (A_jK_j^{\alpha_k}L_j^{\alpha_l}M_j^{\alpha_m})^{\sigma-1}\zeta_{jh}^{\sigma-1}Q_{sh}\left(1+\frac{R_{jf}}{R_{jh}}\right)$$

$$\frac{R_{jT}}{P_{sh}} = (A_jK_j^{\alpha_k}L_j^{\alpha_l}M_j^{\alpha_m})^{\frac{\sigma-1}{\sigma}}\zeta_{jh}^{\frac{\sigma-1}{\sigma}}Q_{sh}^{\frac{1}{\sigma}}\left(1+\frac{R_{jf}}{R_{jh}}\right)^{\frac{1}{\sigma}}$$

Taking logs we derive the equation:

$$\tilde{r}_{jt} = \underbrace{\beta_l l_{jt}+\beta_k k_{jt}+\beta_m m_{jt}+\beta_s q_{sht}+\varepsilon_{jt}^{*}+a_{jt}^{*}}_{\text{de Loecker (2011)}}+\frac{1}{\sigma}ln\left(1+\frac{R_{jf}}{R_{jh}}\right)+u_{it} \tag{1.B.11}$$

All the variables are as defined in section 2. If firms were non-exporters $R_{jf}=0$ we are back to De Loecker (2011).

10.14754/CEU.2018.12

Appendix 1.C Data, Production Function Estimates

1.C.1 Data Cleaning

We follow the cleaning procedures described in preceding literatures (Békés et al. (2011), Bisztray (2016) etc). Specifically, for firms that appear in more than one sector, we assign such firm in a sector in which it appears the most. We fill in missing values of sales, employment, capital, material inputs using the average of the 1 previous and 1 subsequent period's output values. When both or any do not exist, we use the average of 2 or 1 -previous and 2 or 1 forward period's value. We only consider manufacturing firms in our econometic exercise. We list in table 1.8, the manufacturing sectors.

Table 1.8: NACE 2.0 sectors and Description

Nace	description	Nace	description
15	Food and beverages	27	Basic metals
16	Tobacco products	28	Fabricated metal products
17	Textiles	29	Machinery and equipment n.e.cc
18	Wearing Apparels	30	Computer, electronic and optical products
19	Leather and related products	31	Electrical equipment
20	Wood except furniture	32	Consumer electronics & communication equip
21	Paper and paper products	33	Optical instruments and photographic equip.
22	Printing and production of recorded media	34	Motor vehicles, trailers and semi-trailers
23	Coke and refined petroleum products	35	Other transport equipment
24	Chemical products &pharmaceuticals	36	Furniture
25	Rubber and plastic products	37	Recycling
26	Other non-metallic mineral products		

1.C.2 Production Function Estimation

We estimate our quality-adjusted and revenue productivity using the proxy method proposed Levinsohn and Petrin (2000) with Ackerberg et al. (2015) corrections. (including export in the productivity estimates) and procedures. We use the stata prodest estimation function developed in Mollisi and Rovigatti (2017). We report industry parameters of the quality-adjusted productivity in table(1.9) and of revenue productivity in table (1.10). In addition to the parameters, we also report industry elasticity of substitution in table (1.9).

10.14754/CEU.2018.12

Table 1.9: Parameter Estimates (by Industry) for Quality-Adjusted Productivity

	Sectors - Teaor03							
Variables	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
log employment	0.161***	0.656***	0.400***	0.476***	0.469***	0.218***	0.162***	0.0686***
	(0.00559)	(0.0222)	(0.0160)	(0.0128)	(0.0178)	(6.35e-05)	(0.00840)	(0.00493)
log domestic share	0.749***	0.459***	0.332***	0.327***	0.166***	0.562***	0.605***	0.906***
	(0.0126)	(0.0674)	(0.0217)	(0.00829)	(0.0156)	(0.0155)	(0.00395)	(0.0113)
log capital	0.0131	0.185***	0.0698***	0.0824***	0.0495***	0.0470***	0.0875***	0.00267
	(0.0101)	(0.0425)	(0.0129)	(0.0105)	(0.0118)	(0.00246)	(0.0147)	(0.0114)
log materials	0.134***	0.0341	0.264***	0.235***	0.341***	0.230***	0.172***	0.0485***
	(0.00312)	(0.0583)	(0.000604)	(0.00384)	(0.0123)	(0.0164)	(0.00340)	(0.00271)
Elasticity of Substitution σ:	2.34	3.18	4.01	4.06	7.02	2.78	2.39	2.65
Observations	39,314	124	12,165	16,714	5,051	19,320	4,611	39,661
Number of groups	7,526	13	2,437	3,719	956	4,415	832	9,702

	Sectors - Teaor03							
Variables	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
log employment	0.0616***	0.269***	0.333***	0.216***	0.346***	0.358***	0.352***	0.482***
	(0.0123)	(0.0176)	(0.0240)	(0.00709)	(0.0247)	(0.0118)	(0.0267)	(0.0182)
log domestic share	1.020***	0.538***	0.384***	0.557***	0.334***	0.336***	0.449***	0.578***
	(0.264)	(0.00435)	(0.0174)	(0.00367)	(0.00386)	(0.00184)	(0.000848)	(0.0234)
log capital	-0.0203**	0.0318	0.0749*	0.0240*	0.0636*	0.0751***	0.0245	0.00469
	(0.00867)	(0.0389)	(0.0417)	(0.0136)	(0.0383)	(0.0110)	(0.0182)	(0.0133)
log materials	0.0317*	0.197***	0.273***	0.271***	0.297***	0.296***	0.293***	0.144***
	(0.0192)	(0.0218)	(0.0355)	(0.00268)	(0.0259)	(0.0171)	(0.00828)	(0.0176)
Elasticity of Substitution σ:	1.98	2.86	3.60	2.80	3.99	3.98	3.23	2.73
Observations	118	7,779	19,052	11,519	3,581	49,157	35,842	2,008
No. of groups	22	1,211	3,071	2,375	544	9,207	6,793	455

	Sectors - Teaor03						
Variables	(31)	(32)	(33)	(34)	(35)	(36)	(37)
log employment	0.439***	0.387***	0.245***	0.399***	0.308***	0.341***	0.157***
	(0.0372)	(0.00827)	(0.000337)	(0.00785)	(0.0104)	(0.000463)	(0.0142)
log domestic share	0.298***	0.225***	0.644***	0.150***	0.362***	0.419***	0.593***
	(0.00879)	(0.000915)	(0.0197)	(0.0106)	(0.0211)	(0.0284)	(0.0403)
log capital	0.0638**	0.0891***	-0.00348	0.102***	0.109***	-0.00221	0.0881***
	(0.0302)	(0.0168)	(0.0120)	(0.0115)	(0.0312)	(0.0157)	(0.0207)
log materials	0.332***	0.439***	0.204***	0.441***	0.317***	0.320***	0.229***
	(0.0345)	(0.0314)	(0.0229)	(0.00579)	(0.0279)	(0.0261)	(0.0165)
Elasticity of Substitution σ:	4.36	5.44	2.55	7.67	3.76	3.39	2.67
Observations	10,756	9,255	12,068	4,100	1,925	19,548	683
No. of groups	1,992	1,822	2,075	636	410	4,516	250

Bootstrapped standard errors in parentheses. $***p < 0.01$, $**p < 0.05$, $**p < 0.1$

10.14754/CEU.2018.12

Table 1.10: Parameter Estimates (by Industry) Conventional Revenue Productivity

	Sectors - Teaor03							
Variables	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
log employment	0.586***	0.988***	0.381***	0.461***	0.520***	0.464***	0.407***	0.642***
	(0.0170)	(0.0467)	(0.00877)	(0.0221)	(0.0353)	(0.0142)	(0.0336)	(8.65e-06)
log capital	-0.0252	0.307***	0.0457	0.0402***	-0.143***	0.0426**	0.197**	0.198***
	(0.0706)	(0.0339)	(0.0556)	(0.0135)	(0.0346)	(0.0206)	(0.0777)	(4.33e-06)
log materials	0.537***	0.145*	0.509***	0.469***	0.440***	0.459***	0.481***	0.236***
	(0.0281)	(0.0837)	(0.0423)	(0.0116)	(0.0359)	(0.0222)	(0.0269)	(4.33e-06)
Observations	39,314	124	12,165	16,714	5,051	19,320	4,611	39,661
Number of groups	7,526	13	2,437	3,719	956	4,415	832	9,702

	Sectors - Teaor03							
Variables	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
log employment	0.545***	0.607***	0.481***	0.453***	0.486***	0.526***	0.446***	0.793***
	(0.0561)	(0.0125)	(0.0112)	(0.00791)	(0.0242)	(0.0238)	(0.0104)	(0.00534)
log capital	-0.167*	-0.0648	0.0371	0.0293	0.110	-0.0669	0.191***	0.169***
	(0.0949)	(0.0788)	(0.0560)	(0.0439)	(0.0678)	(0.0738)	(0.0434)	(0.0357)
log materials	0.556***	0.316***	0.508***	0.595***	0.500***	0.527***	0.358***	0.187***
	(0.0774)	(0.0422)	(0.0215)	(0.0168)	(0.0776)	(0.0350)	(0.0190)	(0.0292)
Observations	118	7,779	19,052	11,519	3,581	49,157	35,842	2,008
No. of groups	22	1,211	3,071	2,375	544	9,207	6,793	455

	Sectors - Teaor03						
Variables	(31)	(32)	(33)	(34)	(35)	(36)	(37)
log employment	0.453***	0.426***	0.427***	0.434***	0.514***	0.514***	0.572***
	(0.0127)	(0.0238)	(0.0190)	(0.0133)	(0.0194)	(0.0209)	(0.0178)
log capital	0.135***	0.00739	0.0899	0.168***	0.00721	0.0698	0.0819
	(0.0431)	(0.0710)	(0.0797)	(0.0579)	(0.0501)	(0.0683)	(0.0688)
log materials	0.432***	0.557***	0.476***	0.473***	0.453***	0.413***	0.500***
	(0.0348)	(0.0436)	(0.0429)	(0.0339)	(0.0723)	(0.0147)	(0.122)
Observations	10,756	9,255	12,068	4,100	1,925	19,548	683
No. of groups	1,992	1,822	2,075	636	410	4,516	250

Bootstrapped standard errors in parentheses. $***p < 0.01$, $**p < 0.05$, $**p < 0.1$

Table 1.11: Production Function Estimation (1st Stage of 2-Step Method)

Dep. Variable:	QA Productivity		Revenue Productivity	
Log Sales	(1)	(2)	(3)	(4)
Log Capital	0.043***	0.041***	0.041***	0.039***
	(0.012)	(0.013)	(0.009)	(0.010)
Log Labour	0.237***	0.235***	0.240***	0.238***
	(0.002)	(0.003)	(0.002)	(0.001)
Log Material	0.749	0.742***	0.769***	0.764***
	(0.000)	(0.001)	(0.001)	(0.002)
Log Domestic MS	0.038***	0.040***		
	(0.003)	(0.001)		
Importers dummy		0.125***		0.116***
		(0.003)		(0.002)
Observations	39128	39126	39128	39126
Sector FE	Yes	Yes	Yes	Yes

$*$, $**$ and $***$ indicates 10%, 5% and 1% significance. MS=market share

1.C.3 Some Additional Properties of Estimates

Table 1.12: Regression of Ratio QA Prod to Revenue Prod

Dep. Variable	Ratio Weighted-Average Revenue to QA Prod			
	(1)	(2)	(3)	(4)
Time Trend (1993-1995)	-0.007***			
	(0.000)			
Time Trend (1996-2003)		0.002***		0.004***
		(0.000)		(0.000)
Time Trend (2004-2007)			0.017***	0.037***
			(0.000)	(0.000)
Constant	0.589***	0.559***	0.394***	0.574***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	46663	174237	48554	269454

This regression estimates the slope of the Weighted-Average Revenue to the Quality-Adjusted Productivity $*$, $**$ and $***$ indicates 10%, 5%, and 1% significant levels respectively

Table 1.13: Summary Statistics for Productivity Measures, Sales and Capital

	Correlations				
	Quality-Adjusted Productivity	Revenue Productivity	Sales Revenue	Capital	Market Shares
Quality-Adjusted Productivity	1.00				
Revenue Productivity	0.45**	1.00			
Sales Revenue	0.09**	0.34**	1 .00		
Capital	0.01**	-0.06**	0.80**	1.00	
Market Shares	-0.20**	0.25**	0.77**	0.58**	1.00
	Standard Deviations				
	0.777	1.083	1.936	2.356	1.944

Notes: This table shows the correlation and standard deviations for our firm-level variables. All variables are in logs. $**$, $*$ and † are 1%, 5% and 10% significant levels respectively.

1.C.4 Additional Robustness Results

Clustering at the firm level

Table 1.14: Estimating the Effects of Trade Liberalization on Productivity(clustering at firm)

Dependent Variable:	Quality-Adjusted Productivity						
	Two-Steps Approach						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariffs	-0.115***	-0.129***					
	(0.040)	(0.041)					
Lagged Tariffs			-0.108**	-0.050**	-0.053**	-0.059***	-0.026
			(0.042)	(0.023)	(0.023)	(0.022)	(0.039)
Lagged Productivity				0.646***	0.644***	0.644***	0.102***
				(0.011)	(0.011)	(0.011)	(0.020)
Foreign x Lag Tariffs						0.046	
						(0.040)	
Dependent Variable:	Revenue Productivity						
	Two-Steps Approach						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariffs	-0.164***	-0.177***					
	(0.041)	(0.042)					
Lagged Tariffs			-0.160***	-0.065***	-0.068***	-0.076***	-0.029
			(0.043)	(0.024)	(0.024)	(0.023)	(0.040)
Lagged Productivity				0.638***	0.635***	0.635***	0.101***
				(0.011)	(0.012)	(0.012)	(0.021)
Foreign x Lag Tariffs						0.057	
						(0.042)	
Importers dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	No	No	No	Yes
Industry-Year FE	No	Yes	No	No	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	No	No	No
Industry FE	Yes	No	Yes	Yes	No	No	No
Observations	27827	27827	19442	19442	19442	19433.000	19442
R-squared	0.132	0.163	0.093	0.532	0.546	0.546	0.275

Notes This table reports the results of the effect of tariffs cut on firm-level productivity. Foreign is a dummy that takes a value=1 if firm is foreign-owned and 0 if domestic or state-owned. I excluded firms in industry 34 and 35 (i.e. "Motor vehicles, trailers and semi-trailers" and Other transport equipments) and firms with export sales more than 70% of its total sales to ensure that our results are not driven by export platform firms. In column 1-7 robust standard errors are clustered at the **firm level** in parentheses. $*$, $**$ and $***$ indicates 10%, 5% and 1% significant levels.

Estimating with the Full Sample

Table 1.15: Estimating the Effects of Trade Liberalization on Productivity (Full Sample)

Dependent Variable:	Quality-Adjusted Productivity						
	Two-Steps Approach						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariffs	-0.118***	-0.144***					
	(0.027)	(0.019)					
Lagged Tariffs			-0.099***	-0.045**	-0.050**	-0.063**	-0.023*
			(0.022)	(0.022)	(0.021)	(0.027)	(0.013)
Lagged Productivity				0.656***	0.655***	0.654***	0.146***
				(0.021)	(0.022)	(0.022)	(0.018)
Foreign x Lag Tariffs						0.082*	
						(0.042)	
Dependent Variable:	Revenue Productivity						
	Two-Steps Approach						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariffs	-0.162***	-0.185***					
	(0.024)	(0.017)					
Lagged Tariffs			-0.143***	-0.060**	-0.065***	-0.076***	-0.026**
			(0.019)	(0.023)	(0.022)	(0.027)	(0.012)
Lagged Productivity				0.629***	0.628***	0.627***	0.139***
				(0.022)	(0.022)	(0.022)	(0.017)
Foreign x Lag Tariffs						0.066*	
						(0.034)	
Importers dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	No	No	No	Yes
Industry-Year FE	No	Yes	No	No	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	No	No	No
Industry FE	Yes	No	Yes	Yes	No	No	No
Observations	39126	39126	28054	28054	28054	28044	28054

Notes: This table reports the results of the effect of tariffs on firm-level productivity using the full sample. Foreign is a dummy that takes a value 1 if firm is foreign-owned and 0 if domestic or state-owned. In column 1-7 robust standard errors are clustered at the industry level in parentheses. $*$, $**$ and $***$ indicates 10%, 5% and 1% significant levels.

10.14754/CEU.2018.12

Estimates Without Controlling For Importer's Dummy

Table 1.16: Estimating the Effects of Trade Liberalization on Productivity

Dependent Variable:	QA Productivity						
	Two-Steps Approach						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariffs	-0.147***	-0.161***					
	(0.012)	(0.014)					
Lagged Tariffs			-0.135***	-0.059*	-0.061**	-0.069**	-0.015
			(0.021)	(0.031)	(0.028)	(0.030)	(0.010)
Lag Productivity				0.652***	0.650***	0.650***	0.109***
				(0.017)	(0.017)	(0.017)	(0.010)
Foreign x Lag Tariffs						0.059***	
						(0.014)	
Dependent Variable:	Revenue Productivity						
	Two-Steps Approach						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariffs	-0.193***	-0.207***					
	(0.013)	(0.014)					
Lagged Tariffs			-0.185***	-0.073**	-0.075**	-0.085**	-0.015
			(0.022)	(0.032)	(0.029)	(0.031)	(0.010)
Lagged Productivity				0.644***	0.642***	0.641***	0.107***
				(0.018)	(0.018)	(0.018)	(0.011)
Foreign x Lag Tariffs						0.070***	
						(0.019)	
Importers dummy	No	No	No	No	No	No	No
Firm FE	No	No	No	No	No	No	Yes
Industry-Year FE	No	Yes	No	No	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	No	No	No
Industry FE	Yes	No	Yes	Yes	No	No	No
Observations	27829	27829	19444	19444	19444	19435	19444

Notes This table reports the results of the effect of tariffs cut on firm-level productivity. Foreign is a dummy that takes a value=1 if firm is foreign-owned and 0 if domestic or state-owned. I excluded firms in industry 34 and 35 (i.e. "Motor vehicles, trailers and semi-trailers" and Other transport equipments) and firms with export sales more than 70% of its total sales to ensure that our results are not driven by export platform firms. In column 1-7 robust standard errors are clustered at the industry level in parentheses. $*$, $**$ and $***$ indicates 10%, 5% and 1% significant levels.

10.14754/CEU.2018.12

Chapter 2

Increasing Marginal Cost and Welfare Implications

2.1 Introduction

Most trade models typically attributes large welfare gains to trade liberalization (Melitz (2003), Krugman (1980) etc). These models have been broadly used for policy debates in support for freer trade. However, recent empirical studies have found a net welfare losses from freer trade (Hsieh et al., 2018). This disconnection between theory and recent empirical findings result from some assumptions featured in these trade models, such as the symmetry of countries and constant marginal cost technology. For example, Hsieh et al. (2018) relaxes the symmetry assumptions and shows that import variety gains are attenuated by domestic variety losses, and domestic productivity gains are attenuated by import productivity losses resulting to a net effect of welfare losses from Canada-US Free Trade Agreement (CUSFTA).

Given the implications of these trade models for policy debates on freer trade, this paper asks two important questions. First, how can we identify the prevailing marginal costs technology among manufacturing firms? Second, what are the implications of the marginal cost structure for welfare during periods of trade liberalization? Since the marginal cost structure is a consequence of the production capacity of the firm (Ahn and McQuoid, 2017)[1], answers to these questions are important in understanding how production capacity affects welfare gains from trade liberalization.

By addressing these questions, we make two contributions to the literature. First, we provide a novel structural method of estimating the marginal cost structure which can be easily applied to a different setting. Our framework relies on the notion that the marginal cost structure could be inferred from the relationship between a firm's domestic and foreign sales conditional on both the supply and demand shocks. We also corroborate our findings by employing an instrumental variable approach pioneered in Hummels et al.

[1] Specifically, Ahn and McQuoid (2017) shows a strong relationship between increasing marginal cost structure and production capacity constraints in their study on Indonesian manufacturing firms.

(2014) and applied to trade in Berman et al. (2015). In all our empirical specifications, we find the prevalence of increasing marginal cost technology. This finding is similar to Vannoorenberghe (2012), Ahn and McQuoid (2017), Blum et al. (2013) etc which employed data from a different setting and an empirical methodology which can be best described as OLS. Our contribution here lies in providing a new structrual framework and an instrumental variable approach which guarantees a more credible identification. This is important as exporting is an endogenous event, therefore, OLS regression would likely result to imprecise estimates. Second, we propose an extension of Melitz (2003) trade model by introducing an increasing marginal cost structure and re-deriving the resulting welfare equation. The modified model highlights a new channel for reduction in potential welfare gains from trade liberalization which is unaccounted for in previous studies that relies on constant marginal cost assumption. The practical implication of this result is that policies which addresses production capacity be implemented simultaneously with trade liberalizing policies to ensure the full realization of the gains from trade[2].

We begin our analysis in section 2.2, where we present our data and a brief descriptive statistics. Our data is a panel of manufacturing firm-level data from Hungary, taken from four different sources and merged together for this analysis. The first dataset consists of firm-level balance sheet information for the period 1993 to 2014 originally from the Hungarian Tax Authority (APEH). This data consist of firms classified according to their NACE-2 industry classification, total sales and exports revenue, labour and cost of material inputs, ownership type etc. The second is an extremely disaggregated trade data for the period 1992-2003 assembled by Hungarian customs[3]. This data consist of firm's export and import shipments to and fro specific countries at the 9-digit combined nomenclature (CN-9). That is, in each time period, we observe the nominal value of products exported by a firm and its export destination and products imported by a firm and its source country. The third dataset, is a country-level product import data for the period 1995-2003 originally from United Nations Comtrade database (UNCOMTRADE), but cleaned and prepared by Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). This data consists of HS-6 products of the universe of a country's imports. We use these information to construct instruments in our empirical exercise as discussed later. Depending on the estimation strategy, we combine some of these datasets as discussed in the relevant sections. The descriptive statistics show that the characteristics of firms are

[2]There has been a huge debate among policy makers and trade commissions on how capacity constraints may hinder the gains from trade. For example, United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) devotes a chapter UNESCAP (2011) to discuss the importance of addressing capacity constraints in the least developed industries as this is pertinent to their success in global markets.

[3]Hungary joined the EU in 2004, so we do not have access to firm-level import and export starting after 2003.

quite heterogeneous and firm's sales are concentrated in the domestic market, whereas export sales are concentrated within a small set of larger firms.

In section 2.3, we present our empirical model, similar to the framework in Ahn and McQuoid (2017). Our framework builds on existing heterogeneous firms model augmented with flexible marginal cost which embeds all possible structure of the marginal cost. We consider a firm that faces demand in two markets- domestic and foreign- and produce with a cobb-douglas technology using capital and labour as inputs. Capital is predetermined, while labour is a perfectly variable input (i.e. chosen at each time period). On the demand side, we consider a representative consumer in each of the two countries facing the standard CES utility function and chooses varieties to consume subject to a budget constraint. The conventional demand systems emerges which depends negatively on the price and positively on the variety-specific demand shifter. Using the first order condition, we derive an estimable equation of domestic sales on exports and other controls such as the capital, productivity, a time-varying unobserved firm-specific demand conditions and a time-varying industry fixed effect. This equation makes it possible to test for the marginal cost structure. The econometric equation shows that the relationship between domestic and foreign sales depends on the marginal cost structure - negative for increasing marginal cost, positive for decreasing and no-relationship for constant marginal cost. We propose two empirical strategies. In the first, we employ an instrumental variable approach similar to Hummels et al. (2014) and Berman et al. (2015), where we estimate the model using instruments exogenous to the firm and orthogonal to the domestic demand conditions faced by the firm. Our instrument is constructed by mapping each firm's exposure to exogenous demand shocks in all countries which imports from Hungary. While in the second strategy, we exploit our model by constructing proxies for the unobserved domestic and foreign demand conditions, and time-varying industry effects from observable variables. We substitute these proxies into our econometric equation and estimate by OLS.

In section 2.4, we present our findings from both empirical strategies. Our results confirm the presence of increasing marginal cost structure. We conduct a number of robustness checks to test the sensitivity of the results to several instruments, data restrictions and specifications. Overall, our results are robust across all specifications suggesting the presence of increasing marginal costs.

In section 2.5, we study the implications of our findings for welfare gains from trade liberalization. To do this, we modify the baseline Melitz model by incorporating the increasing marginal cost structure and study the welfare effect of trade liberalization. We find that reduction in bilateral tariffs has two opposing effects on welfare defined as the inverse of aggregate price index. On one hand, it increases the aggregate price index through its effect on prices of domestic goods and imports. On the other hand, it decreases the aggregate price of domestic goods through (i) its positive effect on average productivity as market shares are reallocated from less to more productive firms, and through (ii) the drop in prices of imported goods since tariffs are declining. The dominating channel is unclear, but one thing we learn from this model is the presence of a new channel that reduces aggregate welfare gains from trade liberalization which is not accounted for if the constant marginal cost assumption is assumed.

We conclude the paper in section 6, and provide additional details on the data and derivation of the theoretical results in the appendix.

2.1.1 Related Literature

This paper is related to the literature on the "new" trade theory (Melitz, 2003, Krugman, 1980, Bernard et al., 2003 etc), most of which assumes that firms produce with a constant marginal cost technology and studies the welfare implications from trade liberalization. More recent work assumes increasing marginal cost -Vannoorenberghe (2012), Liu (2015) etc- and finds that domestic and export sales growth are substitutes. Relative to these literature, we do not impose any specific marginal cost structure, but instead, we estimate the prevalent marginal cost structure which we find to be increasing. We then introduce the increasing marginal cost structure into the "new" trade theory and study its welfare implications from trade liberalization.

Our paper is also related to the empirical literature that estimates the marginal cost structure prevalent within firms (Blum et al., 2013 - for Chilean firms, Vannoorenberghe, 2012 - for French firms, Soderbery, 2014 - for Thai firms and Ahn and McQuoid, 2017 - for Indonesian firms); all finds the marginal cost structure to be increasing. The empirical strategies in these papers can be best described as OLS. Since exporting is likely an endogeneous event, estimation will require an exogenous event that influences export decisions and helps identify the effect of an increase in exporting on domestic sales. We contribute to this literature by improving on the identification by means of two credible estimation strategies. In the first, we provide an instrumental variable approach where we instrument firm-level exports by demand conditions in export destinations faced by the firm. In the second, we offer a structural approach where we construct variables for unobserved demand shifters and control for these variables in the regression.

Our paper is also related to Berman et al. (2015) that studies how sales in home and foreign markets are related using a panel of french manufacturing firms and finds that exports and domestic sales are positively related. Their focus is not on the marginal cost structure, but on whether home and export sales are substitutes or complements. Using similar reduced form approach, we show that this relationship is negative for Hungarian manufacturing firms, casting doubts on the external validity of their findings. The closest paper to ours is by Almunia et al. (2018) which exploits the geographical variation in the reduction of domestic demand across Spanish regions during the 2008 economic recession to establish a negative causal effects of demand driven domestic sales on exports. The key difference in both papers are the identification strategy, the countries studies and time periods. Our paper can be seen as additional evidence that corroborates the presence of increasing marginal cost structure, but goes a step further to study the welfare effects of this cost structure within the Melitz (2003) framework.

On a macro level, our paper is related to Dai et al. (2014) which studies the trade diversion of free trade agreements (FTA) from internal trade to new trading partners using aggregate country-level export data. They find that FTAs led to a decrease in internal trade (domestic sales) within member countries. The diversion of internal trade intensifies with the number of FTAs a given country joins. We provide micro-level estimates of trade diversion due to exogenous foreign demand shock and declining tariffs.

Very recently, there has been a growing literature on welfare losses from trade liberalization. Hsieh et al. (2018) challenges the conventional knowledge of productivity and variety gains from trade liberalization. They show that import variety gains from trade liberalization are attenuated by domestic variety losses, and domestic productivity gains from trade liberalization is attenuated by import productivity losses. The evaluate these losses and gains and finds "new" welfare losses in Canada from CUSFTA. In addition, Foellmi et al. (2015) finds that capital constraints can reduce welfare gains from trade liberalization as it inhibits firms from investing in R&D. We complement to these literature on welfare losses by showing that there are also welfare losses arising from increasing marginal costs (capacity constraint)[4] and that models which assume a constant marginal cost may overstate the welfare gains from trade liberalization. This result is also similar to one of the findings in Ahn and McQuoid (2012) that employed a structural model and constructs the counterfactual aggregate domestic goods price index. They compared their counterfactual domestic price index with the observed domestic price index, and concludes that the actual domestic price index would be lower had there been no capacity constrained firms in their data, thus a source of welfare losses. The main difference between ours and theirs is that we employ a general equilibrium framework, by also considering the export partners of the country. We show in equilibrium that the potential gains (found in existing studies) from trade still exists, but we now have a new channel which offsets these potential gains.

Our paper is also related to Armenter and Koren (2015) that finds that the Melitz model

[4]Ahn and McQuoid (2017) , Soderbery (2014) etc show that capacity constraint results to increasing marginal cost

is unable to simultaneously match the size and share of exporters given the observed distribution of total sales of U.S. manufacturing firms. They show that while data suggests that exporters have 4-5 times more total sales, the Melitz model predicts that exporters are expected to be between 90 to 100 times larger than non-exporters. Relative to this paper, our model suggests that exporters are larger than non-exporters by a fraction of the magnitude predicted by the Melitz model.
To the best of our knowledge, this paper is the first to credibly show that the constant marginal assumption in the "new" trade models is not innocuous especially in understanding the effect of trade liberalization on welfare. Similar export policies in different countries may yield differential impacts on welfare and depends amongst other things on the prevalent marginal cost structure. Thus, in order to fully harness the gains from trade, understanding the prevailing marginal cost structure is important[5].

2.2 Data and Descriptive Statistics

In this section, we describe our data sources and present some descriptive statistics

2.2.1 Data

Our data comes from four different datasets. The first is a panel of the universe of Hungarian firms balance sheet data for the period 1993-2014 taken from Hungarian Tax Authority (APEH) and includes balance sheet and income statement information such as net value of sales and exports, fixed assets, wage bills, annual average employment, costs of goods and material inputs. For the purpose of this paper, we focus on manufacturing firms[6] that reports employment figures only and delete observations for non-manufacturing firms. We drop observations for which total exports is greater than total sales and merge the data with producer price indexes (PPI) at the 2-digit NACE industry identifier. Manufacturing sectors consist of 64,979 firms and 324,351 firm-year observations. Out of these, approximately 39% are exporters and they account for about 96% of total sales revenue. Exports account for approximately 40% of total manufacturing sales. The second dataset is the firm-product-destination panel data for the period 1992-2003 taken from Hungarian statistical Office. It is assembled from customs declarations filled out when exporting or importing. It consists of a complete set of transactions on export and import shipments in Hungary at an extremely disaggregated level (CN-9) to several destinations for exports and source countries for imports. The total number of

[5]In terms of policy, our results suggests that easing the capacity constraint should come first prior to trade liberalization.

[6]In appendix, I describe the sectors we considered in this work.

observation is 12,117,483. Since we are not interested in imports, we keep only the data for exports which amounts to 2,466,408 observations[7] and aggregate at the HS-6 product level[8].

The third dataset is a country-level import data of disaggregated products at the HS-6 level for the periods ranging from 1995 to 2003. This data was originally collected from United Nations Comtrade database but cleaned and prepared by CEPII-BACI. It consist of imports at the HS-6 product level of over 200 countries and 5000 products[9]. We aggregate each specific product imported by a given country over all its trade partners in each year and exploit the variation in total yearly imports of each product in our analysis.

2.2.2 Merging Data

From the data description, we remind the reader that each of our data set spans different intersecting periods. We create two different datasets, each suitable for each empirical strategy as described below.

Step 1: The first dataset is a balance sheet data which spans between 1993 to 2014. We estimate the total factor productivity of revenue (TFPR) at the NACE-2 industry level following the proxy method developed by Ackerberg et al. (2015)[10] and save our TFPR estimates. I then restrict this data to only exporters and we are left with 133,089 observations. This dataset will be used in our first estimation strategy.

Step 2: For our second estimation strategy, we merge our updated balance sheet dataset in Step 1 with firm's trade data using the firm's unique identifier and year variable. We also merge this data to the countries-product-import data using product, destination and year identifiers. Since the country's-product-import data (CEPII-BACI dataset) ranges between 1995-2003, we restrict our merged dataset to this period. In each row, we observe a firm in a given year, its characteristics, each HS-6 product it exports to a specific country and the total Worldwide imports of that HS-6 product in that specific country[11]. I construct export demand instrument as discussed later in section (2.3.3) and aggregate over products and year at HS-6 level for each firm. We are left with 41887 observations and 11429

[7]We follow the basic cleaning detailed Békés et al. (2011). Detailed stylized facts about both datasets are contained in the paper.

[8]We aggregate because we merged this data with country-level HS-6 product import data. Please note that the CN-6 level is the same as the HS-6 (Békés et al., 2011).

[9]For detailed documentation on the construction of the database, see Gaulier and Zignago (2010).

[10]We describe the estimation strategy in the appendix.

[11]This information will be useful in constructing instruments for the IV approach as discussed in later sections

unique firms identifiers. This will be our main data for the descriptive statistics below.

2.2.3 Descriptive Statistics

We provide some descriptive statistics about the firms in our data using the merged sample described in step 2 of section 2.2.2. Our sample is an unbalanced panel of 41887 observations and 11429 unique firms exporting at least once during the period 1995-2003. We report information for these firms on the number of employees, domestic sales, exports and total sales revenue in millions of Hungarian Foriths (HUF), export shares and log change of domestic and export sales in Table 2.1. The characteristics of firms in our data are very heterogeneous. Firms in the 3^{rd} quartile have 9 times more employees, 18 times more domestic sales, 34 times more exports sales, 11 times more total sales than firms in the 1^{st} quartile. In addition, both domestic and foreign sales grew faster by 49% and 76% respectively for firms in the 3^{rd} quartile than those in the 1^{st} quartile. The distribution of export shares show that firms' sales are concentrated in their domestic market. 50% of firms sells at most 27% of their total sales in the export market; however firms at the 75% percentile sells about 74% of its total sales in the export market. This confirms that overall, firm's sales are concentrated in the domestic market, whereas export sales are concentrated within a small set of larger firms.

Table 2.2 shows the relationship between export share and the firm's size proxied by

Table 2.1: Descriptive Statistics: firm size, sales, sales growth and export share

	Mean	1st quartile	Median	3rd quartile	S.D.
Number of employees	117.01	10	29	91	390.20
Domestic sales	1792.55	27.14	120.68	498.03	42300
Export sales	1268.12	8.24	51.31	284.34	16100
Total Sales	3060.67	83.31	263.37	943.68	51400
Export Share	0.40	0.06	0.27	0.74	0.35
Δ ln domestic sales	0.09	-0.18	0.05	0.31	0.89
Δ ln export sales	0.07	-0.31	0.06	0.45	1.14

Notes: The values are in millions of Hungarian Foriths (HUF). Export share is the ratio exports to total sales. Total observations is 41887 with 11429 firm.

number of employees. We report the result of a regression of export shares on dummies representing intervals of sizes in terms of number of employees including sector and year dummies. Clearly, exporting increases with firm size since larger firms have higher export share.

Table 2.2: Export share by firm-size class

Employment size	Export share	No. of Observations
1-20 employees	0.199	17653
	(0.008)**	
21-50 employees	0.217	8742
	(0.008)**	
50-100 employees	0.271	5856
	(0.008)**	
101-200 employees	0.331	4235
	(0.009)**	
>200 employees	0.354	5403
	(0.008)**	

This table shows the coefficient of regression results of firms export share on dummies corresponding to their employment bins. We control for sector and year dummies. Column 2 is the number of observations in each bin. Standard error are in parentheses +, $*$ and $**$ corresponds to 10%, 5% and 1% significant levels respectively.

2.3 Empirical Framework

In this section, we present the empirical framework for inferring the marginal cost structure from firm-level trade data. We start with a model of demand and supply and derive an estimable econometric equation. We propose two estimation strategies and discuss its identification in subsequent sub-sections.

2.3.1 Demand

We consider a world consisting of two symmetric countries home H and foreign F and a representative industry with many firms producing differentiated goods. Consumers in both countries have identical constant elasticity of substitution (CES) preferences with same elasticity of substitution denoted by σ. Consumers in country $i = \{H, F\}$ total expenditure is denoted by R_{it}. A representative consumer in each country i maximizes its utility given by

$$U_{it} = \left[\int_{\omega \in \Omega} (\zeta_{it}(\omega))^{\frac{1}{\sigma}} (q_{it}(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \quad \text{for } i \in \{H, F\} \tag{2.3.1}$$

subject to the budget constraint:

$$\int_{\omega \in \Omega} p_{it}(\omega) q_{it}(\omega) d\omega = R_{it}$$

where $\zeta_{it}(\omega)$ is the idiosyncratic shock to the taste of product ω in country i, $q_{it}(\omega)$ is the demand for variety ω in country i and $p_{it}(\omega)$ is the price of variety ω in country i. Demand faced by each firm i at time t is derived as:

$$q_{it}(\omega) = \zeta_{it}(\omega)\chi_{it}p_i(\omega)^{-\sigma} \tag{2.3.2}$$

where $\chi_{it} = P_{it}^{\sigma-1}R_{it}$ is the aggregate level of demand in country i at time t, this can be interpreted as the position of the demand curve common to all firms and $P_{it} = [\int_{w\in\Omega}\zeta_{it}(\omega)(p_{it}(\omega))^{1-\sigma}d\omega]^{\frac{1}{1-\sigma}}$ is a summary of the prices of all available varieties in an industry in country i.

2.3.2 Supply

We assume that all firms j are heterogeneous in their productivity levels A_{jt} and produces a single variety j (to avoid abuse of notations we use j in place of ω such that $q_{it}(\omega) = q_{ijt}$) under monopolistic competition. Firms produce with a Cobb-Douglas technology using labor L_{jt} and physical capital K_{jt}. While labor is a variable input and can be freely adjusted at any point in time, physical capital is assumed to be fixed in the short run. Firm j's production function in time t is:

$$q_{jt} = A_{jt}K_{jt}^{\alpha_k}L_{jt}^{\alpha_l}$$

we normalise the wage rate to one and express the variable cost below as:

$$TVC_{jt} = q_{jt}^{\frac{1}{\alpha_l}}A_{jt}^{-\frac{1}{\alpha_l}}K_{jt}^{-\frac{\alpha_k}{\alpha_l}}$$

Firms can export some of their output to the foreign market by paying a fixed export costs f_F which reflects additional cost incurred by doing business abroad. We assume that the price which exporters receive is different from that paid by foreign consumers. Let $\tau_{it} > 1$ be the import tariff or shipping cost and p_{it}^* be the price received by an exporter, we define price paid by foreign consumers as $p_{Ft}(\omega) = p_{Ft}^*(\omega)\tau_{Ft}$.
The timing is as follows: First, prior to realizing the demand (ζ_{ijt}) and productivity shock (A_{jt}), firms decides on whether to produce and export and pays the associated fixed costs (f_j and f_{xj}). Secondly, both shocks are realised simultaneously. Finally, each firm observes the demand and decides the quantity of output to sell in each market by choosing an optimal price. Given the market demand for its variety, a firm's problem is to maximize per-period profit by choosing an optimal price to sell in both markets. A firm

in the home market that sells to both domestic and foreign markets faces the problem:

$$\max_{q_{jHt}q_{jFt}} \left\{ q_{jHt}^{\frac{\sigma-1}{\sigma}}(\zeta_{jHt}\chi_{Ht})^{\frac{1}{\sigma}} + \frac{q_{jFt}^{\frac{\sigma-1}{\sigma}}(\zeta_{jFt}\chi_{Ft})^{\frac{1}{\sigma}}}{\tau_{Ft}} - \frac{(q_{jHt}+q_{jFt})^{\frac{1}{\alpha_l}}}{A_{jt}^{\frac{1}{\alpha_l}}K_{jt}^{\frac{\alpha_k}{\alpha_j}}} - f_{Ht} - f_{Ft} \right\} \tag{2.3.3}$$

The first order condition yields:

$$\underbrace{\left(\frac{\sigma-1}{\sigma}\right)q_{jHt}^{-\frac{1}{\sigma}}(\zeta_{jHt}\chi_{Ht})^{\frac{1}{\sigma}}}_{MR\_home\_sales} = \underbrace{\frac{(q_{jHt}+q_{jFt})^{\frac{1-\alpha_l}{\alpha_l}}}{\alpha_l A_{jt}^{\frac{1}{\alpha_l}}K_{jt}^{\frac{\alpha_k}{\alpha_l}}}}_{Marginal\_cost} \tag{2.3.4}$$

$$\underbrace{\frac{\left(\frac{\sigma-1}{\sigma}\right)q_{jFt}^{-\frac{1}{\sigma}}(\zeta_{jFt}\chi_{Ft})^{\frac{1}{\sigma}}}{\tau_{Ft}}}_{MR\_export\_sales} = \underbrace{\frac{(q_{jHt}+q_{jFt})^{\frac{1-\alpha_l}{\alpha_l}}}{\alpha_l A_{jt}^{\frac{1}{\alpha_l}}K_{jt}^{\frac{\alpha_k}{\alpha_l}}}}_{Marginal\_cost} \tag{2.3.5}$$

Equating equation (2.3.4) and (2.3.5), we obtain:

$$q_{jHt} = \frac{\zeta_{jHt}\chi_{Ht}}{\zeta_{jFt}\chi_{Ft}}\tau_{Ft}^{\sigma}q_{jFt} \tag{2.3.6}$$

Subsitituting equation (2.3.6) into the RHS of (2.3.4) , taking logs and simplifying, we obtain the estimable empirical equation as[12]:

$$lnq_{jHt} = \mu + \alpha_{jt} + \delta lnA_{jt} + \alpha_{kt} + \beta lnK_{jt} + \gamma lnq_{jFt} + \eta_{jt} \tag{2.3.7}$$

where $\mu = \sigma ln(\frac{\sigma-1}{\sigma}) + \sigma ln\alpha_l$ and $\eta_{jt} = -\sigma ln\eta_{jt}^*$ is the constant term and exogenous error term respectively where η_{jt}^* is assumed to be a random optimization error, $\alpha_{jt} = ln\zeta_{jHt} + \frac{(\alpha_l-1)\sigma}{\alpha_l}ln\left[\frac{\zeta_{jHt}\tau_{Ft}^{\sigma}}{\zeta_{jFt}}\right]$ is the firm-time fixed effect, $\sigma_{kt} = ln\chi_{Ht} + \sigma\left(\frac{\alpha_l-1}{\alpha_l}\right)ln(\frac{\chi_{Ht}}{\chi_{Ft}})$ is the sector-time fixed effect[13] which capture industry-specific change in input prices and business cycle conditions; $\delta = \frac{\sigma}{\alpha_l}$, $\beta = \frac{\sigma\alpha_k}{\alpha_l}$ and $\gamma = \frac{\sigma(\alpha_l-1)}{\alpha_l}$ are coefficients of log of productivity, capital and and export sales respectively.

We can infer the marginal cost structure from the relationship between domestic sales and exports (i.e. the coefficient γ) in equation (2.3.7). For constant marginal cost, this

[12]We approximate $ln\left(\frac{\zeta_{jHt}\chi_{Ht}\tau_{Ft}^{\sigma}}{\zeta_{jFt}\chi_{Ft}}+1\right)$ to $ln\left(\frac{\zeta_{jHt}\chi_{Ht}\tau_{Ft}^{\sigma}}{\zeta_{jFt}\chi_{Ft}}\right)$. This assumption is true if domestic demand is very high relative to foreign demand. This condition enables us to separate variables proxying the sector-time fixed effect from that of the firm fixed effect. We relax this assumption in the structural estimation and our results remain unchanged.

[13]This variable is the time fixed effect if we had focus on a single industry. We use data of all manufacturing firms in Hungary in our empirical analysis.

implies that $\alpha_l = 1$, and so the coefficient on export sales is $\gamma = 0$. Hence, exports and domestic sales are unrelated in firms with constant marginal cost technology. Increasing marginal cost is the case where $0 < \alpha_l < 1$ such that the coefficient of export sales is $\gamma < 0$. This implies that a negative relationship between domestic sales and exports after controlling for every observable and unobservable variables is the case where increasing marginal cost structure is prevalent. Finally, for decreasing marginal cost $\alpha > 1$, we expect to find a positive relationship between foreign and domestic sales.

Estimating equation (2.3.7) with firm-year fixed effect α_{jt} is not feasible as each firm is observed once in a given year, as this backs out all the variablility in the RHS variables. Alternatively, one can resort to firm fixed effects and control for industry-year fixed effects. Firm fixed effects control for unobserved time-invariant demand conditions faced by the firm in both domestic and export markets. However, the estimate of γ will be biased if there are omitted variables from time-variant demand conditions. Since, the foreign demand shock is positively correlated with exports, this will lead to a downwards bias of γ. As such, we may obtain a negative coefficient of gamma, whereas the true coefficient is positive[14]. Given the potential limitations of the fixed-effect regression, we follow two - empirical strategies that corrects for these issues. The first is a reduced form regression where we instrument for the unobserved demand conditions and in the second, we explore a structural estimation approach to uncover the unobservable foreign demand shocks. We describe both in details below:

2.3.3 Empirical Strategy I

In this subsection, we estimate a reduced form regression using an instrumental variable approach. We proceed by approximating the firm-time fixed effect with a firm fixed effect. This will obviously make it impossible to identify our parameters of interest γ, since the foreign demand conditions is positively correlated with exports and negatively correlated with domestic sales. To control for this problem and identify the variation in exports γ, we use an instrument which: reflects foreign demand conditions and not domestic supply shocks; exogenous to the firm, and orthogonal to domestic demands. We build on Hummels et al. (2014) and Berman et al. (2015) type of instruments which are uncorrelated with the characteristics of the firm, but captures firm-specific demand in the foreign market it sells while controlling for firm-specific home market demand. Our

[14] Assume a case where the true coefficient of $\gamma_{true} > 0$ (i.e. $\alpha_l > 1$). If we estimate equation (2.3.7) by firm-fixed effect, the omitted variable bias from this estimation is represented as $\gamma = \gamma_{true} + \gamma_{fd}\frac{cov(\zeta_{jFt},q_{jFt})}{var(q_{jFt})}$ where γ_{fd} is expressed as $\gamma_{fd} = \frac{\sigma(1-\alpha_l)}{\alpha_l} < 0$. We know that $cov(\zeta_{jFt}, q_{jFt}) > 0$, so $\gamma_{fd}\frac{cov(\zeta_{jFt},q_{jFt})}{var(q_{jFt})} < 0$. This implies that it is possible to wrongly infer γ to be less than 0 ($\gamma < 0$) when $\gamma_{true} > 0$.

baseline instrument involves computing the sum of foreign imports of a product in the product-destination served by a firm j in a given year weighted by the share of each product-destination in the total exports of firm j over the period. Products denoted by p are defined at the HS-6 level. To be precise, the instrument takes the form:

$$F_{jt} = \sum_{dp} s_{jdp} IM_{dpt} \tag{2.3.8}$$

where s_{jdp} is time-invariant and represents the average share of each product p sold in country d in firm j's exports over the period it exports. IM_{dpt} is the total value of imports of product p in country d and year t. The instrument ensures that all the variations in the foreign demand faced by a firm at each period comes from IM_{dpt}. This ensures exogeneity of the foreign demand shock on firm's characteristics. I also control for domestic demand shock faced by a firm to ensure that the results are not driven by correlations between domestic and foreign demand shocks. This variable is defined as the sum of world imports from Hungary for all products exported by firm j, weighted by the share of each product in the firm's exports. That is:

$$D_{jt} = \sum_{p} s_{jp} IM_{HUN,p,t} \tag{2.3.9}$$

The construction of D_{jt} follows same structure as F_{jt}. Here s_{jp} denotes the share of total exports of product p in firm j's total exports and $IM_{HUN,p,t}$ is the total Hungarian import of product p in time t. The variation in the domestic demand instrument D_{jt} comes from the variation in $IM_{HUN,p,t}$. This variable controls for possible international business cycle correlation in demand faced by firms in my sample. To be able to construct these instruments, we merge our disaggregated (HS 6-digit) country-level import data with the firm-product-destination data and the balance sheet data. Our main reduced form econometric model is a two-stage least square (2SLS) estimator represented below as:

$$1^{st}\text{ Stage :} \qquad lnq_{jFt} = \mu + \alpha_j + \alpha_{kt} + \gamma_f lnF_{jt} + \gamma_d lnD_{jt} + \beta_1 lnK_{jt} + \delta_1 lnA_{jt} + \epsilon_{jt} \tag{2.3.10}$$

$$2^{nd}\text{ Stage :} \qquad lnq_{jHt} = \mu + \alpha_j + \alpha_{kt} + \beta lnK_{jt} + \gamma ln\hat{q}_{jFt} + \delta lnD_{jt} + \delta lnA_{jt} + \eta_{jt} \tag{2.3.11}$$

where $ln\hat{q}_{jFt}$ is firm j's predicted value of log of exports, all other variables are as defined above. lnD_{jt} and lnF_{jt} are the instruments and α_j approximates for firm-level time-invariant variables that are jointly correlated with the covariates and the dependent variable. Productivity A_{jt} is unobserved, so we estimate it using the method proposed in Ackerberg et al. (2015) (See appendix). In the estimation, the standard errors are robust and clustered at the NACE 2-digit sector.

Identification

Identification of γ requires that our instruments for firm exports is uncorrelated with the second stage error term: $cov(F_{jt}, \eta_{jt}) = 0$. This condition will likely be satisfied provided the possible correlations between variations in domestic and foreign demand of a product is controlled. This explains our inclusion of a variable that captures domestic demand (D_{jt}) addressed to a firm. One possible issue with this strategy is that home demand faced by domestic firms is not properly observed because firms may have several product mix in the foreign and domestic market but we assume same structure since we do not observe the product mix sold domestically. However, identification requires that D_{jt} capture variations in domestic demand which are correlated to export demand. This is the case here since the construction of F_{jt} and D_{jt} relies on the firm's export products structure[15]. Another potential concern is that the weights used in the construction of the instrument may be correlated with unobserved firm specific characteristics. That is, if firms self-select into specific markets based on their productivity and any unobserved characteristics, then the instrument is correlated with firm characteristics. While firm fixed effects can control for firm-level presample[16] unobserved characteristics, it fails to control for time-varying ones. To ensure identification, we use weights of HS6-product-destination in the first year the firm began exporting as an alternative specification. Most firms in our sample exports fewer products in their first period of exporting and gradually scales up the number of products. This would lead to dropping several product-destination observations. We construct presamples weight by considering only firms for which we observe their first period of exporting. To ensure the robustness of our results, we explore a number of other alternative instruments detailed in the robustness section.

2.3.4 Empirical Strategy II

In this step, we take the full structure of our estimation equation to data and test for the presence of increasing marginal costs. This approach offers some advantage over the reduced form estimation. Unlike the reduced form method where we lose a large proportion of our balance sheet observations after merging several datasets[17], this strategy offers the option of using our entire balance sheet data. That is, instead of relying on a shorter panel of firm-level product destination data in constructing instruments that reflect the demand conditions faced by a firm, this strategy makes it possible to construct

[15]Note that the correlation between F_{jt} and D_{jt} is approximately 0.65.

[16]By this we imply the first period which we observe the firm in our data

[17]This is because our balance sheet data spans between 1993-2014, our trade data spans from 1993 - 2003 and the country-level product import data span from 1995 - 2003. Merging both database implies that we use information from 1995-2003.

the unobservable demand parameters from observable variables in the balance sheet data. This ensures a good match between our theory and the data. We proceed by recovering, the foreign and domestic demand shock parameter ζ_{jFt}, ζ_{jHt} and the productivity A_{jt} from observable variables. To this end, we derive the firm's domestic sales R_{jHt} and exports R_{jFt} from the first-order order conditions in equation (2.3.4) and (2.3.5) as:

$$R_{jHt} = Z^{E(\sigma-1)} A_{jt}^{\frac{E(\sigma-1)}{\alpha_l}} K_{jt}^{\frac{\alpha_k E(\sigma-1)}{\alpha_l}} \zeta_{jHt}\chi_{Ht}(\zeta_{jHt}\chi_{Ht} + \tau_{Ft}^{-\sigma}\zeta_{jFt}\chi_{Ft})^{\frac{E}{\alpha_L}-1} \tag{2.3.12}$$

$$R_{jFt} = Z^{E(\sigma-1)} A_{jt}^{\frac{E(\sigma-1)}{\alpha_l}} K_{jt}^{\frac{\alpha_k E(\sigma-1)}{\alpha_l}} \zeta_{jFt}\chi_{Ft}\tau_{jt}^{-\sigma}(\zeta_{jHt}\chi_{Ht} + \tau_{jt}^{-\sigma}\zeta_{jFt}\chi_{Ft})^{\frac{E}{\alpha_L}-1} \tag{2.3.13}$$

and the total revenue, $R_{jt}^T = R_{jHt} + R_{jFt}$ is expressed as:

$$R_{jt}^T = \begin{cases} Z^{E(\sigma-1)} A_{jt}^{\frac{E(\sigma-1)}{\alpha_l}} K_{jt}^{\frac{\alpha_k E(\sigma-1)}{\alpha_l}} (\zeta_{jHt}\chi_{Ht})^{\frac{E}{\alpha_L}} & \text{if firm sells at home} \\ Z^{E(\sigma-1)} A_{jt}^{\frac{E(\sigma-1)}{\alpha_l}} K_{jt}^{\frac{\alpha_k E(\sigma-1)}{\alpha_l}} (\zeta_{jHt}\chi_{Ht} + \tau_{jt}^{-\sigma}\zeta_{jFt}\chi_{Ft})^{\frac{E}{\alpha_L}} & \text{if firm sells in both} \end{cases} \tag{2.3.14}$$

where $E = \frac{\alpha_l}{\alpha_l - \sigma(\alpha_l - 1)} < 1$ and $Z = (\frac{\sigma-1}{\sigma})\alpha_l$. The relationship between home and domestic sales revenue is driven by the assumption on the parameter α_l. We remind the reader that our aim is to estimate[18]:

$$\ln q_{jHt} = \mu + z_{jt} + \delta \ln A_{jt} + \beta \ln K_{jt} + \gamma \ln q_{jFt} + \eta_{jHt} \tag{2.3.15}$$

where $\mu = \sigma \ln(\frac{\sigma-1}{\sigma}) - \sigma$ and $\eta_{jt} = \ln \eta_{jt}^*$ is the constant term and exogenous error term respectively. $z_{jt} = \ln(\zeta_{jHt}) + \ln(\chi_{Ht}) + \sigma \ln \alpha_l + \frac{(\alpha_l - 1)\sigma}{\alpha_l} \ln \left[\frac{\zeta_{jHt}\chi_{Ht}\tau_{Ft}^{\sigma}}{\zeta_{jFt}\chi_{Ft}} + 1\right]$ is the combination of firm-time and sector-time fixed effects. δ, β and γ are as already defined above. We deflate R_{jHt} and R_{jFt} using industry domestic and foreign price indexes to obtain the corresponding sales quantities. Both z_{jt} and A_{jt} are not directly observable in the data, so we construct these variables in the following steps.

Step 1: Divide equation (2.3.12) by (2.3.13) and normalize ζ_{jHt} to 1, we obtain the expression:

$$\frac{\zeta_{jFt}}{\tau_{jt}^{\sigma}} = \frac{R_{jFt}\chi_{Ht}}{R_{jHt}\chi_{Ft}} = \frac{P_{sHt}^{\sigma-1} R_{sHt} R_{jFt}}{P_{sFt}^{\sigma-1} R_{sFt} R_{jHt}} \tag{2.3.16}$$

where R_{sHt} and R_{sFt} is the total industry revenue from domestic and export sales respectively. P_{sHt} and P_{sFt} is the domestic and export price index respectively. Other variables are as defined above. ζ_{jFt} is the measure of competitiveness of

[18] We remind the reader that equation (2.3.15) is slightly different from equation (2.3.7) because we do not approximate $ln\left(\frac{\zeta_{jHt}\chi_{Ht}\tau_{Ft}^{\sigma}}{\zeta_{jFt}\chi_{Ft}} + 1\right)$ to $ln\left(\frac{\zeta_{jHt}\chi_{Ht}\tau_{Ft}^{\sigma}}{\zeta_{jFt}\chi_{Ft}}\right)$. See footnote (13)

firm j in the export market relative to the domestic market expressed as the ratio of industry share of firm j in the export market to its industry share in the domestic market. We can substitute equation (2.3.16) into z_{jt} to obtain the variable:

$$z_{jt} = ln\chi_{Ht} + \sigma ln\alpha_l + \frac{(\alpha_l - 1)\sigma}{\alpha_l} ln\left[\frac{R_{jHt}}{R_{jFt}} + 1\right]$$

Step 2: Substitute equation (2.3.16) into equation (2.3.14b) and express A_{jt} as:

$$A_{jt} = (R_{jHt} + R_{jFt})^{1-\alpha_l} Z^{-\alpha_l} K_{jt}^{-\alpha_k} \left(\frac{R_{jHt}}{R_{sHt}}\right)^{\frac{1}{\sigma-1}} P_{sHt}^{-1} \tag{2.3.17}$$

Step 3: Construct z_{jt} and A_{jt} using estimated industry elasticity of substitution (σ) from the methodology in chapter 1 of this dissertation (see Table 2.15 in the appendix), and industry coefficient of labour (α_l) and capital (α_k) from empirical strategy 1 (see Table 2.17 in the appendix).

Step 4: We estimate equation (2.3.15) by OLS

Since this method does not require information on the export destination, we use our entire balance sheet data from 1993-2014, whilst restricting the data to firms for which we observe both positive exports and domestic sales.

2.4 Empirical Results

2.4.1 Instrumental Variable Results

We present the main results from the instrumental variable approach in Table (2.3) where we instrument foreign sales with foreign demand addressed to the firm -F_{jt} (First stage estimates are in table(2.9) in the appendix). We present the OLS estimate in column (1) and IV estimates in columns (2-9) using lnF_{jt} as instruments of log exports and ΔlnF_{jt} as instruments of change in log exports in columns (2-7) and columns (8-9) respectively. Column (1) controls for productivity and domestic demand variations (D_{jt}) , and industry-year dummies. In column (2), we include year and firm dummies, D_{jt} and industry-specific controls such as: the number of firms operating in the same domestic industry and industry domestic sales. In columns (3-9), we include industry-year dummies in place of industry-specific controls.

The OLS result predicts a weak negative impact of exporting on domestic sales which is not suprising because of omitted variable bias since exporting is not an exogenous event. In column (3), we use the foreign demand instrument to predict exporting in the first stage but we do not control for the domestic demand condition. We find a positive relationship between domestic and foreign sales which is possible if demand is positively correlated across countries. This suggests a positive business cycle correlation between foreign and domestic demand and supports the inclusion of domestic demand conditions as a control variable in the regression. In our most preferred specification (column 7), where we include the variable for the domestic demand addressed to a firm, and control for the characteristics of the firm, we find that predicted variations in exports is negatively related to the variations in domestic sales. The magnitude is strong and significant. This result is stable even when we do not control for capital and productivity (columns 2 & 4).

Findings from the preferred specification implies that a 10% exogenous increase in exports implies a 1.6% decrease in domestic sales. It is imperative to emphazise that our results does not imply a complete substitution of sales between domestic and foreign markets. For example, with an estimated elasticity of -0.156, our finding suggests that if our average firm with 40% export share, increases its exports by 100 HUF, this results to a decrease in domestic sales by 23.4 HUF. A back of the envelope calculation shows that firms in the first quartile of total sales reduces domestic sales by approximately 423,384 HUF in order to increase its exports by 824,000 HUF, whereas the median manufacturing firm reduces its domestic sales by 1,882,608 HUF in order to increase its exports by 5,131,400 HUF. Clearly the net effect is an increase in total sales, consistent with the model's prediction[19].

In column (8) and (9), we report the coefficients for the relationship between domestic and export sales when all variables are expressed in first differences. We use the first difference of the foreign demand as instruments for the first difference of export sales. Industry- year fixed effects is included in both columns, however we include firm fixed effect only in column (9). Our results, in both columns are significant, but the magnitude is weak. These specifications imply that growth in export sales as a result of growth in foreign demand shock reduces the growth in domestic sales. Overall, our results suggests the presence of an increasing marginal costs of production.

We compare these results with similar studies in the literature (Berman et al., 2015, Ahn and McQuoid, 2017 and Almunia et al., 2018). Berman et al. (2015) estimates the relationship between domestic and foreign sales using French firm-level data during the periods 1995–2001. We estimate a regression specification similar to columns (2) and (3) in Table (3) of Berman et al. (2015) and reports our coefficients in columns (3) and (4) Table (2.3). As argued by Berman et al. (2015), this specification provides a causal effect

[19]This can be clearly seen by taking derivatives of equation (2.3.12), (2.3.13) and (2.3.14b) with respect to ζ_{jFt}

of exporting on domestic sales, and not estimates of the marginal cost structure[20]. They find that exports induced by an exogenous foreign-demand shock led to an increase in domestic sales, contradicting our estimates that finds a decrease in domestic sales. The disparity in the two results could be attributed to differences in production capacity and financial market development across the two countries. It is imperative to note that the period for our analysis spans between 1993 to 2003, prior to Hungary entry to the EU. It is likely that the financial markets in Hungary during this period was less developed than that in France, and Hungarian firms may have been unable to access capital required to scale up capacity prior to exporting.
We also estimate similar regression specifications as in Ahn and McQuoid (2017)-Table (5)- in their study on Indonesia, and compare our estimates with theirs. Results from these specifications were reported in Table (2.18) in the appendix. Clearly our findings are very similar to theirs with slight differences in magnitude, confirming the prevalence of increasing marginal cost structure. Almunia et al. (2018) studies a similar question as ours using firm-level information from Spain. Unlike our regression specification, theirs regresses exports on domestic sales while controling for some observables. We estimate a similar regression equation as theirs and report the results in Table (2.19) in the appendix. Comparing our estimates with theirs (in Table 1), we find a similar pattern in almost all cases with some differences in the magnitude. The coefficient on domestic sales in their most preferred specification is -0.28 and statistically significant at 1% levels. In ours (Column 4, of Table 2.19), it is -0.20 and also significant at 1% levels.

2.4.2 Structural Method Results

We present the results from the second empirical strategy in Table (2.4) columns 1-6. In column 1, we omit capital from this specification. This is expected to bias the coefficient of exports γ upwards towards zero if increasing marginal cost is prevalent because capital is correlated with both domestic and export sales. This is confirmed when we compare column 1 (-0.045) to column 2 (-0.067)- a case where we control for capital. This suggests that firms simultaneously increase capital investments with exporting. Note that in both columns (1) and (2), we exclude the variable that captures the demand shocks addressed to a firm z_{jt}. This exclusion is expected to bias our results upwards towards zero. We confirm this in column 3 as coefficient of exports is -0.084 compared to -0.067 in column 2. Our preferred specification is column 3, where we control for the demand conditions, productivity and capital inputs of the firm to reduce the possibility of omitted variables bias. Our estimates imply that a 10% increase in exports (while controlling for foreign

[20] Hummels et al. (2014) argues that this specification allows the supply shocks(such as productivity) to jointly influence the relationship between exports and domestic sales

Table 2.3: Estimating the Effects of Foreign sales on Domestic Sales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Estimator	OLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	(2SLS)
Dep. variable	ln of domestic sales							Δ ln of domestic sales	
ln export sales$_{it}$	-0.058	-0.114	0.032	-0.100	-0.128	-0.129	-0.156		
	(0.016)**	(0.024)**	(0.016)*	(0.039)*	(0.033)**	(0.044)**	(0.030)**		
ln domestic demand$_{it}$	0.030	0.070		0.062	0.051	0.051	0.037		
	(0.006)**	(0.009)**		(0.014)**	(0.012)**	(0.011)**	(0.009)**		
ln productivity$_{it}$	0.512				0.550	0.547	0.683		
	(0.036)**				(0.042)**	(0.037)**	(0.051)**		
ln capital$_{it}$							0.356		
							(0.017)**		
ln no. of firms$_{st}$		0.098							
		(0.080)							
ln sector domsales$_{it}$		0.378							
		(0.041)**							
ln export$_{it}$×export share$_{i0}$						0.010			
						(0.088)			
Δln export sales$_{it}$								-0.063	-0.041
								(0.018)**	(0.022)$^{+}$
Δln domestic demand$_{it}$								0.021	0.011
								(0.005)**	(0.005)$^{+}$
Δln productivity$_{it}$								0.487	0.455
								(0.031)**	(0.027)**
Observations	41886	41886	41886	41886	41886	41886	41886	29629	27696
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Year Dummies	No	Yes	No	No	No	No	No	No	No
Sector×yearr FE	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kleib.-Paap stat.		196.73	1170.55	215.70	247.26	573.71	278.40	159.23	98.54

Notes: Robust standard errors, clustered by industry in parentheses. Firm fixed effects is included in all estimation except column (7). In column (1), I report the OLS, column (2)-(8) reports the IV results. Our instrument in (2)-(6) is the foreign demand in HS6 variety exported by the firm. In columns (7)-(8) we use the first difference of the foreign demand. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$ are 1%, 5% and 10% significant levels respe-. tively

10.14754/CEU.2018.12

demand shock and other relevant variables) implies a 0.84% decrease in domestic sales. Quantifying these results in terms of our data suggests that, all things being equal, a firm in the first quartile will have to reduce its domestic sales by 228,000 HUF in order to increase it exports by 824,000 HUF, whereas the median firm will have to reduce its domestic sales by 1,014,000 HUF so as to increase its exports by 5,131,300 HUF. Clearly, these effects are statistically and economically significant. Columns (4-6) presents the case where we take the first-differences of variables. Clearly we observe that our results are strongly negative compared to when levels were used. An interpretation of this difference in coefficients between levels and first-differences is the idea that the missing time-varying covariates (time-varying demand shocks and capital) are strongly serially correlated and share similar underlying trends with the corresponding firm-level exports, however, their year-to-year variation is weakly correlated with annual changes in exports. In sum, our results suggest the pervasiveness of increasing marginal cost structure for manufacturing firms in Hungary. Findings from both methodology are qualitatively similar and points to the same directions, thus invalidating the constant marginal cost assumption in standard trade models.

Table 2.4: Estimating the Effects of Foreign sales on Domestic Sales

Dependent	(1)	(2)	(3)	(4)	(5)	(6)
Variable	ln domestic sales			Δ ln domestic sales		
ln export sales	-0.045	-0.067	-0.084			
	(0.003)**	(0.003)**	(0.010)**			
ln productivity	1.275	1.253	1.267			
	(0.020)**	(0.020)**	(0.025)**			
ln capital		0.174	0.177			
		(0.005)**	(0.005)**			
Δ ln export sales				-0.066	-0.074	-0.133
				(0.002)**	(0.002)**	(0.008)**
Δ ln productivity				1.479	1.506	1.546
				(0.018)**	(0.021)**	(0.023)**
Δ ln capital					0.159	0.167
					(0.004)**	(0.004)**
Observations	127278	127278	127278	93965	93965	93965
Firm FE	yes	yes	yes	yes	yes	yes
Industry-Year Dummies	yes	yes	yes	yes	yes	yes
Demand Shocks	no	no	yes	no	no	yes
Rsquared	0.831	0.851	0.854	0.692	0.705	0.707

Notes: This regression reports the results for the estimation of the increasing marginal cost structure for all manufacturing firms in Hungary. Robust standard errors clustered at the firm-level are in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$.

2.4.3 Robustness

We check the robustness of our results by using alternative instruments and sample restrictions as enumerated below to ensure that our results are not sensitive to any specific method of computation of our instruments or any source of exogenous variation.

1. First, we exclude motor and motor vehicles industry from our data. This is because of the huge presence of multinational firms' subsidiaries involved in the value-chain process in the Hungarian auto industry . Domestic suppliers of auto parts may sell to both these subsidiaries and to their parent company (Bisztray, 2016). It might be the case that these firms substitutes between selling to a parent foreign company and its subsidiaries in Hungary if multinational auto firms are switching production across different locations. Excluding these industries will ensure that our results are not driven by these patterns. We present the findings in the appendix Table 2.6. The coefficients of exports are very identical to our baseline results.

2. Second, we substract the values of yearly exports from Hungary of each HS6 product from the imports of countries serviced by Hungarian firms in constructing the foreign demand instrument. This ensures our instruments are not driven by supply shocks from Hungary, but demand shocks from those countries. We present the results from this adjustment in Table (2.8) in the appendix. The coefficients of exports are very identical to our baseline results.

3. Third, more productive firms may produce more of a specific good and may select themselves into specific markets. If such markets grow faster on average, this implies that the weights we use in constructing the instruments is correlated with time-varying firm-level characteristics such as productivity and will introduce some bias in our estimation. Firm fixed-effect backs out time-invariant characteristics but not the time-varying ones. To address this possibility, we reconstruct our baseline instruments using weights for the first period which the firm exports. By doing this, we restrict our data to only firms for which we observe their first period of export entry. Most firms during their first period of exporting, sells fewer number of products to fewer destinations. We further restrict the data to only firm's products that were exported in the first period which the firm began exporting. By doing this, we lose 66% of our initial observations. The estimates using this instrument is reported in Table (2.7) of the appendix (also see Table (2.11) for the first stage results). The coefficients of exports are very identical to our baseline results.

4. Fourth, we consider the foreign demand addressed to the core product of the firm while still controlling for domestic demand addressed to the core product. We de-

fine firms' core products as the HS-4 product with the highest value of exports in the period we observe. Eckel et al. (2015) finds that firm's tend to produce more of products in their core competence because of lower costs. A foreign demand shock on a firms core products could be a good instrument for firm's exports. We create instruments that reflects foreign demand shock in the firm's core competence and study the effect of exports driven by this foreign shock on domestic sales. This instrument is constructed in a similar way as our baseline instruments. Specifically, we define the foreign demand instruments as $F_{jt}^{core} = \sum_d s_{jd}^{core} IM_{d,t}^{core}$, and the domestic demand as $D_{jt}^{core} = IM_{HUN,t}^{core}$ respectively, where s_{jd}^{core} is the weight of firm j's core product exported to destination d, constructed as the ratio of total exports of the core product to destination d to the total exports of its core products to all destinations. We report the estimate using this instrument in Table 2.5 in the appendix. Our estimates here are identical to our baseline results.

5. Finally, it could be that the estimated increasing marginal cost is irrelevant in the mid or long term. That is, firms invest in capacity and produce at a constant marginal cost. To check for this possibility, we estimate up to the fourth-differences using our structural strategy and balance sheet data. Our choice for this strategy and data lies in the longer span of the balance sheet data which make it possible to check for up to the fourth-differences. We present our results in Table (2.14) of the appendix. In all specifications, we still find a negative and statistically significant relationship between exports and domestic sales. The magnitude of the negative relationship declined marginally over time from -0.133 for first differences and -0.119 for the fourth differences. This implies that capital adjust slowly over time, consistent with Dix-Carneiro (2014) which finds that adjustments to trade liberalization may take several years using Brazilian data.

Does this finding have any implication for welfare? In the next section, we explore the welfare implication of trade liberalization in a standard long-run trade model with increasing marginal cost technology.

2.5 Welfare Implications of Increasing Marginal Costs

In this section, we propose an extension of Melitz (2003) model of international trade by introducing an increasing marginal cost structure, and highlighting the mechanisms through which it reduces aggregate welfare. Our point here is to emphasize that domestic policies which help firms scale up production capacity have a role in ensuring that the full gains from trade are realized.

2.5.1 An Economy Without Trade

The demand side is unchanged, with preferences of a representative consumer given by the usual C.E.S. utility function over a continuum of goods and subject to the budget constraint. This yields the usual demand, revenue, aggregate revenue and price equations given by: $q_h(\omega) = p_h(\omega)^{-\sigma} P_h^{\sigma} Q_h$; $r_h(\omega) = p_h(\omega)^{1-\sigma} P_h^{\sigma-1} R_h$; $R_h \equiv P_h Q_h = \int_{\omega\in\Omega} r(\omega)d\omega$; and $P_h = \left[\int_{\omega\in\Omega} p_h(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}}$ respectively, where $\sigma > 1$ is the elasticity of substitution between any two goods and ω denotes varieties.

On the supply side, we assume a representative industry with a continuum of firms, each producing a different good ω using labor l as the only input which is supplied inelastically at its aggregate level L. The firm produces with a technology that exhibits an increasing marginal cost $q = \psi l^{\alpha_l}$ where ψ is productivity, with $0 < \alpha_l < 1$ and a fixed overhead costs f. The average cost function is denoted as:

$$l = f + \left(\frac{q}{\psi}\right)^{\alpha} \qquad \text{where } \alpha \equiv \frac{1}{\alpha_l} > 1$$

Wage is normalised to one. The profit maximization implies a pricing rule of the form:

$$p_h(\psi(\omega)) = \left(\frac{\sigma}{\sigma-1}\alpha\right)^{\frac{V}{\alpha}} \left(\frac{1}{\psi(\omega)}\right)^{V} (P_h^{\sigma-1} R_h)^{\frac{(\alpha-1)V}{\alpha}} \tag{2.5.1}$$

where $V = \frac{\alpha}{1+\sigma(\alpha-1)} < 1$. The corresponding profit of the firm is $\pi(\psi) = \frac{r_h(\psi)}{V\sigma} - f$, where $r_h(\psi)$ is denoted as:

$$r_h(\psi) = \left(\frac{\rho}{\alpha}\right)^{\frac{(\sigma-1)V}{\alpha}} (P_h\psi)^{V(\sigma-1)} R_h^V \tag{2.5.2}$$

So profit can be written as:

$$\pi(\psi) = \frac{R_h^V}{V\sigma}\left(\frac{\rho}{\alpha}\right)^{\frac{(\sigma-1)V}{\alpha}} (P_h\psi)^{V(\sigma-1)} - f \tag{2.5.3}$$

where $\rho = \frac{\sigma-1}{\sigma}$. It follows that the ratio of any 2 firms' output and revenue depends on the ratio of their productivity:

$$\frac{q(\psi_1)}{q(\psi_2)} = \left(\frac{p(\psi_2)}{p(\psi_1)}\right)^{\sigma} = \left(\frac{\psi_1}{\psi_2}\right)^{V\sigma}; \qquad \frac{r(\psi_1)}{r(\psi_2)} = \left(\frac{\psi_1}{\psi_2}\right)^{V(\sigma-1)} \tag{2.5.4}$$

This implies that more productive firms have bigger output, sales revenue and profits, however the magnitude is lesser compared to Melitz (2003) since the elasticity of substitution is scaled by a constant V such that $0 < V < 1$[21] .

Aggregation

Let M be mass of firms and $\mu(\psi)$ be a distribution of productivity over a subset of $(0, \infty)$ for producing firms, then the aggregate price can be rewritten as $P_h = \left[\int_0^\infty p_h(\psi)^{1-\sigma} M\mu(\psi)d\psi \right]^{\frac{1}{1-\sigma}}$. Using equation (2.5.1) we can express the aggregate price as:

$$P_h = M^{\frac{1}{V(1-\sigma)}} \left(\frac{\alpha}{\rho} \right)^{\frac{1}{\alpha}} \left(\frac{1}{\tilde{\psi}} \right) R_h^{\frac{\alpha-1}{\alpha}} \tag{2.5.5}$$

where $\tilde{\psi}$ is the weighted average productivity of firms and expressed as:

$$\tilde{\psi} = \left[\int_0^\infty (\psi)^{V(\sigma-1)} \mu(\psi) d\psi \right]^{\frac{1}{V(\sigma-1)}} \tag{2.5.6}$$

and the weighted average aggregate revenue and profit respectively.

$$R_h = \int_0^\infty r(\psi) M\mu(\psi) d\psi = Mr(\tilde{\psi})$$

$$\Pi = \int_0^\infty \pi(\psi) M\mu(\psi) d\psi = M\pi(\tilde{\psi})$$

Free Entry Condition

We assume a large pool of potential entrants into the industry. Before entry, firms make an initial investment (sunk cost) denoted by f_e in terms of units of labor and then draws its initial productivity ψ from a common distribution $f(\psi)$ with support over $(0, \infty)$ and with a cumulative density function denoted by $F(\psi)$. A Firm that realises low productivity draws may decide to exit immediately without producing. Firms that produces faces a constant probability δ of exiting in each period. The resulting value function of each firm becomes:

$$\nu(\psi) = \max\{0, \frac{1}{\delta}\pi(\psi)\}$$

where $\psi^* = \inf\{\psi : \nu(\psi) > 0\}$ identifies the cut-off productivity of producing firms. This implies that $\pi(\psi^*) = 0$ is the zero cutoff profit condition. The distribution of productivity

[21] This consistent with a few and growing literature which showed that the Melitz model overstates the differences in sales between more productive and less productive firms. For example Armenter and Koren (2015) showed that while exporters are more productive than non-exporters, they have 4-5 times more total sales than non-exporters. However, the Melitz model would predict that exporters are expected to have 90 to 100 times larger total sales compared to non-exporters.

is therefore determined by the initial productivity draws conditional on successful entry.

$$\mu(\psi) = \begin{cases} \frac{f(\psi)}{1-F(\psi^*)} & \text{if } \psi \geq \psi^* \\ 0 & \text{otherwise} \end{cases}$$

Therefore, the ex-ante probability of entry and producing is $p_{in} = 1 - F(\psi^*)$. This defines aggregate productivity in equation (2.5.6) as a function of the cut-off productivity

$$\tilde{\psi}(\psi^*) = \left[\frac{1}{1-F(\psi^*)} \int_{\psi^*}^{\infty} \psi^{V(\sigma-1)} f(\psi) d\psi\right]^{\frac{1}{V(\sigma-1)}}$$

Let $\bar{\nu} = \frac{1}{\delta}\bar{\pi}$ be average value of firms, conditional on successful entry. So value of entry becomes:

$$\nu_e = p_{in}\bar{\nu} - f_e = \frac{1-F(\psi^*)}{\delta}\bar{\pi} - f_e$$

Since the mass of prospective entrant is unbounded, free entry condition implies that firms will enter till the value of entry is zero:

$$\bar{\pi} = \frac{\delta f_e}{1-F(\psi^*)} = \frac{\delta f_e}{p_{in}} \tag{2.5.7}$$

Zero Cut-off Profit Condition

Weighted average profits and revenue can be defined in terms of the cut-off level as:

$$\bar{r} \equiv r(\tilde{\psi}) = \left[\frac{\tilde{\psi}(\psi^*)}{\psi^*}\right]^{V(\sigma-1)} r(\psi^*)$$

$$\bar{\pi} \equiv \pi(\tilde{\psi}) = \left[\frac{\tilde{\psi}}{\psi^*}\right]^{V(\sigma-1)} \frac{r(\psi^*)}{V\sigma} - f$$

The zero profit condition pins down the revenue of the cut-off firm given by $\pi(\psi^*) = 0 \implies r(\psi^*) = V\sigma f$. Let $k(\psi^*) = (\tilde{\psi}(\psi^*)/\psi^*)^{V(\sigma-1)} - 1$, we express average profit and revenue as:

$$\bar{\pi} = fk(\psi^*), \qquad \bar{r} \equiv r(\tilde{\psi}) = \left[\frac{\tilde{\psi}(\psi^*)}{\psi^*}\right]^{V(\sigma-1)} V\sigma f \tag{2.5.8}$$

Equilibrium in Closed Economy

The free entry and zero cut-off profit condition pins down the cut-off productivity ψ^* and average profit $\bar{\pi}$. Let $L = L_p + L_e$ where L_p and L_e represent respectively the aggregate labor used for production and initial investment prior to entry. Then $L_p = R_h - \Pi$ and $L_e = M_e f_e$, where M_e is the mass of potential entrants. In equlibrium, we impose an aggregate stability condition such that new entrants will equate existers

$$p_{in}M_e = \delta M \implies M_e = \frac{\delta M}{p_{in}}$$

$$L_e = M_e f_e = \frac{\delta M}{p_{in}} f_e = \bar{\pi} M = \Pi$$

So the aggregate revenue is show as:

$$L = L_p + L_e = R - \Pi + \Pi \implies L = R_h$$

This implies that

$$M = \frac{R_h}{\bar{r}} = \frac{L}{V\sigma(\bar{\pi} + f)}$$

The aggregate price in equation (2.5.5) can be expressed in the form below:

$$P_h = M^{\frac{1}{V(1-\sigma)}} \left(\frac{\alpha}{\rho}\right)^{\frac{1}{\alpha}} \left(\frac{1}{\tilde{\psi}}\right) L^{\frac{\alpha-1}{\alpha}}$$

Welfare per worker defined as $W = P_h^{-1}$ is given by:

$$W = M^{\frac{1}{V(\sigma-1)}} \left(\frac{\rho}{\alpha}\right)^{\frac{1}{\alpha}} L^{\frac{1-\alpha}{\alpha}} \tilde{\psi} \tag{2.5.9}$$

Welfare is larger in a bigger country because of an increase in product varieties. Note that for $\alpha = 1$ (constant marginal cost), we obtain same welfare as in Melitz (2003). In sum, welfare in the close economy exhibits same qualitative characteristics as the case with constant marginal cost.

2.5.2 An Economy with Trade

We now consider an open economy where a firm can export to a foreign country. For simplicity, we assume one export market which is symmetric to the domestic economy in every aspect. Consumers in both countries have same CES preferences, and chooses variety to consume subject to a budget constraint. The demand equation in both countries are the same and equal to that derived in the closed economy.

On the supply side, firms are producing with an increasing marginal cost technology. This implies that firms can not maximise profits independently in both foreign and domestic markets. We denote f_x as fixed cost of exporting and express total variable cost function:

$$l = \left(\frac{q_f + q_h}{\psi}\right)^{\alpha}$$

We assume that consumers in foreign market bears the per unit trade cost $\tau > 1$ which implies that the price a firm sells a product in a foreign country is different from the price a consumer pays for it. Let $p_f^*(\omega)$ be price a producer sells its product in the foreign country and $p_f(\omega)$ the price a consumer in the foreign country buys this product such that $p_f(\omega) = \tau p_f^*(\omega)$. Profit maximization yields the following FOC for prices:

$$p_h(\omega) - \frac{\sigma\alpha}{\sigma - 1}\psi^{-\alpha}\left(p_h(\omega)^{-\sigma} R_h P_h^{\sigma-1} + p_f^*(\omega)^{-\sigma}\tau^{-\sigma} P_f^{\sigma-1} R_f\right)^{\alpha-1} = 0$$

$$p_f^*(\omega) - \frac{\sigma\alpha}{\sigma - 1}\psi^{-\alpha}\left(p_h(\omega)^{-\sigma} R_h P_h^{\sigma-1} + p_f^*(\omega)^{-\sigma}\tau^{-\sigma} P_f^{\sigma-1} R_f\right)^{\alpha-1} = 0$$

This implies same factory gate prices for both domestic and export market. Since $p_f = \tau p_f^* = \tau p_h$, it follows that $P_f = \tau P_h$. The domestic price of an exporter with productivity ψ can be expressed as:

$$p_{h,exp}(\psi) = \left(\frac{\alpha}{\rho}\right)^{\frac{V}{\alpha}} \left(\frac{1}{\psi}\right)^{V} \left[P_h^{\sigma-1}(R_h + \tau^{-1} R_f)\right]^{\frac{(\alpha-1)V}{\alpha}} \tag{2.5.10}$$

With the assumption of symmetry, price of imported variety becomes:

$$p_{f,imp}(\psi) = \tau p_{h,exp}(\psi) = \tau \left(\frac{\alpha}{\rho}\right)^{\frac{V}{\alpha}} \left(\frac{1}{\psi}\right)^{V} \left[P_h^{\sigma-1}(R_h + \tau^{-1} R_f)\right]^{\frac{(\alpha-1)V}{\alpha}} \tag{2.5.11}$$

The aggregate expenditure in both markets are equal, so revenue of an exporting firm with productivity ψ in both markets becomes:

$$r_h(\psi) = \left(\frac{\rho}{\alpha}\right)^{\frac{V(\sigma-1)}{\alpha}} \psi^{V(\sigma-1)} P_h^{(\sigma-1)V} R_h^V (1 + \tau^{-1})^{V-1} \tag{2.5.12}$$

$$r_f(\psi) = \left(\frac{\rho}{\alpha}\right)^{\frac{V(\sigma-1)}{\alpha}} \psi^{V(\sigma-1)} P_h^{(\sigma-1)V} R_f^V \tau^{-1} (1 + \tau^{-1})^{V-1} \tag{2.5.13}$$

and total revenue is expressed as:

$$r_T(\psi) = \begin{cases} \left(\frac{\rho}{\alpha}\right)^{\frac{V(\sigma-1)}{\alpha}} \psi^{V(\sigma-1)}(P_h^{\sigma-1}R_h)^V & \text{if firm sells at home} \\ \left(\frac{\rho}{\alpha}\right)^{\frac{V(\sigma-1)}{\alpha}} \psi^{V(\sigma-1)}P_h^{(\sigma-1)V}R_h^V(1+\tau^{-1})^V & \text{if firm sells in both} \end{cases} \tag{2.5.14}$$

We see that the relationship between domestic and export sales is driven by the marginal cost technology α. Clearly, a drop in tariffs leads to a decrease in domestic sales and an increase in export sales. This pattern is absent in Melitz (2003) as firms maximize profits independently across markets. Aggregate revenue increases at a slower magnitude with declining tariffs, and profits remains unchanged when compared to the model with constant marginal cost as shown below.

The profit of an exporting firm is given by: $\pi(\psi) = r_h + r_f - \frac{1}{\psi^\alpha}(q_h + q_f)^\alpha - f - f_x$ where $\frac{1}{\psi^\alpha}(q_h + q_f)^\alpha = p_h(\psi)^{1-\sigma}R_hP_h^{\sigma-1}(1+\tau^{-1})\frac{\rho}{\alpha}$ and $r_h + r_f = p_h(\psi)^{1-\sigma}R_hP_h^{\sigma-1}(1+\tau^{-1})$. We now express profit as:

$$\pi(\psi) = \frac{r_h + r_f}{\sigma V} - f - f_x \tag{2.5.15}$$

such that each firms' profit in export and domestic market is given by:

$$\pi_d(\psi) = \frac{r_d(\psi)}{V\sigma} - f, \qquad \pi_f(\psi) = \frac{r_x(\psi)}{V\sigma} - f_x$$

A firm exports if $\pi_f(\psi) \geq 0$, so a firm's combined profit is defined as:

$$\pi(\psi) = \pi_d(\psi) + \max\{0, \pi_f(\psi)\}$$

Similar to the closed economy case, let $\psi_x^* = inf\{\psi : \psi \geq \psi^* \text{ and } \pi_f(\psi) \geq 0\}$ represent the new cut-off productivity level for exporting firms. Thus, if $\psi_x^* > \psi^*$ then some firms with productivity levels between ψ^* and ψ_x^* produce only for the domestic market. Let $k_x = \frac{1-F(\psi_x^*)}{1-F(\psi^*)}$ denote the ex-ante probability that a successful entrant exports (i.e. fraction of exporting firms). We thus represent $M_x = k_xM$ as the mass of exporting firms. The aggregate price of domestically produced varieties sold in the home country is given by:

$$P_h = \left[\int_0^\infty M[(1-k_x)p_h(\psi)^{1-\sigma} + k_xp_{h,exp}(\psi_x)^{1-\sigma}]d\mu(\psi)\right]^{\frac{1}{1-\sigma}}$$

where $p_h(\psi) = \left(\frac{\alpha}{\rho}\right)^{\frac{V}{\alpha}}\left(\frac{1}{\psi}\right)^V(P_h^{\sigma-1}R_h)^{\frac{(\alpha-1)V}{\alpha}}$ is the price in non-exporting firms and $p_{h,exp}(\psi_x) = \left(\frac{\alpha}{\rho}\right)^{\frac{V}{\alpha}}\left(\frac{1}{\psi_x}\right)^V(P_h^{\sigma-1}R_h)^{\frac{(\alpha-1)V}{\alpha}}\left[(1+\tau^{-1})\right]^{\frac{(\alpha-1)V}{\alpha}}$ is the price in exporting firms.

Simplifying, we obtain the aggregate price expressed below as:

$$P_h = M^{\frac{1}{(1-\sigma)V}} \left(\frac{\alpha}{\rho}\right)^{\frac{1}{\alpha}} R_h^{\frac{\alpha-1}{\alpha}} \tilde{\psi}^{-V} [(1-k_x) + k_x(1+\tau^{-1})^{V-1}]^{\frac{1}{(1-\sigma)V}} \tag{2.5.16}$$

Firm Entry and Exit

We derive the equilibrium conditions in this sub-section. We start with the zero profit condition and later, the free entry condition. In an economy with trade, average domestic revenue is given by: $r_d(\tilde{\psi}) = \int_0^\infty r(\psi)\mu(\psi)d\mu$, which can be expressed as:

$$r_d(\tilde{\psi}) = \left(\frac{\rho}{\alpha}\right)^{\frac{V(\sigma-1)}{\alpha}} P_h^{(\sigma-1)V} R_h^V \Big[(1-k_x) + k_x(1+\tau^{-1})^{V-1}\Big] \tilde{\psi}(\psi^*)^{V(\sigma-1)} \tag{2.5.17}$$

For a firm with the cut-off productivity of entry (ψ^*), this firm sells only in the domestic market since $\psi^* < \psi_x^*$, so it's domestic revenue is given by:

$$r_d(\psi^*) = \left(\frac{\rho}{\alpha}\right)^{\frac{V(\sigma-1)}{\alpha}} \psi^{*V(\sigma-1)} (P_h^{\sigma-1} R_h)^V$$

Taking the ratio of average domestic to cut-off revenue, we express average domestic revenue in terms of the cut-off revenue as:

$$r_d(\tilde{\psi}) = \gamma \left(\frac{\tilde{\psi}(\psi^*)}{\psi^*}\right)^{V(\sigma-1)} r_d(\psi^*) \qquad \text{where } \gamma = (1-k_x) + k_x(1+\tau^{-1})^{V-1}$$

From the cut-off profits, we have that $\pi_d(\psi^*) = \frac{r_d(\psi^*)}{V\sigma} - f = 0$, so that the cut-off domestic revenue becomes $r_d(\psi^*) = fV\sigma$ and average profit from domestic sales is expressed as:

$$\pi_d(\tilde{\psi}) = \gamma \left(\frac{\tilde{\psi}(\psi^*)}{\psi^*}\right)^{V(\sigma-1)} \frac{r_d(\psi^*)}{V\sigma} - f = fk(\psi^*)$$

where $k(\psi^*) = \left[\gamma\left(\frac{\tilde{\psi}(\psi^*)}{\psi^*}\right)^{V(\sigma-1)} - 1\right]$. Similarly, a firm with the export productivity cut-off ψ_x^* makes zero profit from exporting such that the cut-off export revenue is:

$$\pi_f(\psi_x^*) = 0 \implies r_f(\psi_x^*) = V\sigma f_x$$

We express the average export sales revenue and profit below as:

$$r_f(\tilde{\psi}_x) = \left(\frac{\tilde{\psi}_x(\psi_x^*)}{\psi_x^*}\right)^{V(\sigma-1)} r_f(\psi_x^*) = \left(\frac{\tilde{\psi}_x(\psi_x^*)}{\psi_x^*}\right)^{V(\sigma-1)} V\sigma f_x$$

$$\pi_f(\tilde{\psi}_x) = f_x k(\psi_x^*)$$

where $k(\psi_x^*) = (\tilde{\psi}_x(\psi_x^*)/\psi_x^*)^{V(\sigma-1)} - 1$. The zero cut-off profit condition implies that:

$$\frac{r_f(\psi_x^*)}{r_d(\psi^*)} = \left(\frac{\psi_x^*}{\psi^*}\right)^{V(\sigma-1)} \tau^{-1}(1+\tau^{-1})^{V-1} = \frac{V\sigma f_x}{V\sigma f}$$

$$\psi_x^* = \psi^*[\tau(1+\tau^{-1})^{1-V}]^{\frac{1}{V(\sigma-1)}} \left(\frac{f_x}{f}\right)^{\frac{1}{V(\sigma-1)}} \tag{2.5.18}$$

Equation (2.5.18) defines the cut-off export productivity. It is decreasing with trade liberalization, consistent with the literature. We now derive an expression for average profit as a function of the cut-off productivity levels.

$$\bar{\pi} = \pi_d(\tilde{\psi}) + k_x \pi_x(\tilde{\psi}_x) = f k(\psi^*) + k_x f_x k(\psi_x^*) \qquad \textbf{New ZCP} \tag{2.5.19}$$

The free entry condition is same as the closed economy case. That is the value of entry $\nu_e = 0$ if and only :

$$\bar{\pi} = \frac{\delta f_e}{k_{in}} \qquad \textbf{FE}$$

The new ZCP curve and FE curve identifies ψ^* and $\bar{\pi}$ (proof is similar to that in Melitz (2003)) which in turn determines the export productivity cut-off ψ_x^* in equation (2.5.18), as well as average productivity $\tilde{\psi}$, $\tilde{\psi}_x$ and the ex-ante successful entry and export probabilities p_{in} and k_x. Using the stability condition $p_{in} M_e = \delta M$, we have the total quantity of labour used in entry to be: $L_e = M_e f_e = \frac{\delta f_e}{p_{in}} M = \bar{\pi} M = \Pi$. Since aggregate labour used in production must satisfy $L_p = R_h - \Pi$, then total labour $L = L_p + L_e$ is the same as the closed economy case and equal to $L = R_h$. From the average revenue equation $\bar{r} = r_d(\tilde{\psi}) + k_x r_x(\tilde{\psi}_x)$ and profit $\bar{\pi} = \pi_d(\tilde{\psi}) + k_x \pi_x(\tilde{\psi}_x)$, we show that both average revenue and profits can be expressed as:

$$\bar{\pi} = \frac{r_d(\tilde{\psi})}{V\sigma} + k_x \frac{r_x(\tilde{\psi}_x)}{V\sigma} - f - k_x f_x \implies \bar{r} = V\sigma(\bar{\pi} + k_x f_x + f)$$

So the total sales and mass of producing firms is expressed below as:

$$R_h = \bar{r} M \implies M = \frac{L}{V\sigma(\bar{\pi} + k_x f_x + f)}$$

Therefore, the aggregate price of domestically produced goods in equation (2.5.16) can be written as:

$$P_h = M^{\frac{1}{(1-\sigma)}} \left(\frac{\alpha}{\rho}\right)^{\frac{1}{\alpha}} \tilde{\psi}^{-V} f(\tau)[V\sigma(\bar{\pi} + k_x f_x + f)]^{\frac{\alpha-1}{\alpha}} \tag{2.5.20}$$

Where $f(\tau) = [(1-k_x)+k_x(1+\tau^{-1})^{V-1}]^{\frac{1}{(1-\sigma)V}}$ is a decreasing function of τ (i.e. $\frac{df(\tau)}{d\tau} < 0$). Equation (2.5.20) implies that trade liberalization (tariff reduction), may result to rising prices of domestic goods in the home country as tariffs has a direct negative effect on the aggregate price index of domestic varieties. This effect is a direct consequence of the increasing marginal cost structure. Intuitively, consider a firm producing at full capacity and selling only in the domestic economy. With decreasing tariffs, this firm is faced with increased demand from abroad. In order to meet demands in both markets, the firm hires additional workers which marginally increases its production. Given that the production plant is fixed and capacity constrained, marginal cost of production will rise which is reflected in the price of domestic varieties. If it was a constant marginal cost technology ($\alpha = 1$), there will be no direct effect of tariff reduction on aggregate price of domestic goods[22].

We now consider the price of imported variety in deriving an expression for the aggregate price. Denote $M_t = M + M_x$ as the number of domestic and imported varieties in the economy. The aggregate price will be a combination of domestic price of products manufactured by non-exporters and exporters, and the price of imported varieties multiplied by the tariffs. By symmetry, we also assume that the foreign country produces with an increasing marginal cost technology[23]. The new aggregate price is expressed as:

$$P_h^a = \left[\int_0^\infty \{M[(1-k_x)p_h(\psi)^{1-\sigma} + k_x p_{h,exp}(\psi_x)^{1-\sigma}] + M_x\tau^{1-\sigma}p_{h,imp}(\psi_x)^{1-\sigma}\}d\mu(\psi)\right]^{\frac{1}{1-\sigma}}$$

where $p_{h,imp}(\psi_x) = p_{h,exp}(\psi_x)$. We define the weighted average productivity $\tilde{\psi}_t$ of all firms selling in a country as :

$$\tilde{\psi}_t = \left[\frac{1}{M_t}\left\{M[(1-k_x)+k_x(1+\tau^{-1})^{V-1}]\tilde{\psi}^{V(\sigma-1)} + M_x\tau^{1-\sigma}(1+\tau^{-1})^{V-1}\tilde{\psi}_x^{\,V(\sigma-1)}\right\}\right]^{\frac{1}{V(\sigma-1)}}$$

[22]There will be indirect effects as shown in Melitz (2003). A reduction in tariffs will result in higher average productivity ($\frac{d\tilde{\psi}}{d\tau} > 0$) through reallocation of market shares to more productive firms, which obviously reduces the aggregate price of domestic goods. On the other hand, due to an upward shift in the cut-off productivity (ψ^*) from declining tariffs, average profit increases resulting to a declining mass of firms ($\frac{dM}{d\tau} < 0$), which imply an increase in aggregate price of domestic varieties. Both opposing channels are indirect effects of declining trade tariffs on aggregate price and these effects are present in the standard Melitz framework. The latter channel is true only if there are no imports of varieties from the foreign country. We will study the case of bilateral movement of goods below.

[23]The welfare losses we wish to highlight here is present even if a constant marginal cost structure is assume for the foreign country

where $\tilde{\psi}_x$ is the weighted average productivity of exporters in the foreign country. Re-expressing the aggregate price:

$$P_h^a = M_t^{\frac{1}{V(1-\sigma)}} \left(\frac{\alpha}{\rho}\right)^{\frac{1}{\alpha}} L^{\frac{\alpha-1}{\alpha}} \tilde{\psi}_t^{-1} \tag{2.5.21}$$

and welfare per worker becomes:

$$W = M_t^{\frac{1}{V(\sigma-1)}} \left(\frac{\rho}{\alpha}\right)^{\frac{1}{\alpha}} L^{\frac{1-\alpha}{\alpha}} \tilde{\psi}_t \tag{2.5.22}$$

Unlike Melitz (2003), where trade liberalization increases welfare per worker through its positive effect on average productivity $\tilde{\psi}$ and number of varieties M_t, in our model, the effect of trade liberalization on welfare is not straightforward. While the channel for productivity gains from trade tariffs reduction is still at play here, our model imply that trade liberalization may result to welfare losses. We summarize this finding below:

Prediction 1 *Under the increasing marginal cost assumption, there is a "new" channel for welfare losses associated with reduction in tariffs. This channel is absent in standard "new" trade models.*

See proof in the appendix. Our point here is that trade liberalization has two opposing effects on aggregate welfare. The first effect is an increase in aggregate productivity (larger welfare) through reallocation of resources from less to more productive firms. The second effect is the rise in firm-level prices, and aggregate prices (lower welfare). The dominating channel effect is unclear as we do not quantify the net effects due to data limitations.

Understanding the marginal cost structure is important as it sheds some information about whether firms are capacity constraint and helps to understand the welfare implication associated with trade liberalization. Since increasing marginal cost is a consequence of capacity constrained (Ahn and McQuoid, 2017, Suslow, 1986, Bresnahan and Suslow, 1989), our results highlight a significant role capacity plays in the ability of countries to fully benefits from globalization. Such market distortions can result to rising prices and a drop in consumer welfare (Soderbery, 2014). It suggests the importance of understanding and addressing the impact of production capacity on international trade.

2.6 Conclusion

In this paper, we employed a matched firm-product-destination dataset for exporting firms in Hungary and show that the firm's always substitute domestic sales for exports

while controlling for supply determinants. This suggests the prevalence of increasing marginal costs technology, contrary to the conventional assumption of constant marginal costs in models of international trade. With the objective of revalidating the welfare implications from trade liberalization, we build in an increasing marginal costs technology into Melitz (2003) trade model and find that trade liberalization (tariffs cuts) results to two opposing effects on aggregate welfare. On one hand, it increases welfare through its positive effect on aggregate productivity. On the other hand, it results to a new channel of welfare losses through its negative effects on firm-level prices (higher prices), which has not been accounted for in previous studies. Due to data limitations, we do not evaluate the net effect of trade liberalization on welfare, but we hope to do so in future work as the required data becomes available.
A number of existing literature using survey datasets where firms are asked if they are capacity constraint have attributed increasing marginal cost technology to production capacity constraints (Ahn and McQuoid, 2017). Thus, our results suggest that production capacity could hinder the full realization of the gains from trade liberalization, and makes a case for addressing production capacity through domestic policies concurrently with trade policies.

10.14754/CEU.2018.12

Appendix

Appendix 2.A Robustness Results

2.A.1 Some Derivations

Estimable Empirical Equations

We can rewrite equation (2.3.4) as

$$q_{jHt} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} \alpha_l^{\sigma} A_{jt}^{\frac{\sigma}{\alpha_l}} K_{jt}^{\frac{\sigma\alpha_k}{\alpha_l}} (q_{jHt} + q_{jFt})^{(\frac{\alpha_l-1}{\alpha_l})\sigma} \zeta_{jHt}\chi_{Ht}\eta_{jt}^{-\sigma}$$

where η_{jt} can be since as a random optimization error. Substituting equation (2.3.6) into the RHS of the above equation, we get:

$$q_{jHt} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} \alpha_l^{\sigma} A_{jt}^{\frac{\sigma}{\alpha_l}} K_{jt}^{\frac{\sigma\alpha_k}{\alpha_l}} \left(\frac{\zeta_{jHt}\chi_{Ht}\tau_{jt}^{\sigma}}{\zeta_{jFt}\chi_{Ft}} + 1\right)^{(\frac{\alpha_l-1}{\alpha_l})\sigma} q_{jFt}^{(\frac{\alpha_l-1}{\alpha_l})\sigma} \zeta_{jHt}\chi_{Ht} \tag{2.A.1}$$

Taking log of equation (2.A.1), and approximating $ln\left(\frac{\zeta_{jHt}\chi_{Ht}\tau_{jt}^{\sigma}}{\zeta_{jFt}\chi_{Ft}} + 1\right)$ to $ln\left(\frac{\zeta_{jHt}\chi_{Ht}\tau_{jt}^{\sigma}}{\zeta_{jFt}\chi_{Ft}}\right)$, we obtain the estimable equation (2.3.7).

Deriving Revenue Equations (2.3.12) and (2.3.13)

We express the FOC in equation (2.3.4) as: $q_{jHt} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} \alpha_l^{\sigma} A_{jt}^{\frac{\sigma}{\alpha_l}} K_{jt}^{\frac{\sigma\alpha_k}{\alpha_l}} (q_{jHt}+q_{jFt})^{(\frac{\alpha_l-1}{\alpha_l})\sigma} \zeta_{jHt}\chi_{Ht}$. We also express equation (2.3.6) in terms of exports as $q_{jFt} = \frac{\zeta_{jft}\chi_{Ft}q_{jHt}}{\zeta_{jHt}\chi_{Ht}\tau_{jt}^{\sigma}}$. Substituting q_{jFt} into q_{jHt} we obtain:

$$q_{jHt} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} \alpha_l^{\sigma} A_{jt}^{\frac{\sigma}{\alpha_l}} K_{jt}^{\frac{\sigma\alpha_k}{\alpha_l}} (\zeta_{jHt}\chi_{Ht} + \zeta_{jFt}\chi_{Ft}\tau_{jt}^{-\sigma})^{(\frac{\alpha_l-1}{\alpha_l})\sigma} q_{jHt}^{(\frac{\alpha_l-1}{\alpha_l})\sigma} (\zeta_{jHt}\chi_{Ht})^{\frac{1}{V}} \tag{2.A.2}$$

where $V = \frac{\alpha_l}{\alpha_l+\sigma(1-\alpha_l)}$. We express (2.A.2) as

$$q_{jHt}^{\frac{1}{V}} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} \alpha_l^{\sigma} A_{jt}^{\frac{\sigma}{\alpha_l}} K_{jt}^{\frac{\sigma\alpha_k}{\alpha_l}} (\zeta_{jHt}\chi_{Ht} + \zeta_{jFt}\chi_{Ft}\tau_{jt}^{-\sigma})^{(\frac{\alpha_l-1}{\alpha_l})\sigma} (\zeta_{jHt}\chi_{Ht})^{\frac{1}{V}}$$

so that domestic sales can be re-written as:

$$q_{jHt} = \left(\frac{\sigma-1}{\sigma}\alpha_l\right)^{\sigma V} A_{jt}^{\frac{\sigma V}{\alpha_l}} K_{jt}^{\frac{\sigma\alpha_k V}{\alpha_l}} (\zeta_{jHt}\chi_{Ht} + \zeta_{jFt}\chi_{Ft}\tau_{jt}^{-\sigma})^{(\frac{\alpha_l-1}{\alpha_l})\sigma V} (\zeta_{jHt}\chi_{Ht}) \tag{2.A.3}$$

Domestic revenue is express as: $r_{jHt} = p_{jHt}q_{jHt} = q_{jHt}^{\frac{\sigma-1}{\sigma}} \zeta_{jHt}^{\frac{1}{\sigma}} \chi_{Ht}^{\frac{1}{\sigma}}$. Substituting (2.A.3) in r_{jHt}, we obtain domestic revenue Equation (2.3.12). Analogously, we can derive Equation (2.3.13).

Proof of Result 1

We proof a simpler case where we assume that all firms sell to both the domestic and export markets. The result generalises to the case where a subset of firms sell exclusively to the domestic market and the remaining sells to both the domestic and export markets. In this case where the all firms exports, the aggregate productivity can be re-expressed as:

$$\tilde{\psi}_t = (1+\tau^{-1})^{\frac{V-1}{V(\sigma-1)}} \left[\frac{1}{M_t}\left(M\tilde{\psi}^{V(\sigma-1)} + M_x\tau^{1-\sigma}\tilde{\psi}_x^{V(\sigma-1)}\right)\right]^{\frac{1}{V(\sigma-1)}} \tag{2.A.4}$$

and welfare per worker

$$W = \left(\frac{\rho}{\alpha}\right)^{\frac{1}{\alpha}} L^{\frac{1-\alpha}{\alpha}} (1+\tau^{-1})^{\frac{V-1}{V(\sigma-1)}} \left(M\tilde{\psi}^{V(\sigma-1)} + M_x\tau^{1-\sigma}\tilde{\psi}_x^{V(\sigma-1)}\right)^{\frac{1}{V(\sigma-1)}} \tag{2.A.5}$$

Taking logs of welfare per worker and differentiating with respect to tariffs τ we obtain:

$$\frac{\partial \ln W}{\partial \tau} = \underbrace{\frac{\partial\left(\frac{V-1}{V(\sigma-1)}\ln(1+\tau^{-1})\right)}{\partial\tau}}_{\text{New welfare losses from reduction in tariffs}} + \underbrace{\frac{\partial\left(\frac{1}{V(\sigma-1)}\ln[M\tilde{\psi}^{V(\sigma-1)} + M_x\tau^{1-\sigma}\tilde{\psi}_x^{V(\sigma-1)}]\right)}{\partial\tau}}_{\text{Welfare gains from tariffs reduction in Melitz (2003)}} \tag{2.A.6}$$

The first term is the new losses that could be realised from trade liberalization. The sign of this derivative is positive, which implies that this term is negative for tariffs reductions. The second term represents the welfare gains from trade liberalization in Melitz (2003). The only difference is the scaling constant V. We refer the reader to appendix E in Melitz (2003) for the detailed proof.

10.14754/CEU.2018.12

2.A.2 Robustness Results and First Stage Estimates

Table 2.5: Estimating the Effects of Foreign sales on Domestic Sales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Estimator	OLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dependent variable	ln of domestic sales							Δ ln of domestic sales	
ln export sales$_{it}$	-0.078	-0.088	0.033	-0.078	-0.113	-0.105	-0.147		
	(0.018)**	(0.029)**	(0.019)$^{+}$	(0.029)**	(0.024)**	(0.031)**	(0.025)**		
ln domestic demand$_{it}$	0.081	0.128		0.115	0.095	0.098	0.068		
	(0.013)**	(0.021)**		(0.020)**	(0.019)**	(0.016)**	(0.016)**		
ln productivity$_{it}$	0.500				0.519	0.531	0.653		
	(0.037)**				(0.039)**	(0.037)**	(0.050)**		
ln capital$_{it}$							0.336		
							(0.017)**		
ln number of firms$_{st}$		0.199							
		(0.162)							
ln industry domestic sales$_{st}$		0.285							
		(0.118)*							
ln export$_{it}\times$ export share$_{i0}$						-0.051			
						(0.070)			
Δln export sales$_{it}$								-0.046	-0.020
								(0.017)**	(0.024)
Δln domestic demand$_{it}$								0.042	0.013
								(0.010)**	(0.011)
Δln productivity$_{it}$								0.915	0.860
								(0.135)**	(0.097)**
Observations	38020	38020	38020	38020	38020	38020	38020	26353	24421
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Year Dummies	No	Yes	No	No	No	No	No	No	No
Industry × year dummies	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: We use the instrument $F_{jt}^{core} = \sum_d s_{jd}^{core} IM_{d,t}^{core}$ for foreign demand and $D_{jt}^{core} = IM_{HUN,t}^{core}$ for domestic demand. This instrument focuses on the firm's core products defined as the product (HS4) with the largest value of exports over the period. Robust standard errors, clustered by industry level are in parentheses. Firm fixed effect is included in all estimation except column (7). In column (1), I report the OLS, column (2)-(8) reports the IV results. Our instrument in (2)-(6) is the foreign demand in HS6 variety exported by the firm. In columns (7)-(8) we use the first difference of the foreign demand. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$ are 1%, 5% and 10% significant levels respectively.

10.14754/CEU.2018.12

Table 2.6: Estimating the Effects of Foreign sales on Domestic Sales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Estimator	OLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dep. variable	ln of domestic sales							Δ ln of domestic sales	
ln export sales$_{it}$	-0.060	-0.095	0.038	-0.081	-0.111	-0.105	-0.139		
	(0.017)**	(0.037)*	(0.016)*	(0.033)*	(0.029)**	(0.038)**	(0.025)**		
ln domestic dem$_{it}$	0.031	0.064		0.057	0.047	0.048	0.033		
	(0.006)**	(0.014)**		(0.012)**	(0.011)**	(0.010)**	(0.008)**		
ln productivity$_{it}$	0.501				0.529	0.538	0.660		
	(0.036)**				(0.039)**	(0.037)**	(0.048)**		
ln capital$_{it}$							0.344		
							(0.014)**		
ln no. of firms$_{st}$		0.086							
		(0.171)							
ln sector domsales$_{it}$		0.373							
		(0.129)**							
ln export$_{it}$×eshare$_{i0}$						-0.042			
						(0.077)			
Δln export sales$_{it}$								-0.057	-0.038
								(0.016)**	(0.021)$^{+}$
Δln domestic dem$_{it}$								0.019	0.009
								(0.005)**	(0.005)$^{+}$
Δ ln productivity$_{it}$								0.476	0.450
								(0.031)**	(0.028)**
Observations	40785	40785	40785	40785	40785	40785	40785	29629	27696
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Year Dummies	No	Yes	No	No	No	No	No	No	No
Sector×yr FE	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kleib.-Paap stat.		204.77	1211.94	225.89	252.51	580.73	282.99	161.70	96.89

Notes: We exclude observations in industry 34 & 35. These are the manufacture of motor vehicles and other transport equipment industry. Robust standard errors, clustered by industry in parentheses. Firm fixed effects is included in all estimation except column (7). In column (1), I report the OLS, column (2)-(8) reports the IV results. Our instrument in (2)-(6) is the foreign demand in HS6 variety exported by the firm. In columns (7)-(8) we use the first difference of the foreign demand. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$ are 1%, 5% and 10% significant levels respectively.

10.14754/CEU.2018.12

Table 2.7: Estimating the Effects of Foreign sales on Domestic Sales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Estimator	OLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dep. variable	ln of domestic sales							Δ ln of domestic sales	
ln export sales$_{it}$	-0.074	-0.255	-0.045	-0.261	-0.264	-0.282	-0.347		
	(0.013)**	(0.110)*	(0.041)	(0.128)*	(0.127)*	(0.195)	(0.126)**		
ln domestic demand$_{it}$	0.023	0.081		0.093	0.078	0.078	0.079		
	(0.011)*	(0.035)*		(0.039)*	(0.037)*	(0.035)*	(0.031)**		
ln productivity$_{it}$	0.450	0.561			0.565	0.551	0.745		
	(0.044)**	(0.070)**			(0.078)**	(0.045)**	(0.098)**		
ln capital$_{it}$							0.369		
							(0.049)**		
ln no. of firms$_{st}$		0.007							
		(0.170)							
ln sector domestic sales$_{st}$		0.212							
		(0.092)*							
ln export$_{it}\times$ export share$_{i0}$						0.097			
						(0.378)			
Δln export sales$_{it}$								-0.117	-0.056
								(0.108)	(0.118)
Δln export sales$_{it}$								0.025	0.003
								(0.029)	(0.032)
Δln productivity$_{it}$								0.828	0.650
								(0.209)**	(0.175)**
Observations	13830	13830	13830	13830	13830	13830	13830	6487	5636
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Year Dummies	No	Yes	No	No	No	No	No	No	No
Industry $\times$Year Dummy	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

We use weights for each HS6 product sold in the first year the firm enters the export market in constructing the instrument. Robust standard errors, clustered by industry in parentheses. Firm fixed effect is included in all estimation except column (6). In column (1), we report the OLS, column (2-9) reports the IV results. Our instrument in (2)-(7) is the foreign demand in HS6 variety exported by the firm. In column (8-9) we use the 1st difference of foreign demand. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$ are 1%, 5% and 10% significance respectively.

10.14754/CEU.2018.12

Table 2.8: Estimating the Effects of Foreign sales on Domestic Sales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Estimator	OLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Dep variable	ln of domestic sales							Δ ln of domestic sales	
ln export sales$_{it}$	-0.059	-0.099	0.041	-0.080	-0.109	-0.106	-0.140		
	(0.016)**	(0.025)**	(0.015)**	(0.039)*	(0.033)**	(0.043)*	(0.029)**		
ln domestic dem$_{it}$	0.030	0.066		0.057	0.046	0.046	0.033		
	(0.006)**	(0.009)**		(0.015)**	(0.013)**	(0.012)**	(0.010)**		
ln productivity$_{it}$	0.509				0.535	0.540	0.670		
	(0.036)**				(0.042)**	(0.037)**	(0.051)**		
ln capital$_{it}$							0.350		
							(0.016)**		
ln no. of firms$_{st}$		0.078							
		(0.079)							
ln sector domsales$_{it}$		0.371							
		(0.041)**							
ln export$_{it}\times$ eshare$_{it}$						-0.022			
						(0.086)			
Δ ln export sales$_{it}$								-0.053	-0.032
								(0.016)**	(0.021)
Δ ln domestic dem$_{it}$								0.018	0.007
								(0.006)**	(0.006)
Δ ln productivity$_{it}$								0.477	0.444
								(0.031)**	(0.028)**
Observations	41632	41632	41632	41632	41632	41632	41632	30259	30259
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Year Dummies	No	Yes	No	No	No	No	No	No	No
Sector×yr FE	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kleib-Paap stat.	—	317.29	1041.82	353.93	390.65	445.98	413.25	245.84	139.35

We substract the values of yearly exports from Hungary of each HS6 from the imports of countries which Hungarian firms serviced. Robust standard errors, clustered by industry in parentheses. Firm fixed effects is included in all estimation except column (7). In column (1), I report the OLS, column (2)-(8) reports the IV results. Our instrument in (2)-(6) is the foreign demand in HS6 variety exported by the firm. In columns (7)-(8) we use the first difference of the foreign demand. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$ are 1%, 5% and 10% significant levels respectively.

10.14754/CEU.2018.12

Table 2.9: First Stage Results: Baseline Instrument

	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent var	ln of export sales						Δ ln of export sales	
ln foreign demand$_{it}$	0.206	0.305	0.206	0.200	0.162	0.195		
	(0.015)**	(0.009)**	(0.019)**	(0.013)**	(0.007)**	(0.012)**		
ln domestic dem$_{it}$	0.153		0 .153	0.139	0.090	0.122		
	(0.020)**		(0.019)**	(0.019)**	(0.014)**	(0.017)**		
ln productivity$_{it}$				0.523	0.143	0.630		
				(0.030)**	(0.022)**	(0.037)**		
ln capital$_{it}$						0.320		
						(0.014)**		
ln no. of firms$_{st}$	0.590							
	(0.145)**							
ln isector domsales$_{it}$	0.086							
	(0.089)							
ln export$_{it}$× eshare$_{i0}$					1.283			
					(0.042)**			
Δln foreign demand$_{it}$							0.163	0.155
							(0.013)**	(0.016)**
Δln dom. demand$_{it}$							0.115	0.098
							(0.017)**	(0.018)**
Δln productivity$_{it}$							0.542	0.548
							(0.027)**	(0.026)**
Observations	41886	41886	41886	41886	41886	41886	30458	30458
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Year Dummies	No	Yes	No	No	No	No	No	No
Sector×yr FE	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

First Stage results for our main specification. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$ are 1%, 5% and 10% significant levels respectively

10.14754/CEU.2018.12

Table 2.10: First Stage Results: Estimating the Effects of Foreign sales on Domestic Sales

	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent var.	ln of export sales						Δ ln of export sales	
ln foreign demand$_{it}$	0.209	0.307	0.209	0.203	0.162	0.198		
	(0.015)**	(0.009)**	(0.014)**	(0.013)**	(0.007)**	(0.012)**		
ln domestic dem$_{it}$	0.151		0 .152	0.138	0.090	0.122		
	(0.020)**		(0.020)**	(0.019)**	(0.014)**	(0.018)**		
ln productivity$_{it}$				0.520	0.146	0.627		
				(0.031)**	(0.023)**	(0.038)**		
lcapital$_{it}$						0.315		
						(0.013)**		
ln no. of firms$_{st}$	0.545							
	(0.150)**							
ln industry dom. sales$_{it}$	0.089							
	(0.091)							
ln export$_{it}\times$ eshare$_{i0}$					1.290			
					(0.042)**			
Δln foreign demand$_{it}$							0.165	0.157
							(0.016)**	(0.016)**
Δln dom. demand$_{it}$							0.115	0.099
							(0.018)**	(0.018)**
Δln productivity$_{it}$							0.542	0.549
							(0.027)**	(0.026)**
Observations	40784	40784	40784	40784	40784	40784	29629	27696
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Year Dummies	No	Yes	No	No	No	No	No	No
Sector×year dummies	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

We exclude industry 34 and 35 in this estimation. These are the automobile industry. Since there is a huge GVC in this section (e.g. audi), we exclude these industries in our estimation. + $p < 0.10$, * $p < .05$, ** $p < .01$ are 1%, 5% stage rand 10% significance levels respectively.

10.14754/CEU.2018.12

Table 2.11: First Stage Results: Estimating the Effects of Foreign sales on Domestic Sales

	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable	ln of export sales						Δ ln of export sales	
ln foreign demand$_{it}$	0.083	0.160	0.074	0.074	0.052	0.068		
	(0.013)**	(0.011)**	(0.013)**	(0.012)**	(0.012)**	(0.014)**		
ln domestic demand$_{it}$	0.216		0.232	0.217	0.137	0.201		
	(0.024)**		(0.022)**	(0.023)**	(0.020)**	(0.024)**		
ln productivity$_{it}$	0.547			0.543	0.144	0.669		
	(0.028)**			(0.029)**	(0.033)**	(0.040)**		
ln capital$_{it}$						0.347		
						(0.026)**		
ln no of firms$_{st}$	0.404							
	(0.237)$^{+}$							
ln sector domestic sales$_{st}$	0.093							
	(0.119)							
ln export$_{it}\times$ export share$_{i0}$					1.640			
					(0.091)**			
Δln foreign demand$_{it}$							0.065	0.067
							(0.014)**	(0.011)**
Δln domestic demand$_{it}$							0.160	0.143
							(0.025)**	(0.031)**
Δln productivity$_{it}$							1.039	0.889
							(0.185)**	(0.149)**
Observations	13830	13830	13830	13830	13830	13830	6487	5636
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Year Dummies	Yes	No	No	No	No	No	No	No
Industry ×Year Dummy	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

First Stage results for the case where we use weights for each HS6 product sold in the first year the firm enters the export market. Standard errors in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

10.14754/CEU.2018.12

Table 2.12: First Stage Results: Core Product Instruments

	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable	ln of export sales						Δln of export sales	
ln foreign demand$_{it}$	0.220	0.288	0.219	0.211	0.169	0.205		
	(0.015)**	(0.012)**	(0.014)**	(0.012)**	(0.007)**	(0.011)**		
ln domestic demand$_{it}$	0.252		0.248	0.220	0.100	0.189		
	(0.020)**		(0.019)**	(0.019)**	(0.014)**	(0.018)**		
ln productivity$_{it}$				0.518	0.121	0.624		
				(0.040)**	(0.020)**	(0.049)**		
ln capital$_{it}$						0.307		
						(0.014)**		
ln number of firms$_{st}$	0.674							
	(0.189)**							
ln industry domestic sales$_{st}$	0.069							
	(0.086)							
ln export$_{it}\times$ export share$_{i0}$					1.298			
					(0.032)**			
Δln export sales$_{it}$							0.169	0.145
							(0.013)**	(0.015)**
Δln domestic demand$_{it}$							0.152	0.116
							(0.017)**	(0.016)**
Δln productivity$_{it}$							1.154	1.120
							(0.211)**	(0.186)**
Observations	38020	38020	38020	38020	38020	38020	26353	24421
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Year Dummies	Yes	No	No	No	No	No	No	No
Industry $\times$ year dummies	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

We use instruments based on core products of the firm. Robust standard errors clustered at the industry level
$^{+}$ in parentheses $p < 0.10$, * $p < .05$, ** $p < .01$

10.14754/CEU.2018.12

Table 2.13: First Stage Results: Estimating the Effects of Foreign sales on Domestic Sales

	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)
Dependent variable	ln of export sales						Δ ln of export sales	
ln foreign demand$_{it}$	0.198	0.301	0.198	0.193	0.157	0.187		
	(0.011)**	(0.009)**	(0.011)**	(0.010)**	(0.007)**	(0.009)**		
ln domestic demand$_{it}$	0.159		0 .159	0.144	0.090	0.128		
	(0.018)**		(0.018)**	(0.017)**	(0.012)**	(0.017)**		
ln productivity$_{it}$				0.523	0.141	0.631		
				(0.030)**	(0.022)**	(0.038)**		
ln capital$_{it}$						0.319		
						(0.014)**		
ln number of firms$_{st}$	0.560							
	(0.140)**							
ln industry dom. sales$_{it}$	0.081							
	(0.087)							
ln export$_{it}\times$ exp. share$_{i0}$					1.287			
					(0.042)**			
Δln foreign demand$_{it}$							0.156	0.150
							(0.010)**	(0.013)**
Δ ln domestic demand$_{it}$							0.118	0.102
							(0.015)**	(0.016)**
Δ ln productivity$_{it}$							0.541	0.545
							(0.027)**	(0.026)**
Observations	41632	41632	41632	41632	41632	41632	30259	30259
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Year Dummies	No	Yes	No	No	No	No	No	No
Sector×year dummies	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

First Stage results for the case where we substracted the values of yearly exports (HS6) from Hungary from imports of countries which imported from Hungary. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$ are 1%, 5% and 10% significant levels respectively

10.14754/CEU.2018.12

Table 2.14: Estimating the Effects of Foreign sales on Domestic Sales

Dependent Variable	Δ^2 ln Domestic Sales (1)	Δ^3 ln Domestic Sales (2)	Δ^4 ln Domestic Sales (3)
Δ^2 ln Exports	-0.125		
	(0.009)**		
Δ^2 ln Productivity	1.469		
	(0.027)**		
Δ^2 ln Capital	0.163		
	(0.005)**		
Δ^3 ln Exports		-0.121	
		(0.011)**	
Δ^3 ln Productivity		1.413	
		(0.031)**	
Δ^3 ln Capital		0.164	
		(0.006)**	
Δ^4 ln Exports			-0.119
			(0.012)**
Δ^4 ln Productivity			1.361
			(0.033)**
Δ^4 ln Capital			0.164
			(0.007)**
Observations	79248	67892	58698
Firm FE	yes	yes	yes
Industry-Year Dummies	yes	yes	yes
Demand Shocks	yes	yes	yes
Rsquared	0.655	0.636	0.619

Notes: This regression reports the results for the estimation of the increasing marginal cost structure for all manufacturing firms in Hungary. Robust standard errors clustered at the firm-level are in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$.

Appendix 2.B TFPR, Data Cleaning and Descriptive Statistics

2.B.1 TFPR Estimation

I estimate firm-level TFPR by assuming that firms use a Cobb-Douglas production technology with capital (k), labour (l) and materials (m) as production inputs. I estimate a separate production function for each 2-digit manufacturing sector[24] using the methodology in Ackerberg et al. (2015) . This methodology builds on the framework developed

[24]My data do not allow me to isolate single and multi-product manufacturing firms. This limitation do not allow us observe how inputs are allocated in production of specific inputs there introducing some bias in the estimation

by Olley and Pakes (1996) (henceforth OP) and Levinsohn and Petrin (2000) (henceforth LP) which uses investment i_{it} (in OP) and material inputs m_{it} (in LP) to control for correlation between input levels and unobserved productivity. The key contribution of Ackerberg et al. (2015) lies on the identification of the elasticity of labor which they show is unidentified in the first-stage of the OP and LP procedure[25]. I estimate a value-added Cobb-Douglas production function in the sense that m_{it} does not enter the estimated production function. This implies that the gross output production function is Leontief in the intermediate input[26]. Specifically, I estimate a production function of the form:

$$y_{it} = \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + \epsilon_{it} \tag{2.B.1}$$

Where all variables are in logs. y_{it} is value added revenue of firm i in year t, ω_{it} is the TFPR, l_{it} is the labor input, k_{it} is the capital stock. We deflate all norminal variables using the NACE 2-digit industry specific price indices provided by Hungarian Statistical Office. Since more-productive firms self-select themselves into exports markets (Melitz (2003)), the productivity process becomes:

$$\omega_{it} = f(\omega_{it-1}) + \xi_{it} \tag{2.B.2}$$

where ξ_{it} is the innovation term which captures the unexpected productivity effects from exporting. The innovation term ξ_{it} is by OP/LP assumption uncorrelated with the firm's lagged choice variables.

In the first step of Ackerberg et al. (2015) procedure, we estimate the equation of the form:

$$y_{it} = \phi_t(k_{it}, l_{it}, \boldsymbol{x}_{it}) + \epsilon_{it}$$

where $\phi_t(k_{it}, l_{it}, \boldsymbol{x}_{it}) = \beta_k k_{it} + \beta_l l_{it} + g_t(m_{it}, k_{it}, l_{it}, \boldsymbol{x}_{it})$ and $g_t(m_{it}, k_{it}, l_{it}, \boldsymbol{x}_{it})$ is an inverse material demand function which proxies for unobserved productivity ω_{it} in equation (2.B.1). The vector $\boldsymbol{x_{it}}$ represents the sector and time dummies which represents sector-specific demand and aggregate demand components that affect material demand.

[25]Ackerberg et al. (2015) argues that labor elasticity can be identified under 3 very specific data generating process (DGP) namely: (1) a case where i.i.d. optimization error in l_{it} (after m_{it} or i_{it} have been choosen) and not in m_{it} or i_{it} (2) a case where i.i.d. shocks to the price of labor or output after i_{it} or m_{it} is chosen but before l_{it} is chosen, (3) in the case of OP procedure, labor is non-dynamic and chosen at $t - q$ $(0 < v < 1)$ as a function of productivity in period $t - v$ ω_{it-v} while i_{it} is chosen at t.

[26]Ackerberg et al. (2015) do not suggest that applying their procedure to production functions where m_{it} enters in the estimation because Bond and Söderbom (2005) have shown (for the cobb-douglas function) that under the scalar unobservable assumptions, their procedure and that of LP and OP, the gross output production function cannot identify coefficients of perfectly flexible inputs without input price variation except further assumptions are imposed. Infact, Gandhi et al. (2011) shows that both the gross output production function and value-added production function could still suffer from these identification issues and have proposed a new identification strategy that solves this problem.

We compute the estimate $\hat{\phi}_t(.)$.
In the second step, we use $\hat{\phi}_t(.)$ and together with initial guess of the coefficient vector $\boldsymbol{\beta_z} = \{\beta_k, \beta_l\}$ and for any other candidate vector of $\tilde{\boldsymbol{\beta}}_{\boldsymbol{z}}$, revenue productivity is computed as:

$$\omega_{it}(\tilde{\boldsymbol{\beta}}_{\boldsymbol{z}}) = \hat{\phi}_t(.) - (\tilde{\beta}_k k_{it} - \tilde{\beta}_{it} l_{it})$$

We use our productivity process (equation 2.B.2) to recover the innovation term ξ_{it} by a non-parametric regression of $\omega_{it}(\tilde{\boldsymbol{\beta}}_{\boldsymbol{z}})$ on its own lag $\omega_{it-1}(\tilde{\boldsymbol{\beta}}_{\boldsymbol{z}})$ and prior exporting e_{it-1}. We define the moment condition below and iterate over candidate vector $\tilde{\boldsymbol{\beta}}_{\boldsymbol{z}}$

$$\boldsymbol{E}\left\{ \xi_{it}(\tilde{\beta}_k, \tilde{\beta}_l) \begin{pmatrix} k_{it} \\ l_{it-1} \end{pmatrix} \right\} = 0 \tag{2.B.3}$$

Thus equation (2.B.3) states that for the optimal $\tilde{\boldsymbol{\beta}}_{\boldsymbol{z}}$, the innovation ξ_{it} is uncorrelated with our instruments $\begin{pmatrix} k_{it} \\ l_{it-1} \end{pmatrix}$. With the estimates of the coefficients for every sector, I compute the firm-level TFP $\hat{\omega_{it}}$:

$$\hat{\omega_{it}} = y_{it} - (\hat{\beta}_l l_{it} + \hat{\beta}_k k_{it}) \tag{2.B.4}$$

In the estimation, we use the stata *prodest* estimation function developed by Mollisi and Rovigatti (2017) because of its efficiency over other functions. We report sectoral estimates in table(2.17)

2.B.2 Data Cleaning and Descriptive Statistics

We follow the cleaning procedures described in preceding literatures (Békés et al. (2011), Bisztray (2016) etc). Specifically, for firms that appear in more than one sector, we assign such firm in a sector in which it appears the most. We fill in missing values of output using the average of the 1 previous and 1 subsequent period's output values. When both or any do not exist, we use the average of 2 or 1 -previous and 2 or 1 forward period's value. We only consider manufacturing firms in our econometic exercise. We list in table 2.15, the manufacturing sectors.

In Table (2.16), I present the descriptive statistics. See section 2.1 for the discussions.

Table 2.15: NACE 2.0 sectors and Description

Nace	description	σ	Nace	description	σ
15	Food and beverages	2.34	27	Basic metals	3.99
16	Tobacco products	3.18	28	Fabricated metal products	3.98
17	Textiles	4.01	29	Machinery and equipment n.e.cc	3.23
18	Wearing Apparels	4.06	30	Computer, electronic & optical products	2.73
19	Leather and related products	7.02	31	Electrical equipment	4.36
20	Wood except furniture	2.78	32	Consumer electronics & commu. equip	5.44
21	Paper and paper products	2.39	33	Optical instr. and photographic equip.	2.55
22	Printing and prod. of recorded media	2.65	34	Motor vehicles, trailers and semi-trailers	7.67
23	Coke and refined petroleum products	1.98	35	Other transport equipment	3.76
24	Chemical products &pharmaceuticals	2.86	36	Furniture	3.39
25	Rubber and plastic products	3.6	37	Recycling	2.67
26	Other non-metallic mineral products	2.8			

Table 2.16: Descriptive Statistics

Year	Non-exporting	Entrants	Active Expr	Total		Entrants/Active	Active/Total
1992	2811	0	0	2811			0.00
1993	3600	754	754	4354		1.00	0.17
1994	4283	730	1307	5590		0.56	0.23
1995	4610	799	1806	6416		0.44	0.28
1996	4892	805	2238	7130		0.36	0.31
1997	5495	630	2372	7867		0.27	0.30
1998	5976	734	2650	8626		0.28	0.31
1999	6251	673	2766	9017		0.24	0.31
2000	6586	669	2837	9423		0.24	0.30
2001	7270	628	2845	10115		0.22	0.28
2002	7260	605	3133	10393		0.19	0.30
2003	7445	526	3163	10608		0.17	0.30
2004	7249	724	3569	10818		0.20	0.33
2005	7475	685	3668	11143		0.19	0.33
2006	7520	623	3818	11338		0.16	0.34
2007	7110	721	4191	11301		0.17	0.37
2008	7156	766	4158	11314		0.18	0.37
2009	7100	822	4364	11464		0.19	0.38
2010	6823	793	4712	11535		0.17	0.41
2011	6600	772	4935	11535		0.16	0.43
2012	6174	755	4958	11132		0.15	0.45
2013	5541	724	5130	10671		0.14	0.48
2014	5008	644	5242	10250		0.12	0.51
Total:	140235	15582	74616	214851	**Average:**	0.23	0.34

This is the descriptive statistics of firms that sold in only the domestic market in at least one period and then to both the domestic and export markets in subsequent periods.

Table 2.17: Production Function Estimate by Sector

	Sectors - Teaor03							
Variables	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
log wages	0.849***	0.981***	0.686***	0.712***	0.693***	0.703***	0.637***	0.641***
	(0.001)	(0.210)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
log capital	0.0261***	0.404	0.135***	0.117***	0.126***	0.119***	0.120***	0.132***
	(0.005)	(0.300)	(0.011)	(0.004)	(0.013)	(0.003)	(0.010)	(0.006)
Observations	61717	132	16699	24567	6916	31235	6657	65381
No. of groups	9765	13	2750	4412	1097	5403	973	11869
	Sectors - Teaor03							
Variables	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
log wages	0.782	0.835***	0.711***	0.786***	0.794***	0.696***	0.676***	0.653***
	(0.859)	(0.001)	(0.001)	(0.001)	(0.031)	(0.001)	(0.019)	(0.002)
log capital	0.103	0.038	0.116***	0.126***	0.061***	0.107***	0.128***	0.174***
	(0.065)	(0.009)	(0.008)	(0.004)	(0.025)	(0.005)	(0.010)	(0.010)
Observations	191	10266	26741	18533	4602	78489	55837	2659
No. of groups	27	1371	3562	2933	627	11,664	8638	477
	Sectors - Teaor03							
Variables	(31)	(32)	(33)	(34)	(35)	(36)	(37)	
log wages	0.629***	0.745***	0.682***	0.736***	0.740***	0.757***	0.795***	
	(0.001)	(0.032)	(0.002)	(0.002)	(0.005)	(0.001)	(0.009)	
log capital	0.156	0.108	0.110***	0.132***	0.130***	0.117***	0.090	
	(0.007)	(0.019)	(0.011)	(0.011)	(0.032)	(0.009)	(0.057)	
Observations	15270	13174	17681	5333	2791	34195	1383	
No. of groups	2221	2130	2179	732	473	5816	326	

Standard errors in parentheses. $***p < 0.01$, $**p < 0.05$, $**p < 0.1$

Appendix 2.C Comparison With Similar Studies in the Literature

Table 2.18: Effects of Foreign sales on Domestic Sales -

	Δ ln domestic sales			
	(1)	(2)	(3)	(4)
Δ ln export sales	-0.009	-0.022	-0.036	-0.084
	(0.004)*	(0.005)**	(0.005)**	(0.005)**
Δ ln productivity				0.417
				(0.012)**
Sector-year FE	No	No	Yes	Yes
Firm FE	No	Yes	Yes	Yes
Observations	94493	94493	94493	93306
r2	0.000	0.001	0.032	0.093

This table estimates the baseline regression specification in Ahn et al. (2016) Table 5. Productivity is estimated by the ACF procedure. Robust standard errors clustered at firm-level in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 2.19: Estimating the Effects of Foreign sales on Domestic Sales

Dependent Variable	log Exports		Δlog Exports	
	(1)	(2)	(3)	(4)
ln domestic sales	0.063	-0.061		
	(0.008)**	(0.008)**		
ln Productivity		0.650		
		(0.014)**		
ln Average Wages		0.621		
		(0.022)**		
Δ ln domestic sales			-0.097	-0.196
			(0.010)***	(0.010)***
Δ ln Productivity				0.601
				(0.015)***
Δ ln Average Wages				0.470
				(0.020)**
Observation	127278	127278	93306	93306
Firm-FE	Yes	Yes	Yes	Yes
Sector-Time FE	Yes	Yes	Yes	Yes
R-Squared	0.063	0.129	0.032	0.099

This table reports the OLS regression estimate for a regression specification in Alumnia et al (2018) Equation (9). Column (4) is the main specification of interest. Robust standard errors clustered at the firm-level are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

10.14754/CEU.2018.12

Chapter 3

Exports and Intellectual Property Policies: Does Product Life-Cycle Length Matter?

3.1 Introduction

The relationship between exports of patented products and the level of intellectual property rights[1] (IPR) across potential export destinations has been of interests to several stakeholders including inventors, economists, policymakers etc. In a classical book titled "Imitation to Innovation: The Dynamics of Korea's Technological Learning", Linsu Kim described how Korea metamorphosed from an imitative economy to an innovative one. An example described in pages 136-140 of the book is the case of microwave oven during the late 1970's. Samsung was intrigued by the new microwave oven technology and decided to negotiate for licencing to enable them copy and produce the technology. After being turned down from several attempts to licence the technology from Japanese and U.S. producers, Samsung formed a team to develop its own microwave oven by reverse engineering imported models. They proceeded by importing a number of the world's top microwave ovens to choose the different aspects and parts to reverse engineer. The team took the microwave ovens apart to copy the technology used in building them, and within two years the developed a prototype of a successful microwave. They then used the successful prototype as a bargaining chip to negotiate for licencing to enable them export to the US market as demand was low in Korea. Twenty years later, Samsung became one of world's largest exporter of microwaves with a global market share of over 17%. This implies that imitators could copy patented products by mere access to the product. In the US, Lin and Lincoln (2017) finds that about 9% of firms hold a patent and these firm's exports accounts for 89% of all exports in the US . Since the World Trade Organization's (WTO) has a policy which allows some countries to copy and produce patented products

[1] In this paper, we restrict our focus on patents and we do not consider other types of intellectual property rights. Whenever we use IPR in this paper, we imply patent and vice-versa.

in some industries[2], this may affect the export decisions of US firms especially since this policy is supported by the European Union and not by the US[3]. While some countries have ratified the WTO's Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement, but have not incorporated it into their laws[4], some who have passed it into law, may have not enforced it effectively. These observed heterogeneity in the level of IPR protection across countries could provide an explanation on the patterns of US trade flows.

Maskus and Penubarti (1995) highlights the tradeoff faced by exporting firms with patent on their product. By selling to all countries, the firm increases its profits due to its larger market (market expansion), but this comes at a cost of the risk of imitation which robs the firm of its monopoly profits (market power) as imitators would compete in markets where patent enforcements are low. Selling to a smaller number of countries with strong IPR regulations and/or weak imitative ability reduces the risk of imitation but comes at a cost of lower sales and profits. Hence, the distribution of exports across countries, all things being equal, depends on the relative importance of market size and market power.

Existing empirical studies on the relationship between IPR and export have found mixed results. Ivus, 2010, Rafiquzzaman, 2002, Maskus and Penubarti, 1995 and Lin et al. (2015) provides evidence for a strong positive relationship between country level IPR and exports of innovative products from developed countries (etc), and Ferrantino (1993) finds no significant effect of IPRs. Therefore, it is remains unclear how one can reconcile these findings. Improvements in a country's IPR can increase exports from developed countries since local producers are constrained from producing. It could also lead to a drop in demand since exporters have stronger monopoply power and may raise prices which will subsequently lead to a drop in prices. Moreover, little is known about the differential effects of IPR across industries.

In this paper, I provide new theoretical and empirical evidence on the differential effects of IPR across US industries and its underlying mechanisms. Specifically, I ask two important research questions: How does US exports in high technology sector react to a change in IPR laws across countries? What factors determine the sensitivity of US sectoral exports to IPR reforms? To guide my empirical analysis in answering these questions, I proceed by proposing a partial equilibrium model and derived some testable predictions.

[2]In 2015, WTO's made a decision to prolong the rights of least developed countries (LDCs) to copy and produce patented pharmaceutical products up until the year 2033 https://www.wto.org/english/news_e/news15_e/trip_06nov15_e.htm.

[3]See a press release by the European commision: http://europa.eu/rapid/press-release_IP-15-5620_en.htm and popular media discussions: https://theconversation.com/worlds-poorest-countries-allowed-to-keep-copying-patent-protected-drugs-50799

[4]For example, India ratified the TRIPS agreement in 1995, however, the requirements in this treaty was only passed into law in 2005 Duggan et al. (2016)

I test some of the predictions of the model using US industry-level export data to 119 countries between the periods 1989-2006. Our results show that US exports react positively to patent reforms and cross-industry differences in the length of product life-cycle are strong determinants of the extend to which US exports are sensitive to patent reforms. Specifically, strengthening of patent laws in a country led to an increase in US exports especially in sectors with relatively longer product life-cycle, however this relationship is non-monotonic as exports of products at the topmost quartile of product life-cycle length are less sensitive to patent reforms[5]. I also show that per capita gross domestic product (GDP) of a country provides an incentive for US exports in sectors with relatively longer product life-cycle, however, this relationship is also non-monotonic. These findings are important as it highlights the importance of patent reforms on the availability of high technology products which increases the number of domestically available products and may improve welfare through consumption and productivity through imported technologies and machineries for innovative production.
I proceed with the analysis in section 3.2 where I described the data, cleaning procedures and summary of some basic trends. The data comes from several publicly available data sources combined together for this analysis. The first dataset is a panel of US yearly 10-digit product-level export data from 1989-2006 assembled by Feenstra (1997). In this data, I observe a highly disaggregated product, its export destination, export sales and quantity in each time period and its industry. The second dataset is a panel of country-level patent protection index developed in Ginarte and Park (1997) and extended in Park (2008). This data assigns a numeric index ranging between 0 and 5 which reflects the level of patent protection across a country in each time period. The third dataset is a cross-sectional data of product life-cycle lengths by industry for 37 high technology industries developed in Bilir (2014b). The final dataset is the macro data from Penn World table 8.1 (Feenstra et al., 2015) consisting of information on real GDP and population. I merge the 4 datasets and aggregate our observations to the 3-digit Standard Industrial Classification (SIC-3). The merged dataset consists of 65249 observations, 119 countries and 37 SIC-3 industries. I refer the reader to the relevant subsections for a detailed description of each of the datasets. In Table (3.1), I present a descriptive statistics of the merged datasets and summarise two novel facts from the table.
In section 3.3, I propose a partial equilibrium model to illustrate the trade-off faced by exporting firms in choosing its export destination and derive a relationship between industry exports, IPR, product life-cycle length and per capita GDP which I take to data. In my model, I incorporate the main empirical finding in Smith (1999) -*weak patent rights*

[5]The sectors in this analysis are high-technology sectors which includes, heating equipment, chemical products, electronics machinery, agricultural chemicals, household appliances, among others. See Table (3.8) in the appendix for the complete list of sectors.

are a barrier to U.S. (northern) exports, but only to countries that poses a strong threat of imitation- by assuming a world populated by 3 countries, North, South 1 and South 2. Both southern countries have lower patent laws compared to the North , however imitation risk in South 1 country is very low while imitation risk in South 2 is high. I consider a representative firm in the North that has a patent on its new product. This patented product has an associated imitation time (which may depend on its complexity) and a product life-cycle length. Since imitation risk is low in South 1, the firm sells its products in the North and South 1 and decides the time to export to South 2. The firm's timing decision will depend on the life-cycle length of its product and the length of time to which imitation of its product could occur (time-to-imitation). If product life-cycle is less than the time-to-imitation, then the firm exports its product immediately, since imitation will occur only after product-life ends. But if time-to-imitation is less than product life-cycle length, the firm waits up till the point where the remaining product life-cycle length is at least equal to the time-to-imitation and then begins to export to the south.
The total quantity of goods and revenue exported to a destination depends on the time when exporting occurs during the product life-cycle under our asssumption of a uniform demand across countries and time. The model predicts that following an improvement in IPR regulation in South 2, there is an increase in exports of products with longer product life-cycle length, but this relationship is non-monotonic. That is, firms that manufacture products with lower product lifecycle length are insensitive to IPR reforms since imitation is less likely to occur during the product lifecycle length. However, firms with products having relatively higher life-cycle length are more sensitive, but this sensitivity is decreasing for very high product lifecycle. The intuition is that very high product life-cycle length imply higher risk of product imitation during the product's life resulting to reduced sensitivity to IPR reforms. The model also incorporates a profit shifter for firms in any given destination which is assumed to be per capita GDP. We find a positive and non-monotonic effects of destination country's per capita GDP on US exports they receive. Firms will likely make more profits in richer countries than poorer ones, increasing its incentive to export to such destination. However, with higher product life-cycle length, imitation risk increases and the incentive to export drops.
In section 3.4, I present our econometric framework, discuss the identification strategy and quantify the prediction of the model using datasets already discussed. Since our theoretical results suggest that the sensitivity of US exports to patent reforms is an increasing and non-monotonic function of product life-cycle length, our main specification is a country-level regression of US industry exports flows on an interaction term between (1) patent protection index and product life-cycle length and, (2) patent protection index and the square of product life-cycle length whilst controlling for unobserved country-

time fixed effect and sector fixed effects. Similar empirical specification is employed in quantifying the sensitivity of US exports to per capita income growth across sectors with different product life-cycle length.

In section 3.5, I present results from the empirical framework in section 4, and additonal results from a number of alternative econometric specifications. My analysis reveals that relative to products in sectors with shorter product life-cycle length, products in sectors with longer life-cycle length responds more to strengthened patent laws. That is, countries that implement stricter patent reforms receive more US innovative exports in sectors with relatively longer product life cycle, however, this relationship is non-monotonic. The effect is weak in sectors with short life-cycle length and stronger with longer product life-cycle length with the highest effect in sectors near the 4th sextile. However, for sectors above the 4th sextile, this effect becomes weaker compared to the 4th sextile. This differential sensitivity is economically relevant: a one standard deviation rise in patent protection attracts approximately 12 percentage points more of US exports in 4th sextile sectors than in the 1st sextile of the product life-cycle length. This effect at the 4th sextile is greater than the effect at the 5th and 6th sextile (see Table (3.5)). This finding shows that sector-level effects reflects different modes of firm's response to increasing patent regulations. From a Southern country's welfare perspective, it shows that IPR laws affect the distribution of innovative goods available to consumers and firms which will have effects on consumption and productivity.

Duggan et al. (2016) finds that pharmaceutical firms increased the prices of their patented products by about 3-6 percent after India passed the TRIPs agreement to law. This implies that our results could be driven by prices since improved patent laws increases the market power of firms. To check for this possibility, I repeat the empirical analysis using data on quantity as the dependent variable instead of revenue and the results remain significantly unchanged as reported in Table(3.3). I also use the number of 10-digits products within each 3-digit SIC sector exported to a destination in each time period as the dependent variable. Specifically, I study whether more products within an innovative industry is exported to a destination given an improvement in patent reforms, and how the product lifecycle length influences this relationship. Our estimates reported in Table 3.4 are very similar to our main specification in Table (3.2). These findings suggest that the estimated effect of patents protection on exports of innovative products is not driven by prices. Lin et al. (2015) finds that 82% of US firms with patents export and only 24% of firms without patent exports indicating that a majority of innovative firms are connected through trade with the global economy. Our results are important as it highlights the role played by patents in increasing the availability of high-technology products across countries which obviously improves welfare of individuals and firms in the economy.

Similar results are obtained when GDP per capital is considered instead of patent protection index. An increase in GDP per capita attracts more US exports from sectors with relatively longer product lifecycle length. Just like the case of patent protection, this increase is non-monotonic. Higher GDP per capita raises the possibility of higher revenue and profits for firms. Hence, this creates an incentive to export to such destination [6] even when patent law and enforcement remains unchanged.

Our theoretical model also predicts that *all things being equal*, product life-cycle length have a negative effects on exports from the North to countries with imitation risk . That is, products with higher life-cycle lengths are exported less compared with products with lower life-cycle length. I confirm this prediction in the empirical analysis. This result suggests a potential channel that could explain sectoral trade flows from north to south. I conclude the analysis in section 3.6 and present the derivations of some of the model's predictions, additional data information, and robustness results in the appendix.

3.1.1 Literature Review

This paper is related to a myriad of theoretical and empirical literature studying the effect of patent reforms in southern countries on inventing activities and export patterns from countries in the North. On the theoretical side, Chin and Grossman (1988) and Deardorff (1992) find that extending IPR from the North which innovates to the south which does not innovate encourages Northern firms to develop new technologies. In addition, Chin and Grossman (1988) finds that stricter patent laws reduces welfare in the south, except if countries in the south comprises a large share of market for goods whose technology is subject to improvement. Our paper is also related to Maskus and Penubarti (1997) which finds that if stronger patent rights prevents product imitation, then production of imitated products in the South drops and demand for original Northern products rises. Results from these papers imply an expected increase in Northern firms exports to the South. We contribute to these literature by showing that the product life-cycle length can explain the sensitivity of Northern firm's exports to patent reforms.

On the empirical side, several literatures have used aggregate manufacturing industry-level data to study the effects of stronger patent reforms in the South on exports from North to South. However, results in this regard has been mixed. For example, Ferrantino (1993) finds no impact of strengthening of IPRs, Smith (1999) finds a mixed impact which depends on the imitative ability of the south and Ivus (2010), Maskus and Penubarti (1995), Rafiquzzaman (2002) and Ivus (2015) finds significantly positive impact. One of the biggest identification threats in these literature comes from the fact

[6] The incentive is higher since profits are higher, firms are likely to leverage more on their monopoly rights before products are imitated.

that IPR reforms are done alongside domestic policies making separate identification of the effect of patents on exports difficult. Ivus (2010) tries to overcome this challenge by using colonial origins as an instrument for patent protection. While most of this literature focused on the intensive margin effect, a very few recent literature have looked at the extensive margin effects. For example, Lin et al. (2015) studies the extensive margin effect using a comprehensive firm-level dataset on exports and patents filings and study the role of intellectual property rights in determining the trade patterns across countries. They find that more profitable firms in the North are more sensitive to patent reforms than other firms. Duggan et al. (2016) studied the effects of improved IPR regulation on prices of patented pharmaceutical molecules in India and finds a positive effect (3-6 percent increase) for prices and little impacts for quantities sold. Relative to these literature, we show that improved patent laws in the south may or may not have an effect on exports from the North depending on the product life-cycle length of the industry considered, reconciling contradicting findings in the literature. We also show that the number of 10 digit products that are exported increases and is non-monotonic with patent reforms.

Our paper is also related to another strand of the literature studying the effect of improved patent laws on foreign direct investment (FDI) inflows in developing countries. In particular, Javorcik (2004) studies the effects of IPR protection on the composition of FDI inflows using firm-level dataset from the former Soviet Union and Eastern European countries. They find that weak patent protection deters foreign investors in technology-intensive sectors that rely heavily on IPRs. Bilir (2014a) studied how IPR influence multinationals manufacturing location decisions. Their findings show that countries with stricter patent laws attract multinational activity, but only in sectors with relatively longer product life cycles. Our paper, extends the framework presented in Bilir (2014a) to export flows from north to south. We find similar but weaker effects of improved patents laws on exports compared to its effect on multinational locations of innovative firms.

To our knowledge, this paper is the first to study the sensitivity of sectoral exports (ordered by length of their product life) from the north to patent law reforms in the South. We deviate from estimating the direct effect of patent laws on US exports, but instead, we show that product life-cycle length strongly determines how US industry-level exports reacts to improved patent reforms in potential export destinations.

3.2 Data and Descriptive Statistics

Our data comes from different data sources merged together and used to test the theoretical predictions of our model. I outline the data sources below:

3.2.1 US Yearly Export Data

This consist of US product level export-destination panel data from 1989 to 2006 assembled by Feenstra (1997) for National Bureau of Economic Research (NBER). It consists of highly disaggregated data at the 10-digit Harmonized System (HS-10) product level which has also been aggregated to the 1987 4-digit Standard Industrial Classification (SIC 4) codes. This data is freely available at The Center for International data, University of California Davis website. The full data consists of 5,679,468 observations, 183 countries, 11,473 unique HS-10 and 458 unique SIC-4 product lines. Since this data is useful in this analysis only if it is merged with other datasets such as the product life-cycle length and country-level patent protection data, I aggregate the export data to 1987 SIC-3 to enable me merge this dataset with other data sources. I convert the 1987 SIC-3 product code to 1972 SIC-3 using a concordance table from the NBER webpage.[7] I do this because, the main identifier in the product life-cycle length data is the 1972 SIC-3 product code.

3.2.2 Country Level Intellectual Property Rights Protection Data

This consist of proxies computed every 5-year period that represents the strength of patent protections across 122 countries from the period 1960 to 2005 developed in Ginarte and Park (1997) and updated in Park (2008)[8]. This index has been widely used in several literatures (Bilir (2014a), Ivus (2010), McCalman (2004), Smith (1999), among others) because of its extensive coverage and detailed construction. The index is constructed from five distinct categories related to national patent laws namely: (1) extent of coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms and (5) duration of protection. Thus, it captures both the *de jure* and *de facto* aspects of patent laws. For each country and time pair, each of the 5 categories was given a score ranging from 0 to 1 depending on whether the existing patent laws meet some specific criteria. The overall index for a country-time pair is the unweighted sum of the five values and thus, it ranges between 0 and 5 with higher values indicating stronger patent protection[9]. The results in the empirical section is based on the overall index. I assign every year for which there is no index in the IPR data during

[7]See: http://www.nber.org/nberces/nberces5811/conc_sic72_sic87_documentation.pdf

[8]An updated version up till 2010 is available on http://fs2.american.edu/wgp/www/

[9]This index shows that the 5 countries with the highest protection on average between 1960-2005 are USA,Belgium, Netherlands, United Kingdom, and Germany and the 5 with the lowest protection are Myanmar, Papau New Guinea, Angola, Mozambique and Ethiopia which might not be surprising. For extensive discussions on the construction of the index, we refer the reader to Ginarte and Park (1997) and Park (2008)

the period 1989-2006 to the closest available in the IPR data[10]. For example, 1990 IPR index is assigned to countries in the export data for the years: 1989, 1990, 1991 and 1992; 1995 IPR index is assigned to countries in the export data for the years 1993, 1994, 1995, 1996 and 1997.

3.2.3 Product Life-Cycle Lengths by Industry

Product life-cycle length is a cross-sectional dataset developed in Bilir (2014a). This index reflects the idea that a product life-cycle is not based on several versions of a product developed using the same innovative idea. But instead, the economic lifetime of the innovative idea which may span more than one version of the product. The main implication of this idea is that innovative ideas overlaps several versions of a product and once imitated, the firm suffers a loss in profit from current and future versions of a product. This idea is consistent with the theory developed in section 3.3. The employed measurement approach captures cross-sectoral variation in the lengths of product life-cycle by examining the economic durability of embedded technologies. This index is constructed using detailed data on US registered patents and citations from NBER US Patent citation dataset (Hall et al., 2001). The authors used the "forward citation" lag[11] method in constructing the index. The measured industry life-cycle $\hat{T}_j$ is the average forward citation lag within an industry[12]. $\hat{T}_j$ is mapped to the export data using the SIC-3 identifier. The sectors with the longest product life cycle are: Heating equipments (except electric), metal cans and shipping containers, and screw machine products, bolts, nuts, screws. The 3 shortest are: watches, clocks and clockwork operated devices; computer and office equipments; and electronic machineries, The list of the sectors and their product lifecycle length is presented in Table (3.8).

3.2.4 Macro Data

The macro data used in this work comes from Penn World table 8.1 described in Feenstra et al. (2015) and it consists of data on gross domestic product, population, output, inputs, income and productivity etc. covering 167 countries between 1950 and 2011. I construct the real GDP per capita using Real GDP and population variables. I also use Data on Human Development Index (HDI) from United Nations Development Programme (UNDP) database[13]. HDI data is used in only the descriptive analysis.

[10] We are not the first to use this assignment method in the literature. For example, Bilir (2014a) also used this assignment method

[11] This is the time lapse between the grant date of the cited patent and its subsequent citation

[12] for a detailed explanation see: Bilir (2014b). The full-data is freely available on: *https://www.aeaweb.org/articles?id=10.1257/aer.104.7.1979.*

[13] Available on: *http://hdr.undp.org/en/data#*

3.2.5 Data Merging and Cleaning

I merge the export data, patent index, product life-cycle lengths data and macro data. Among the 122 countries (including the US) in the patent protection index data, I observe export information for 119 countries, so I keep the data for 119 countries in the patent protection index and US exports dataset. Since our focus is the patent sensitive sectors for which we have product life-cycle data for 37 3-digit SIC sectors, I keep observations for only these sectors in the US export dataset.
I start by merging the export data with the product life-cycle index dataset using the 3-digit SIC sector identifier. Then, I merged this dataset with the country-level patent protection index and macro data set using the country-year identifier. After merging and cleaning up these datasets, our export data sample size reduced to 65,249 US export-destination observations to 119 countries in 37 SIC-3 sectors.

3.2.6 Descriptive Statistics

In Table (3.1), I document a number of facts with respect to product life-cycle length, patent protection and exporting. I start by partitioning countries according to their quartile of average patent protection index in columns (1-4) and column (5) consists of all countries. I have the number of countries in row (1) and each cell, say cell (1,1) (i.e. row-1, column-1) with 34 implies that there are 34 countries in the first quartile of countries classified by their average patent protection index. Total exports are in row (2) and in rows (3-6), we partition exports according to their quartile of product life-cycle length. For example, cell (3,1) implies that a total of $81.9 Billion dollars of exports was sold to countries in the first quartile of average patent protection index. The percentage values in each cell in rows (3-6) is the change in total exports in a quartile of product life-cycle length relative to total exports in the first quartile of product life-cycle length[14]. I find a couple of relationships which I briefly summarise and discuss below.

Fact 1 *US exports to countries are non-monotonically increasing in country-level average patent protection index both in aggregate exports and in exports partitioned by their product life-cycle length.*

While the number of countries in each quartile of patent protection index is somewhat symmetric (row 1), I observe that the total exports across these destinations varies largely in patent protection index. This is also true when I consider average exports to a country (i.e. divide row 2 by row 1). US exports are increasing non-monotonically in countries

[14] For example, in cell (4,1), -25.64% is computed as $\frac{60.9-81.9}{81.9}$. Similar reasoning is applied for other cells

with stronger patent laws. Even when we partition US total exports by quartiles of their product life-cycle length, I still find this pattern (Table 3.1 row 3-6). For example, in cell (2,3), I observe that these countries receive a total US exports of $561 Bn compared to $1,000 Bn in cell (2,2), however this amount is larger than the amount $235 Bn for countries in the first quartile - cell (2,1). This pattern persist when I breakdown exported products into quartiles of the product life-cycle length. This is not very surprising since these countries imitation risk is likely the highest within these group of countries. I shows that countries in the third quartile of average patent protection includes two Chinese provinces Hong Kong and Taiwan etc (see table Table 3.7), which has been in the forefront of public debate on duplicative imitation[15].

Fact 2 *US exports is non-monotonically decreasing in product life-cycle length across all countries and within countries in different quartiles of patent protection index. Moreover, the sensitivity of exports to product life-cycle length depends on the level of patent protection index.*

In column 5, row 3-6 of Table (3.1), I observe that total US exports is sensitive to product life-cycle length - decreasing as product life-cycle increases. This pattern persists for each subsample of countries partitioned according to the quartile of their patent protection index (rows 3-6, columns 1-4). Comparing total exports to all countries between products in the first, second, third and fourth quartiles of product life-cycle length (Table 3.1, column 5), I observe a decrease of 14.89%, 51.44% and 58.30% respectively.

Additionally, export of products with longer product life-cycle length reacts differently across the quartiles of country's patent protection index. Strongest for countries in the third quartile of average patent index and weaker in other quartiles. For example, in cell (4,3), there is a 66.23% drop in exports of products in the second quartile of product life-cycle length when compared with exports in the first quartile of product life-cycle length- cell(3,3). Comparing this with countries in the first, second and fourth quartiles of patent protection index (Table (3.1) columns 1, 2 and 4), we see a lesser drop of 25.64%, 8.87% and 2.52%. Similar pattern emerges for products in the third and fourth quartile of product life-cycle length. This shows that the sensitivity of exports to product-life cycle length depends on the level of patent protection index; strongest for countries in the 3rd quartile of average patent index. Additionally, we show in figure (3.1) that average level of patent protection is strongly positively correlated average per capita GDP with a correlation coefficient of approximately 0.6. In section 3.3, we present a model that predicts some of these facts and test the predictions in section 3.4.

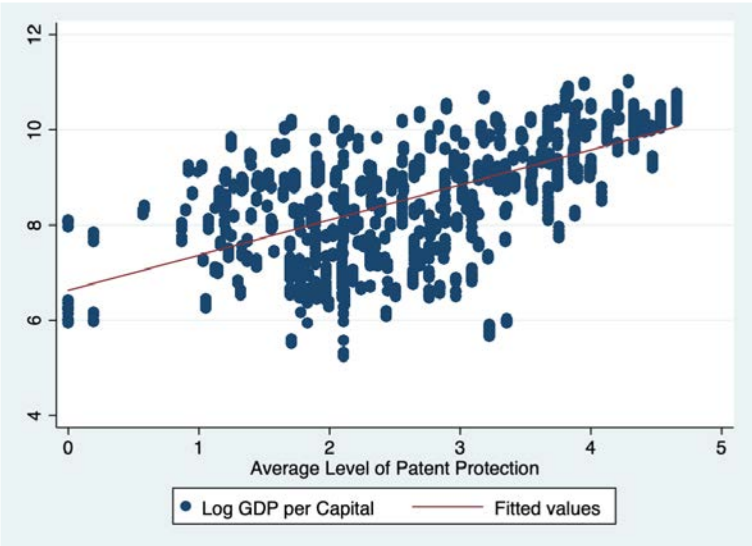
[15]For example see : http://www.businessinsider.com/most-counterfeit-goods-are-from-china-2013-6 http://www.businessinsider.com/donald-trump-accuses-china-massive-theft-intellectual-property-unfair-taxing-tawian-2016-12

Table 3.1: US Exports by Product Life-Cycle and Country's Level of IPR Protection

	Countries in 1st Quartile of avg. Patent Index (1)	Countries in 2nd Quartile of avg. Patent Index (2)	Countries in 3rd Quartile of avg. Patent Index (3)	Countries in 4th Quartile of avg. Patent Index (4)	All Countries in Sample (5)
Number	34	31	27	27	119
Total Exports (89 -06) ($Bn)	235	1000	561	3450	5250
Exports (89 -06) ($Bn)1st Quartile Product life-cycle	81.9	327	308	1190	1906.9
Exports (89 -06) ($Bn)2nd Quartile Product life-cycle	60.9 -25.64%	298 -8.87%	104 -66.23%	1160 -2.52 %	1622.9 -14.89%
Exports (89 -06) ($Bn)3rd Quartile Product life-cycle	38.2 -53.36%	185 -43.43%	70.7 -77.05%	632 -46.89%	925.9 -51.44%
Exports (89 -06) ($Bn)4th Quartile Product life-cycle	54.1 -33.94%	193 -40.98%	79.0 -74.35%	469 -60.59%	795.1 -58.30%

This table shows the total US exports of products by quartile of product life-cycle to different groups of countries defined by their product life-cycle. All values are in Billion US dollars. Due to some approximation errors, the values in rows 4, 5, 6 and 7 of column 6 do not add up exactly as the values in column row 3 column 6. Percentage decreases is computing the change from quartile 1-product life cycle value of exports to its corresponding current value of export.

Figure 3.1: Scatter Plot of Log of GDP per Capita on Average Patent Protection



3.3 The Model

The model developed here is a partial equilibrium model of export destination decisions closely related to the model of multinational firms location decisions in Bilir (2014a). This model captures the trade-off between imitation risk and profit gains faced by exporting firms. Predictions of this model are validated in the empirical section of this paper.

3.3.1 Setup

Consider a world with only three countries North, South 1 and South 2. For simplicity, I denote the countries as A, B and C respectively. Country A is an inventing country with strong IPR laws. Countries B and C have weaker patent laws compared to A. We incorporate the empirical findings in Smith (1999) by distinguishing between two types of countries in the South - one with weak imitative ability and the other with strong imitative ability. We assume Country B to have weaker IPR regulation compared to country A and weak imitative abilities. This country could be seen as countries with either low human capital development or strong aversion for imitation, thus imitating new innovations never happens. Country C has weaker IPR laws compared to country A but with strong imitative abilities. Country C can be viewed as countries with higher human capital development and low aversion for imitation, thus imitation risk is high. This specification takes into account the heterogeneity of countries in the South. Most literatures (with an exception of Auriol et al. (2012)) have assumed a homogeneous South which is not very realistic because it is not necessarily true that least-developed countries can free-ride on patented innovations in the same way as emerging economies such as China, Taiwan or South Korea. For simplicity, I assume that the three countries are symmetric in all aspects except in their levels of per capita income, IPR regulations and imitation risk and they all have monopolistically competitive markets each of size 1. In addition, for the 3 countries, I assume uniform demand for each product across each period during the product life-cycle and profits realised from each country depends on the country's per capita income. I assume time to be continuous and consider a continuum of horizontally differentiated varieties of products in each sector j such that $j = 1, ..., J$. Firms in country A manufactures products using innovations which have been patented and enjoys monopoly profit. Each manufactured product has a sector specific life-cycle length on its patents after which the product becomes obsolete with no economic value. In order to increase profits, the monopolist sells its products in its home market, country B and decides whether to sell to country C. In deciding whether to sell to C, the firm faces a trade-off. On one hand, selling to C increases its profit since its market size is larger

and on the other hand is faced with imitation risk. If imitation is successful, imitators compete with the monopolist in market B and C only. Therefore, the monopolist enjoys monopoly profits until its product is either imitated or obsolete. This setup deviates from the assumption in a two country setting (North and South) where imitators in the South competes with inventors in the North and South markets.[16]
Sectors are distinguished by their pace of product obsolescence which is assumed to be determined by technological developments specific to each sector but exogenous to individuals firms. Let T_j be sector-j's life-cycle length shared by all products within sector-j. Hence, for any given product in sector-j, at time $t \geq T_j$, it reaches its maturity and becomes obsolete and is of no further economic value.
I further assume demand is constant and the same at each period during the product life-cycle and total demand over the product life-cycle is equal to 1. Thus, demand follows a uniform distribution with probability density function $\zeta(t) = \frac{1}{T_j}$.

Product Imitation

Potential imitators exists in country C. Imitators with access to proprietary knowledge necessary for production may commence reverse-engineering of the product. Following Glass and Saggi (2002), Bilir (2014a) and Grossman and Helpman (1991), I further assume that the time to imitation success denoted as q is unknown and success arrives at a constant poisson rate. Assuming arrival time is restricted to a known interval [0, $\bar{q}$], this implies that q follows a uniform distribution over the period[17]. Every successful imitator competes with inventing firms wherever patents are not enforced until the variety becomes obsolete.

A Monopolist Problem

Consider a representative innovative monopolist in the North who has introduced a new product in the market. We assume that technologies embodied in goods can be imitated. To produce this good, the monopolist use product-specific technology which has been patented. A monopolist earns the following exogenous profits $\pi^A(l_1) > 0$, $\pi^B(l_2) > 0$, $\pi^C(l_3) > 0$ if products are exported to country A, B and C respectively such that $\pi^A(l_1) \neq \pi^B(l_2) \neq \pi^C(l_3)$. l is defined as aggregate GDP per capita which captures the country's economic size. Thus, selling to the 3 countries give a profit $\pi^A(l_1) + \pi^B(l_2) + \pi^C(l_3)$ and to A and B only gives $\pi^A(l_1) + \pi^B(l_2)$. Notice that exporting to country C gives the firm a higher profit (since $\pi^C(l_3) \geq 0$) but this comes at a cost of imitation risk. If

[16]The setup in this article reflects more of reality. Imitators cannot re-export products with patent infringements to countries in the North.

[17]To limit the number of cases I assume $\bar{q} > \max_j T_j$

products are imitated, the monopolist competes with the imitator in country B and C. In the absence of imitation in country i, the firm earns revenue defined by $r^i = \sigma\pi^i(l_i)$ where $\sigma > 1$ is the demand elasticity faced by all firms. I assume that innovating firms protect proprietary information formally by patents and imitators can copy an existing knowledge by direct access to the products[18]. Imitators are not aware about a potential product to imitate until a direct contact with the product, which enable them to reverse-engineer the product[19]. This implies that cross-border knowledge and access to products is costly, so imitators are economically constrained to pursue only those varieties that are locally available.

Imitation affects the innovators export decisions because entry by an imitator results to profit losses. Firms competing with imitators gets a fraction of the per-period profits. Denote a variable $\gamma_i \in [0, 1]$ as the level of patent enforcement regulation in country i. From the narratives above, it implies that $\gamma_A = 1, \gamma_B < 1$ and $\gamma_c < 1$. This variable captures laws prohibiting patents infringements such that an increase in γ_i implies an increase in IP regulations. We modelled this as a share of profit which the monopolist receives if his product is imitated. Since Imitation will not occur if either there is a strong patent enforcement regulation or low imitative abilities in country i, I assume $\gamma_B = 1$. This implies that imitation is not likely to occur in country B, so the monopolist share of profit in B is 1.

Faced with the trade-off in exporting to country C, A monopolist in sector-j, selects the optimal product maturity $t^* \in [0, T_j]$ at which to start exporting its products to country C by maximizing its lifetime expected profits (In cases where it leads to no confusion, I remove the superscripts A, B, C. The countries can be identified by the subscripts of l such that A, B, C denotes 1, 2, and 3 respectively) given by:

$$\max_t\{E_q[\Pi_j(t)]\} = \max_t\{(\pi(l_1) + \pi(l_2))t + E_q[(\pi(l_1) + \pi(l_2) + \pi(l_3)) \min\{T_j - t, q\}] + (\pi(l_1) + (\pi(l_2) + \pi(l_3))\gamma_c)E_q[\max\{0, T_j - t - q\}]\} \quad (3.3.1)$$

Equation (1) shows the effect of imperfect patent laws in country B and C on exporting incentives of firms. Exporting to country A and B, a firm earns profit $(\pi(l_1) + \pi(l_2))$ until exporting to country C begins at maturity t, and afterwards is exposed to imitation risk. The firm then earns profit $(\pi(l_1) + \pi(l_2) + \pi(l_3))$ for the length of time q or $T_j - t$ depending on whether the time for imitation (q) precedes time-to-obsolescence ($T_j - t$)

[18]In applying for a patent, inventors are obliged to provide a description of their invention. Thus, by having a direct access to a product and a description of its invention, imitators are able to copy the product.

[19]Imitators are usually concerned about the success of a new product before imitating it. Therefore, if a new product has not been exported to their destination, they are unaware of its success in their home market, and in some cases may not be aware of its existence.

or not. If length of time for a successful imitation q precedes the time-to-obsolescence $T_j - t$, then imitation will occur between the time period $(T_j - t - q)$ and profits will be $\pi(l_1)$ in country A but in country B and C, it will be $(\pi(l_2) + \pi(l_3))\gamma_c$. Thus total profit in this case is $\pi(l_1) + (\pi(l_2) + \pi(l_3))\gamma_c$.

We assume that profits is an increasing function of GDP per capita (l_i) in each country i. Maximizing equation (3.3.1) over possible product maturity $t \geq 0$ at which to start exporting to country C, we derive the expression

$$t^* = T_j - \left(\frac{\bar{q}}{1-\gamma_c}\right)\left[\frac{\pi(l_3)}{\pi(l_2) + \pi(l_3)}\right] \tag{3.3.2}$$

For simplicity, assuming a linear profit function in l_i such that $\pi(l_i) = \pi l_i$, Equation(3.3.2) boils down to

$$t^* = T_j - \left(\frac{\bar{q}}{1-\gamma_c}\right)\left[\frac{l_3}{l_2 + l_3}\right] \tag{3.3.3}$$

which depends positively on the product lifecycle ($\frac{dt^*}{dT_j} > 0$), negatively on the degree of patent enforcement in country C ($\frac{dt^*}{d\gamma_c} < 0$), negatively on the gdp per capita of Country C ($\frac{dt^*}{dl_3} < 0$) and positively on the gdp per capita of Country B ($\frac{dt^*}{dl_2} > 0$).

Intuition: First, firms in the North exports to country C earlier in the product life-cycle when IPR in C becomes stronger ($\frac{dt^*}{d\gamma_c} < 0$), which is self-intuitive. If countries with high imitation risk embark on patent reforms, northern firms would export at an earlier time in their product life-cycle length since the risk of imitation is reduced and profits are higher. Secondly, an increase in average income in country C, increases firms' incentive to export at an earlier time ($\frac{dt^*}{dl_3} < 0$) because profit opportunities are increased. This is so as the potential profits will offset the risk of imitiation. Thirdly, if GDP per capita increases in Country B, then firms will export to C at a later time in the product life-cycle ($\frac{dt^*}{dl_2} > 0$) because if the products are imitated in C, it faces competition in B and expected losses arising from such situation is larger. Finally, the longer the product life-cycle length T_j, the later exports commences ($\frac{dt^*}{dT_j} > 0$) because the expected loss from imitation will span for a longer time. We define $\tau^*(\gamma_c, l_2, l_3) = \left(\frac{\bar{q}}{1-\gamma_c}\right)\left[\frac{l_3}{l_2+l_3}\right]$ as time-to-obsolescence exporting cut-off that is invariant across sectors with different product life-cycle lengths.

Lemma 1 *In sectors where $T_j \leq \tau^*(\gamma_c, l_2, l_3)$, products are always sold to Countries A, B and C at $t_j^* = 0$. In other sectors, manufactured products are initially sold in countries A and B and shipping to C starts once the product has $\tau^*(\gamma_c, l_2, l_3)$ time remaining before* *obsolescence and stays there till it becomes obsolete. That is:*

$$t^* = \begin{cases} 0 & \text{if } T_j \leq \tau^*(\gamma_c, l_2, l_3) \\ T_j - \tau^*(\gamma_c) & \text{if } T_j > \tau^*(\gamma_c, l_2, l_3) \end{cases}$$

From Lemma 1, we can easily deduce that products with life-cycle T_j are shipped to country C for the time periods $T_j - t_j^* = min\{T_j, \tau(\gamma_c, l_2, l_3)\}$. With our assumption of uniform demand over the product life-cycle length, the measure of exports of product j to Country C becomes:

$$C_j(\gamma_c, l_2, l_3) = \int_{t_j^*(\gamma_c)}^{T_j} \zeta_j(t)dt = \frac{T_j - t_j^*(\zeta_c)}{T_j} = min\left\{1, \frac{\tau^*(\gamma_c, l_2, l_3)}{T_j}\right\}$$

Which can be rewritten as:

$$C_j(\gamma_c, l_2, l_3) = \begin{cases} 1 & \text{if} \quad T_j \leq \tau^*(\gamma_c, l_2, l_3) \\ \frac{\tau^*(\gamma_c, l_2, l_3)}{T_j} & \text{if} \quad T_j > \tau^*(\gamma_c, l_2, l_3) \end{cases} \tag{3.3.4}$$

The following implications are deduced from equation (3.3.4). Firstly, as countries improves their patent enforcement laws, a large measure of products in sector j are exported to the country $\left(\frac{dC_j(\gamma_c)}{d\gamma_c} = \frac{dC_j(\gamma_c)}{d\tau^*(\gamma_c, l_2, l_3)} \frac{d\tau^*(\gamma_c, l_2, l_3)}{d\gamma_c} \geq 0\right)$. Secondly, as GDP per capita of countries grows, a larger measure of products in sector j are exported to the country $\left(\frac{dC_j(\gamma_c)}{dl_3} = \frac{dC_j(\gamma_c)}{d\tau^*(\gamma_c, l_2, l_3)} \frac{d\tau^*(\gamma_c, l_2, l_3)}{dl_3} \geq 0\right)$. Finally, the measure of products in sector j exported to C is decreasing in the product life-cycle length $\left(\frac{dC_j(\gamma_c)}{dT_j} \leq 0\right)$. These findings are summarize in Result (1) as:

Result 1 *The quantity of sector j's varieties exported to Country C is weakly increasing in the level of patent enforcement laws and average income per capita and weakly decreasing in product life-cycle lengths.*

This implies that stronger IPR laws in countries with imitation risk increases north's exports since the stricter laws will serve as a caution to potential imitators. In addition, average income per capital would increase exports from the north to countries in the south with imitation risk since the higher expected profits compensates for expected loss if imitation occurs. Finally, the larger the product life-cycle length, the larger the expected loss over the life of the product. This will attenuate exports to countries with imitation risk.

I compute the aggregate export revenue from exporting sector j's product upon the decision to export to Country C. The aggregate export revenue depends on the probability that imitation will occur in C. If imitation occurs, revenue from both Country B and Country C are affected. We obtain the expression for aggregate revenue by integrating product-specific revenues over the product maturities distribution as shown in equation (3.3.5) below.

$$R_j(\gamma_c) = \int_{t_j^*(\gamma_c)}^{T_j} \Big((r_2 + r_3)[1 - \psi(t)] + \gamma_c(r_2 + r_3)\psi(t) \Big) \zeta_j(t)dt \tag{3.3.5}$$

$\psi(t)$ is the probability that a maturity-t product in sector j will be imitated at the current time t. Equation (3.3.5) can be rewritten as:

$$R_j(\gamma_c) = \int_{\{0, T_j - \tau*(\gamma_c)\}}^{T_j} \Big((r_2 + r_3)[1 - \psi(t)] + \gamma_c(r_2 + r_3)\psi(t) \Big) \zeta_j(t)dt$$

Where:

$$\psi(t) = \begin{cases} \frac{t}{\bar{q}} & \text{if } T_j < \tau(\gamma_c, l_2, l_3) \\ \frac{t - (T_j - \tau(\gamma_c, l_2, l_3))}{\bar{q}} & \text{if } T_j \geq \tau(\gamma_c, l_2, l_3) \end{cases}$$

The solution to this problem becomes:

$$R_j(\gamma_c, l_2, l_3) = \begin{cases} (r_2 + r_3)\Big(1 - \frac{T_j}{2\bar{q}}\Big) + \gamma_c(r_2 + r_3)\frac{T_j}{2\bar{q}} & \text{if } T_j \leq \tau^*(\gamma_c, l_2, l_3) \\ (r_2 + r_3)\Big(\frac{\tau^*(\gamma_c, l_2, l_3)}{T_j} - \frac{\tau^*(\gamma_c, l_2, l_3)^2}{2\bar{q}T_j}\Big) + \gamma_c(r_2 + r_3)\frac{\tau^*(\gamma, l_2, l_3)^2}{2\bar{q}T_j} & \text{if } T_j > \tau^*(\gamma_c, l_2, l_3) \end{cases} \tag{3.3.6}$$

Equation (3.3.6) implies that expected aggregate export revenue from exporting products in sector-j upon decision to export to country C is increasing as country C improves its IPR laws $\left(\frac{dR_j(\gamma_c, l_2, l_3)}{d\gamma_c} > 0\right)$ and also increasing as GDP per capita increases $\left(\frac{dR_j(\gamma_c, l_2, l_3)}{dl_3} > 0\right)$. This finding offers additional support to result (1) with the same intuition as already discussed. This is summarized in Result (2):

Result 2 *The expected export revenue from exporting varieties in sector-j upon the decision to export to the country with imitation risk is increasing in IPR reforms and income per capita of the country.*

The intuition for this result is straightforward, if patent enforcement in a country with high imitation risk becomes stronger, this reduces the risk of imitation, hence total revenue from exporting increases. More so, an increase in income per capital in such countries would increase the revenue from exporting. In the next subsection, we study the sectoral response of a change in IPR laws.

3.3.2 Sectoral Response to Changes in Patent Enforcement Laws

Consider a situation where country C enacts a stronger patent enforcement law say from γ_c to γ_c'. From equation(3.3.2), firms export products in sector-j earlier in the product life-cycle and from equation (3.3.4) this implies:

$$\Delta C_j(\gamma') = \begin{cases} 0 & \text{if } \; T_j < \tau^*(\gamma_c, l_2, l_3) \\ \dfrac{T_j - \left(\frac{\bar{q}}{1-\gamma_c}\right)\left(\frac{l_3}{l_2+l_3}\right)}{T_j} & \text{if } \; T_j \in [\tau^*(\gamma_c, l_2, l_3), \tau^*(\gamma_c', l_2, l_3)] \\ \dfrac{\left(\frac{l_3}{l_2+l_3}\right)\left[\left(\frac{\bar{q}}{1-\gamma_c'}\right) - \left(\frac{\bar{q}}{1-\gamma_c}\right)\right]}{T_j} & \text{if } \; T_j > \tau^*(\gamma_c', l_2, l_3) \end{cases} \quad (3.3.7)$$

Where $\Delta C_j(\gamma') = C_j(\gamma_c', l_2, l_3) - C_j(\gamma_c, l_2, l_3)$. From equation (3.3.7), it is easy to see that $\frac{d\Delta C_j(\gamma')}{dT_j} = 0$ for $T_j < \tau^*(\gamma_c, l_2, l_3)$, $\frac{d\Delta C_j(\gamma')}{dT_j} > 0$ for $T_j \in [\tau^*(\gamma_c, l_2, l_3), \tau^*(\gamma_c', l_2, l_3)]$ but this increase is non-monotonic as $\frac{d\Delta C_j(\gamma')}{dT_j} < 0$ for higher values $T_j > \tau^*(\gamma_c', l_2, l_3)$. This result can be summarized as:

Result 3 *Given an increase in IPR laws in countries with high imitation risk, there is an increase in exports of products with longer product life-cycle length, however this increase is non-monotonic.*

This result captures the sectoral effect of improved patent reforms on exports in a country with imitation risk. It is non-trivial, as it sheds some lights on how different sectors reacts (based on their characteristics) to an improvement of patent laws in potential export destinations. It implies that for some sectors with product lifecycle length $T_j < \tau^*(\gamma_c, l_2, l_3)$, there is no effect of improved patent laws on exports since $\Delta C_j(\gamma') = 0$, and for some other sectors this effect is positive. In addition, we observe that exports in sectors with higher product life-cycle length are more sensitive to such patent reforms, however this sensitivity is non-monotonic. That is, sectors with product life-cycle length below the time-to-obsolescence cut-off (prior to the reform) are not sensitive to patent reforms as such sectors already exports to the destination prior to the reform, hence the reform has no impact on their exports. The sensitivity of exports to patent reforms rises for sectors with product life-cycle length higher than the time-to-obsolescence cut-off prior to the reform. However, this sensitivity is non-monotonic since it is smaller for sectors whose product life-cycle length is higher than the new time-to-obsolescence cutoff. The intuition is straightforward. Stronger patent reforms in the south encourages firms with longer product life-cycle length to export more of their output to such destinations because of higher profit opportunity. The non-monotonicity results from the idea that firms in sectors with very high product life-cycle length have more to lose if their product is imitated .

In a similar way, consider a situation where income per capita increases in country C say from l_3 to l_3' , Result (1) and equation (3.3.2) implies:

$$\Delta C_j(l_3') = \begin{cases} 0 & \text{if } T_j < \tau^*(\gamma_c, l_2, l_3) \\ \frac{T_j - \left(\frac{\bar{q}}{1-\gamma_c}\right)\left(\frac{l_3}{l_2+l_3}\right)}{T_j} & \text{if } T_j \in [\tau^*(\gamma_c, l_2, l_3), \tau^*(\gamma_c, l_2, l_3')] \\ \frac{\left(\frac{\bar{q}}{1-\gamma_c}\right)\left[\left(\frac{l_3'}{l_2+l_3'}\right) - \left(\frac{l_3}{l_2+l_3}\right)\right]}{T_j} & \text{if } T_j > \tau^*(\gamma_c, l_2, l_3') \end{cases} \quad (3.3.8)$$

Where $\Delta C_j(l_3') = C_j(\gamma_c, l_2, l_3') - C_j(\gamma_c, l_2, l_3)$ is the change in the export of sector-j's varieties to country C resulting from a change in GDP per capita. Equation (3.3.8) implies $\frac{d\Delta C_j(l_3')}{dT_j} = 0$ for $T_j < \tau^*(\gamma_c, l_2, l_3)$, $\frac{d\Delta C_j(l_3')}{dT_j} > 0$ for $T_j \in [\tau^*(\gamma_c, l_2, l_3), \tau^*(\gamma_c, l_2, l_3')]$ and $\frac{d\Delta C_j(l_3')}{dT_j} < 0$ for higher values $T_j > \tau^*(\gamma_c, l_2, l_3')$. This result can be summarized as:

Result 4 *Given an increase in economic size measure by per capita gross domestic product in countries with high imitation risk, there is an increase in exports of products with longer product life, however this increase is non-monotonic.*

Higher income per capita provides additional incentives for firms in sectors with relatively longer product life-cycle to export to such destination because of increased profits. This increase is non-monotonic as products in sectors with very high product life-cycle lengths are less sensitive since imitation implies a larger possibility of profit loss since the product spans a longer period of time.

I now consider the change in revenue from sector-j's exports following a patent reform in country C. If country C enacts a stricter patent enforcement laws say from γ_c to γ_c', from equation (3.3.2) and result (2) it is easy to see that:

$$\Delta R_j(\gamma_c', l_2, l_3) = \begin{cases} \frac{(\gamma_c' - \gamma_c) H T_j}{2\bar{q}} & \text{if } T_j < \tau^*(\gamma_c^*, l_2, l_3) \\ H\left[1 - \frac{(1-\gamma_c')T_j}{2\bar{q}} - \frac{\tau^*(\gamma_c, l_2, l_3)}{T_j}\left(1 - \frac{\tau^*(\gamma_c, l_2, l_3)(1-\gamma_c)}{2\bar{q}}\right)\right] & \text{if } T_j \in [\tau^*(\gamma_c), \tau^*(\gamma_c')] \\ \left(\frac{H}{T_j}\right)\left(\frac{\tau^*(\gamma_c', l_2, l_3)(\gamma_c' - \gamma_c)}{1-\gamma_c}\right)\left(1 - \frac{\tau^*(\gamma_c, l_2, l_3)(1-\gamma_c)}{2\bar{q}}\right) & \text{if } T_j > \tau^*(\gamma_c', l_2, l_3) \end{cases} \quad (3.3.9)$$

Where $H = (r_2 + r_3)$, $\Delta R_j(\gamma_c', l_2, l_3) = R_j(\gamma_c', l_2, l_3) - R_j(\gamma_c, l_2, l_3)$ is the change in export revenue of sector-j's product as a result of increased patent law in Country C. I show in appendix (3.A.4) that there is an increase in revenue from exports in sectors with longer product lifecycle length following a patent reform $\frac{d\Delta R_j(\gamma_c, l_2, l_3)}{dT_j} > 0$ for $T_j < \tau^*(\gamma_c, l_2, l_3)$ and $T_j \in [\tau^*(\gamma_c), \tau^*(\gamma_c')]$. However this increase is non-monotonic as $\frac{d\Delta R_j(\gamma_c, l_2, l_3)}{dT_j} < 0$ for

$T_j \geq \tau^*(\gamma_c, l_2, l_3)$. This finding is summarized in result (5).

Result 5 *Given an increase in IPR laws in countries with high imitation risk, there is an increase in expected revenue from exports in sectors with longer patent life-cycle length, however this increase is non-monotonic.*

This finding is a direct consequence of result (3). Following a patent reform in the country with high imitation risk, sectors with higher product life-cycle length earns more export revenue because they increase their exports to such countries since imitation risk is lower. The non-monotonicity comes from the idea that sector with product life-cycle length at the topmost quantile of life-cycle length distribution could enjoys monopoly profits for a longer period of time if its products are not imitated. This consideration deters them from responding strongly to patent reforms.

Finally, I consider a situation where GDP per capita increases in country C say from l_3 to l'_3, equation(3.3.2) and result (2) implies that:

$$\Delta R_j(\gamma_c, l_2, l'_3) = \begin{cases} 0 & \text{if } T_j < \tau^*(\gamma_c, l_2, l_3) \\ H\left[\frac{2\bar{q}-(1-\gamma_c)T_j}{2\bar{q}} - \frac{\tau^*(\gamma_c,l_2,l_3)}{T_j}\left(\frac{2\bar{q}-(1-\gamma_c)\tau^*(\gamma_c,l_2,l_3)}{2q}\right)\right] & \text{if } T_j \in [\tau^*(.,l_3), \tau^*(.,l'_3)] \\ \frac{H}{2\bar{q}T_j}\left[\left(\frac{2\bar{q}l_2+\bar{q}l'_3}{l_2+l'_3}\right)\tau^*(\gamma_c,l_2,l'_3) - \left(\frac{2\bar{q}l_2+\bar{q}l_3}{l_2+l_3}\right)\tau^*(\gamma_c,l_2,l_3)\right] & \text{if } T_j > \tau^*(\gamma_c,l_2,l'_3) \end{cases} \quad (3.3.10)$$

Where $\Delta R_j(\gamma_c, l_2, l'_3) = R_j(\gamma_c, l_2, l'_3) - R_j(\gamma_c, l_2, l_3)$ is the increase in export revenue of sector$-j$ product resulting from an increase in per capita GDP in Country-C. Clearly, $\Delta R_j(\gamma_c, l_2, l'_3)$ is weakly increasing in product life-cycle length $\frac{d\Delta R_j(\gamma_c,l_2,l'_3)}{dT_j} \geq 0$ for $T_j < \tau^*(\gamma_c, l_2, l'_3)$. However, this increase is non-monotonic as $\frac{d\Delta R_j(\gamma_c,l_2,l'_3)}{dT_j} < 0$ for $T_j > \tau^*(\gamma_c, l_2, l'_3)$. I proof this in the appendix. This finding is summarised in result (6).

Result 6 *Given an increase in income per capita in countries with high imitation risk, there is an increase in expected revenue from exports in sectors with longer patent life-cycle length, however this increase is non-monotonic.*

This is a direct consequence of Result 4, If higher income per capita provides additional incentives for firms in sectors with relatively longer product life-cycle length to export, it is natural to expect an increase in revenue. This increase is non-monotonic for the same reasons discussed in result 4.

In the next section, we test the prediction of the model outlined above. We note that both result (1) and (2) have been a subject of research since over a decade (Maskus and Penubarti (1995), Ivus (2010), Rafiquzzaman (2002), among others). We re-validate these results and empirically validate results (3) to (6).

3.4 Econometric Framework

In the model presented in section 3.3, I assumed that a representative producer of an innovative product in sector j with patents on its output decides on a time to commence exporting to country C and this depends on the expected profits from exporting. The derived theoretical results highlight the implications of varied country-level IPR regulation and product life-cycle lengths on the distribution of patent sensitive products across countries. To validate the model's predictions, we focus on the intensive margin effects of patent enforcement and product life-cycle length on exports[20]. We describe our econometric approach below.

3.4.1 Baseline Estimation

Our theoretical results show that the sensitivity of North's exports to patent protection and income per capita in the south is an increasing and non-monotonic function of product life-cycle length. These results inform the baseline specification below:

$$ln(Y_{ijt}) = \beta + \beta_1 Pat_{it} \times T_j + \beta_2 Pat_{it} \times T_j^2 + \zeta_1 ln(gdppc)_{it} \times T_j + \zeta_2 ln(gdppc)_{it} \times T_j^2 + \eta_{it} + \eta_j + \epsilon_{ijt} \qquad (3.4.1)$$

where Y_{ijt} denotes value (in USD), quantity of goods or the number of 10 digit products[21] in sector j exported to country i at time t, Pat_{it} denotes IPR protection index in country i at time t, T_j denotes the length of product life-cycle in sector j, $ln(gdppc)_{it}$ is the log of GDP per capita in country i at time t, η_{it} is the country-time fixed effects and n_j is the sector fixed effects. In equation (3.4.1), the main coefficients of interest is β_1 and β_2 - which jointly capture the differential effect of IPR reforms on export patterns across sectors with different product life-cycle length T_j-, and ζ_1 and ζ_2 - which jointly captures the differential effect of income per capita on export patterns across sectors with different product life-cycle lengths T_j. For the empirical results to be consistent with the model, it must be that: $\beta_1{>}0$, $\beta_2 < 0$, $\beta_1 T_j + \beta_2 T_j^2 \geq 0$ and $\zeta_1{>}0$, $\zeta_2 < 0$, $\zeta_1 T_j + \zeta_2 T_j^2 \geq 0$ across the observed range of T_j.

This baseline specification includes some important controls such as the sector fixed effects (η_j) and country-year dummies (η_{it}). Sector dummies control for unobserved omitted

[20]The discrete-time hazard model allows us to study the extensive margin effect. This model would estimate the factors influencing the time-to-export of a patented product in sector j to country i. Such econometric model would require a firm-level panel data on patents, time of first production and time of first export to all possible destinations merged with product life-cycle lengths and country patent index data. We do not have such data; so we focus on the intensive margin effect by using the data already described in section (3.2).

[21]I do not take log when I use the number of 10 digit products as the dependent variable

sector characteristics such as total size of the industry, average firm's productivity, timing of imitation, sector-specific preferences etc. The country-year fixed effects η_{ij} accounts for unobserved time-varying country-level characteristics that affects export activity between the US and countries in our panel. This includes bilateral trade agreements, distance, level of development, language, colonial relationships, competition levels, etc. The residual term ϵ_{ijt} accounts for omitted variables that are orthogonal to the covariates. Standard errors are robust and clustered at the country level.

3.4.2 Identification

Identifying the effects of patent protection improvements have been a major empirical challenge. This is because patent reforms is done alongside with other domestic policies which encourages exports from the developed world. For example, when countries join WTO, they align themselves to the patent protection requirement of the Trade Related Intellectual Property Rights (TRIPS) agreement. Since joining the WTO comes with a reduction of trade barriers such as tariffs, this makes identification of the separate effects of patents improvement difficult. More so, countries that joins WTO has a clear motives of improving its trade relations and as a result may implement other domestic policies which increase trade. This makes causal inference from a simple regression of exports on IP protection impossible.

In the model developed in Section (3.3), variation in product life-cycle lengths T_j, determines US exports sensitivity to patent reforms, while US firm's sensitivity to other domestic policies is theoretically independent of T_j. Thus, cross-sectional variations in T_j captures the effect of patent laws separately from the effects of other domestic policies. It is very unlikely that T_j will be correlated with destination-country patent laws since it is measured using US data. Another potential concern is reverse causality. Our identification relies on the assumption that IPR reforms is independent of US exports. The rationale for this assumption is the following. First, as already mentioned, as part of the rules governing the membership of WTO, countries are required to align their national laws to the TRIPS requirements which includes regulations for IP rights. So it is unlikely that IPR will depend on US exports. Second, our measure of IPR reflects the extent to which patents is incorporated into the written laws governing a country. Since the introduction of new laws comes with a huge cost of abrogation, it is unlikely that it is influenced by US industry exports. However, just like in any non-randomized controlled experimental studies, I do not completely rule out this possibility, but argues that it is very unlikely.

3.5 Main Results

As a first step, I start by estimating the relationship between patent reforms Pat_{it} and export flows from the US omitting interactions with product life-cycle length and country-time fixed effects and including the country, sector and year fixed effects in equation (3.4.1). In Table (3.2) column 1, I find a positive and significant relationship. The result states that *ceteris paribus*, a rise in IPR reforms by one standard deviation in a country is related to an increase in US exports by 12% to such country. Although this finding is consistent with similar studies, we acknowledge some potential identification issues associated with this specification as discussed in section 3.4.2. If there are domestic policies such as a reduction in tariffs introduced simultaneously with IPR reforms, this results to an omitted variable bias, which overstates the coefficient of IPR reforms[22]. Therefore, this finding can be interpreted in terms of correlation rather than causation, consistent with the theoretical prediction in result (1).

In column 2 of Table (3.2), I use a specification with patents protection index and an interaction term between patent protection index and product life-cycle length. Our estimate, show that sectors with longer life cycle lengths are less responsive (exports less) to improved patent laws in destination countries compared with sectors with shorter life-cycle length. In other words, given an improved patent law in a country, there is an increase in US exports, however sectors with longer product lifecycles responds less compared with sectors with shorter product life-cycle length. The coefficient of patent protection index is still not identified in this regression, so we focus on the differential effect of patent laws on exports across sectors with different product life-cycle length.

Predictions from the theoretical model suggests that the relationship between product life-cycle length and exports given a change in patent protection is non-monotonic, which inspired our main estimating equation (3.4.1). In column (4), I estimate the log of exports on an interaction term between patent protection index and product life-cycle length (T_j), patent protection index and the square of product life-cycle length (T_j^2) while controlling for unobserved sector-level time-invariant effects and country-level time-variant effects, to capture the non-linear impact of product life-cycle length on sector-level exports conditional on improved patent regulations. I find that the effects of patent laws is increasing and non-monotonic in product lifecycle length. The results show that the extend to which a change in a country's patent protection increases the value of industry exports it receives from the US depends on the industry's product life-cycle length. Higher sen-

[22]Identification requires an instrument which is correlated with patents but uncorrelated with the omitted variables. Ivus (2010) uses colonial origin as an instrument. Our main interest is not in this specification but on the differential effect of patent protection on US export across sectors with different product life-cycle length.

sitivity of exports for moderate level of product life-cycle length and lower sensitivity for products in the topmost product life-cycle length. I verified that $\beta_1 T_j + \beta_2 T_j^2 \geq 0$ is satisfied for the range of product life-cycle length $T_j \in (7.37, 10.89)$, with a peak effect in a sector with $T_j = 8.83$ years. In terms of our data, our results imply that electronic components and accessories, and agricultural chemicals industries has the peak effect (i.e. increases exports the most with IPR reforms). Computers, and watches industries are below this peak to the right, and other industries are below the peak to the left. This implies that electronic components and accessories, and agricultural chemicals industries reacts the most to improved patent laws when compared with other industries. However, all industries increased their exports to destinations with improved IPR regulations, and the product lifecycle length determines their sensitivity.

In columns (6), I look at the effect of economic growth in a country on industry exports it receives from the US by interacting per capita GDP of country i in period t with the industry's product life-cycle length, and the square of industry's product life-cycle length. The estimated coefficients are very significant and imply that sectors with longer product life-cycle are more responsive to destination country economic growth, however this relationship is non-monotonic. In column (7), I include an interaction term between patent protection index and product life-cycle length (T_j), patent protection index and the square of product life-cycle length (T_j^2), per capita GDP with the industry's product life-cycle length, and per capita GDP with the square of industry's product life-cycle length while controlling for unobserved sector-level time-invariant effects and country-level time-variant effects. Since patents and per capita GDP are strongly positive correlated (Figure 3.1), the correlation between their interaction terms is stronger with a coefficient above 0.70. This implies the presence of multicollinearity in our regression estimates. This shortcoming is reflected in column (7) of Table (3.2) where the coefficients of the interaction terms of per capita GDP have the expected signs and are significant, and that of patents have the expected sign but, loses its significance. Since industry specific shocks may be correlated with IPR, In column (8), I control for industry-time fixed effects. The results becomes significant and consistent with our theory.

Since patent protection increases the market power of exporters, our previous result maybe driven by prices and not quantity. Duggan et al. (2016) finds that the introduction of patent regulations into India laws increased the price of newly patented pharmaceutical molecules by between 3 to 6 percent, with very slight effect on quantity sold. I check for this possibility in the next estimation by using *quantity of exports* as the dependent variable instead of *value of exports*. This is important because it isolates the effect of price changes which might be the case with some products. However, there are some limitations to the usage of this variable. In cases where the unit of measurement

Table 3.2: Destination Country Patent Laws and US Exports

	Dependent Variable: Log Value of Exports							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent	0.116	0.775						
	(0.046)*	(0.217)**						
log GDPpc	0.919							
	(0.182)**							
Patent$\times T$		-0.065	-0.061	0.689			0.090	0.480
		(0.021)**	(0.021)**	(0.284)*			(0.341)	(0.172)**
Patent$\times T^2$				-0.040			-0.008	-0.030
				(0.015)**			(0.018)	(0.009)**
log GDPpc$\times T$					-0.023	0.916	0.865	0.657
					(0.024)	(0.344)**	(0.400)*	(0.155)**
log GDPpc$\times T^2$						-0.051	-0.046	-0.034
						(0.018)**	(0.021)*	(0.008)**
Industry FE	yes	yes	yes	yes	yes	yes	yes	No
Industry-year FE	no	no	no	no	no	no	no	yes
Country-year FE	no	no	yes	yes	yes	yes	yes	yes
Country FE, Year FE	yes	yes	no	no	no	no	yes	No
Observations	60041	65249	65249	65249	60041	60041	60041	60041
R^2	0.838	0.837	0.853	0.856	0.862	0.863	0.863	0.867

Notes: This table shows least-squares estimates of equation (3.4.1) and other different specifications. The sample period is 1989 - 2006, standard errors are clustered at the country level and appears below each estimate. † $p < 0.10$, * $p < .05$, ** $p < .01$ respectively

is unknown or in different units, the quantity variable takes the value zero. Since our dependent variable is defined in log terms, zeros drop out of the estimation. This led to a loss of about 3% of the total observations. Table 3.3, column 1 through 5 shows that the estimates are consistent to that obtained when *value of exports* was used as the dependent variable but with slightly different magnitude. These findings confirm that our previous results are not driven by rising prices but from increased quantity.

To address the zero observations that dropped from this specification and to test its robustness against alternative estimator, I use the poisson pseudo-maximum likelihood (PPML) estimator proposed in Silva and Tenreyro (2010), which handles zero observations. Due to the computational intensity of this estimator, I estimate for only the case where patents are interacted with product lifecycle length as this is our main focus, and report the estimates in the appendix Table (3.14). I find the results to be consistent with the prediction of our model.

3.5.1 Robustness

I employ three alternative specifications and variable definitions to test if our results are sensitive to the specification or data used.

First, I test the robustness of our results by using the number of 10 digit products in each 3-digit sector exported to each countries in each period as our dependent variable. The independent variables are the same as in Table (3.2) above. I report the results in Table (3.4). Clearly, the estimates are similar to that on our main specification (Table (3.2)).

10.14754/CEU.2018.12

Table 3.3: Destination Country Patent Laws and US Exports

	Dependent Variable: Log Quantity of Exports							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent	0.212	0.798						
	(0.058)**	(0.327)*						
log GDPpc	1.233							
	(0.253)**							
Patent×T		-0.058	-0.055	0.609			-0.576	0.460
		(0.032)+	(0.032)+	(0.194)**			(0.580)	(0.743)
Patent×T^2				-0.036			0.029	-0.030
				(0.011)**			(0.032)	(0.040)
log GDPpc×T					-0.009	1.393	1.729	1.208
					(0.034)	(0.546)*	(0.640)**	(0.673)+
log GDPpc×T^2						-0.076	-0.092	-0.063
						(0.029)*	(0.034)**	(0.036)+
Industry FE	yes	yes	yes	yes	yes	yes	yes	no
Industry-year FE	no	no	no	no	no	no	no	yes
Country-year FE	no	no	yes	yes	yes	yes	yes	yes
Country FE, Year FE	yes	yes	no	no	no	no	no	no
Observations	58163	63122	63122	63122	58163	58163	58163	58163
R^2	0.800	0.800	0.812	0.814	0.819	0.820	0.820	0.829

Notes: This table shows least-squares estimates of equation (3.4.1) and other different specifications. The sample period is 1989 - 2006, standard errors are clustered at the country level and appears below each estimate. $^+$ $p < 0.10$, * $p < .05$, ** $p < .01$

The large difference in magnitude is due to the dependent variable is in levels.

Second, It could be that sector-specific shocks are correlated with country-level IPR index. For example, due to a global rise in demand for products from a specific industry (say pharmaceuticals), a country may improve its IPR regulation. To address this possibility, I re-estimate our main regression equation (3.4.1) and control for industry-year and country-year dummies. Results for this estimation is reported in the appendix Table (3.12) for both the case where I use both sales value and quantity of exports as the dependent variable. Clearly we find our results to be very similar to our main specification. Third, there may be selection of exports into specific sectors and to specific countries which are not related to IPR protection. To address this possibility, I control for country-sector dummies and year fixed effect in a similar estimation as equation (3.4.1). I report the results in the appendix Table (3.13). For the case where log of value of exports is our dependent variable, our results retain the expected sign of the coefficient but with smaller magnitude when compared to our baseline estimates. We also verify that $\beta_1 T_j + \beta_2 T_j^2 \geq 0$ is satisfied for the range of product lifecycle length. Thus, our results is consistent with the model's predictions. When I use the quantity of exports, the results are widely insignificant. I am not sure if this latter estimate is a consequence of the observations that dropped when quantity is used as our dependent variable, or whether the results are driven prices. Due to data limitations, I do not investigate this further, but leave it for future examination.

10.14754/CEU.2018.12

Table 3.4: Destination Country Patent Laws and US Exports

	Dependent Variable: Number of 10-digits Products						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Patent	1.594	25.970					
	(0.484)**	(2.272)**					
log GDPpc	12.301						
	(2.253)**						
Patent$\times T$		-2.470	-2.456	57.215			19.381
		(0.222)**	(0.224)**	(8.277)**			(10.869)$^+$
Patent$\times T^2$				-3.215			-1.124
				(0.453)**			(0.594)$^+$
log GDPpc$\times T$					-2.241	66.429	55.152
					(0.271)**	(10.421)**	(12.917)**
log GDPpc$\times T^2$						-3.697	-3.045
						(0.570)**	(0.703)**
Industry FE	yes	yes	yes	yes	yes	yes	yes
Country-year FE	no	no	yes	yes	yes	yes	yes
Country FE, Year FE	yes	yes	no	no	no	no	no
Observations	60041	65249	65249	65249	60041	60041	60041
R^2	0.745	0.740	0.748	0.752	0.753	0.758	0.759

Notes: This table shows the least-squares estimates of equation (3.4.1) where the dependent variable is computed as the number of CN 10 digit products in each 3 digit industry exported to a country in each time period. The sample period is 1989 - 2006, robust standard errors are clustered at the country level and appears below each estimate. $+\ p < 0.10$, $^*\ p < .05$, $^{**}\ p < .01$ respectively

3.5.2 Flexible Estimation

I now estimate a specification that allows the coefficients to vary flexibly across the length of product lifecycle. This approach captures the differential effect of patent laws across the different partitions of the product life-cycle length distribution. I partition T_j into N groups $(S_{1T}, S_{2T}, ..., S_{N-1T}, S_{NT})$ and estimate an equation of the form:

$$ln(Y_{ijt}) = \beta + \sum_{m=2}^{N} \beta_m Pat_{it} \times 1_{T_j \in S_{mT}} + \eta_t + \eta_i + \eta_j + \epsilon_{ijt} \qquad (3.5.1)$$

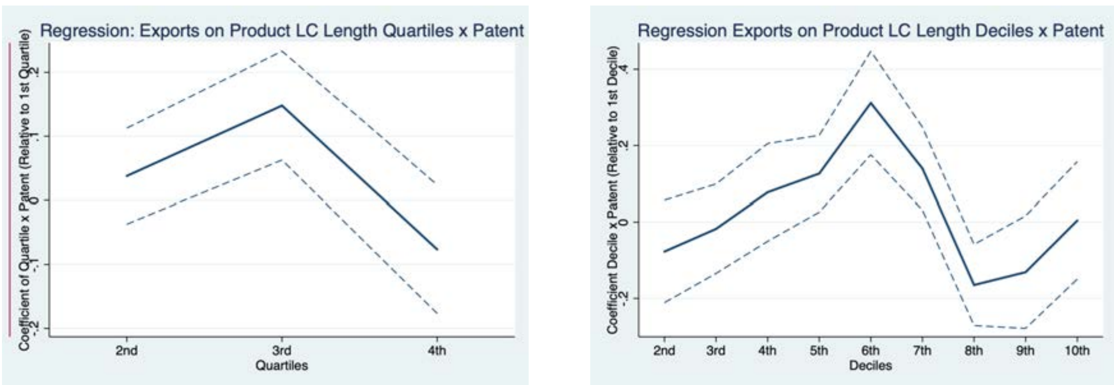
$$ln(Y_{ijt}) = \beta + \sum_{m=2}^{N} \gamma_m ln(GDPpc)_{it} \times 1_{T_j \in S_{mT}} + \eta_t + \eta_i + \eta_j + \epsilon_{ijt} \qquad (3.5.2)$$

This equation interacts a dummy corresponding to each of the top $N-1$ groups. In the baseline estimation, I choose $N = 6$ (sextiles) but the results are consistent to specifications with $N = 4$ (quartiles) and $N = 10$ (deciles) reported in Figure (3.2) and in the appendix Table (3.9), (3.10) and (3.11). β captures the effect of patent reforms on sectors in the 1st sextile of the T_j distribution, β_m is the difference in the impact of patent reforms on US exports between sectors in the $n > 1$ sextile of product life-cycle length compared with the sectors in the 1st sextile and γ_m is the difference in the impact of income growth

10.14754/CEU.2018.12

on US exports between sectors in the $n > 1$ sextile of product life-cycle length and sectors in the 1st sextile. When both export sales and quantity are our dependent variable, a consistent pattern of estimate emerges as shown in Table (3.5). I observe that the sensitivity is highest in the 4^{th} sextile when compared with sectors in other sextiles of the distribution of T_j. This pattern implies that expansion of exports is more in sectors with intermediate product life-cycle length, supporting the non-monotonicity prediction in the theory. This differential sensitivity is economically relevant: a one standard deviation in patent protection attracts approximately 12-18% points more of US exports in the fourth sextile sector than in the first sextile sector of the product life-cycle length distribution. However, this effect at the fourth sextile is greater than the effect at the fifth and sixth sextiles. Similar patterns emerge when I use GDP per capita instead of patent. Overall, our results support the predictions of the model.

Figure (3.2) shows the graph of a similar regression where I use quartiles and deciles instead of sextile in our baseline estimation. Clearly, I observe that for the quartile regression, the effect of IPR reforms on exports is strongest for the sectors in the 3rd quartile of the product lifecyle distribution. For the decile regression, the effect is increasing with a peak effect in sectors within the 6th decile. In summary, these results exhibit the non-monotonic pattern predicted by the theory. The coefficients are reported in the Appendix Table (3.9), (3.10) and (3.11).



(a) Quartile Regression (b) Decile Regression

Figure 3.2: Flexible Regression of Exports on IPR Interacted with Quantiles of Product Lifecycle Length

3.5.3 The Effect of the Length of Product Life-Cycle on Exports

Result (1) also states that the quantity of exports vary across sectors and depends on the product life-cycle length. In particular, exports are weakly decreasing in the length of product life-cycle T_j. To validate this predicition, I estimate the regression specification

10.14754/CEU.2018.12

Table 3.5: Destination Country Patent Laws and US Exports Flexible Regression

Dependent Variable	*Value of Exports*		*Quantity of Exports*	
	(1)	(2)	(3)	(4)
Patent$\times S_2$	-0.007		-0.079	
	(0.035)		(0.049)	
Patent$\times S_3$	0.046		0.162	
	(0.014)**		(0.048)**	
Patent$\times S_4$	0.115		0.187	
	(0.034)**		(0.052)**	
Patent$\times S_5$	-0.120		-0.058	
	(0.039)**		(0.054)	
Patent$\times S_6$	-0.041		-0.040	
	(0.040)		(0.065)	
log GDPpc$\times S_2$		0.011		-0.026
		(0.035)		(0.059)
log GDPpc$\times S_3$		0.082		0.157
		(0.046)$^{+}$		(0.066)*
log GDPpc$\times S_4$		0.133		0.174
		(0.040)**		(0.062)**
log GDPpc$\times S_5$		-0.058		-0.032
		(0.046)		(0.066)
log GDPpc$\times S_6$		-0.035		-0.049
		(0.049)		(0.072)
Industry FE	yes	yes	yes	yes
Country FE, Year FE	yes	yes	yes	yes
Observations	65249	60041	63122	58163
R^2	0.841	0.848	0.800	0.806

This table shows least-squares estimates of flexible equations (3.5.1 and 3.5.2). Product life cycle data was partitioned into sextiles. The effect of patent law on export is unrestricted across sextiles of product life-cycle data. The sample period is 1989 - 2006, standard errors are clustered at the country level and appears below each estimate. $p < 0.10$, * $p < .05$, ** $p < .01$

below:

$$ln(Y_{ijt}) = \beta T_j + \beta' X_{ijt} + \eta_{it} + u_{ijt} \quad (3.5.3)$$

where $ln(Y_{ijt})$ is as defined above, β captures the effect of the length of product life-cycle on exports, η_{it} is the country-year fixed effect which captures any unobserved time-varying country policies targeted at specific sectors with the aim of increasing US exports in such sectors, and X_{ijt} is the country sector-year covariates such as: (I) interaction term between product life-cycle length and patent index, and (II) interaction term between product life-cycle length and per capita income. The estimates are consistent with result (1) as shown in Table 3.6. I find the coefficient of β is negative and significant across all specifications. This imply that sectors with relatively longer product life-cycle length exports less compared with sectors with shorter life-cycle length. For a one-year increase in product life-cycle length of a sector, I expect to see an average drop in US exports in such sector by between 27% to 45% depending on the regression specification. This result is not that surprising as it is evident in the descriptive statistics (see column 5 of Table 3.1). For example, the average product life-cycle length in quartile 1, 2, 3 and 4 is: 8.82, 9.59, 9.84, 10.33. However, the drop in US export sales between quartile 1 and 3 (with a difference in product life-cycle length of approximately 1) is 51.44%. The lower coefficent is due to the fact that I controlled for other variables in the regression. This implies that on average, exports of US firm in an industry is lower by between 27% to 45% compared to another industry with a product life-cycle length that is higher by 1 year. These findings suggest that product life-cycle length could explain sectoral patterns of US exports.

Table 3.6: Export Intensity and Product Life-Cycle Lengths

Dependent Var.	*Quantity of Exports*				*Value of Exports*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
T	-0.318	-0.228	-0.462	-0.602	-0.468	-0.419	-0.863	-0.980
	(0.029)**	(0.074)**	(0.226)*	(0.245)*	(0.046)**	(0.115)**	(0.338)*	(0.371)**
Patent ×T		-0.032		-0.066		-0.017		-0.054
		(0.022)		(0.030)*		(0.033)		(0.044)
log GDPpc×T			0.014	0.052			0.041	0.072
			(0.025)	(0.032)			(0.037)	(0.049)
country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	65249	65249	60041	60041	63122	63122	58163	58163
r2	0.670	0.670	0.677	0.677	0.510	0.510	0.515	0.515

This table shows the least square estimate of equation (3.5.3). The dependent variable is the log of the quantity of exports and values of exports. Standard errors in parentheses are robust and clustered at the country level. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

3.6 Conclusion

This article contributes to the body of literature examining the sensitivity of US exports to destination-countries intellectual property regulations. I employ both theoretical and empirical approaches in this work. Using a partial equilibrium model of firm's export destination decisions, I find predictions with respect to the spatial and sectoral consideration of US exports. In particular, the model predicts that the sensitivity of exports to destination-country patent reforms and economic development is concentrated in sectors with relatively longer lengths of product life cycles, however, this relationship is non-monotonic, attaining the highest sensitivity in sectors with intermediate length of product life-cycle .

I validate the theoretical predictions using a panel of US product-level export data in 37 SIC-3 sectors to 118 countries during the period 1989-2006. This data was merged with a cross-sectional data of product life-cycle length and country-level panel data of patent protection index and GDP per capita. By interacting patent protection index with product life-cycle lengths, we provide an explanation about the systematic variations in US export (measured by both export sales and quantity) patterns. The results provide evidence that cross-sector differences in the length of product life-cycle are strong determinants of US export sensitivity to patent reforms in destination countries.

Our finding suggests that patent laws affect the distribution of high-tech sector goods available to individuals in an economy. This is likely to have an effect on consumption through the love of variety and productivity of firms through its usage as imported inputs and machinery[23]. These findings are important in understanding factors that shape export patterns in the high tech sectors in the US.

An interesting extension is to study the extensive margin effects instead of the intensive margin effects in this paper. Specifically, this will involve estimating the effects of improved patent laws on the time firms commerce exporting (time-to-export) to such destinations. This will require a finely disaggreagated product-level data at the firm-level and time the products was first manufactured and exported to each export destination. Since we do not have access to this data, we leave it for future work.

[23]Halpern et al. (2015) finds that firms that use imported inputs are more productive that others, Koren and Csillag (2016) finds imported machinery to increase productivity of worker-firm matches

10.14754/CEU.2018.12

Appendix

Appendix 3.A Model Solutions

3.A.1 Optimal time to export:

From equation (3.3.1):

$$\max_t \{E_q(\Pi_j(t))\} = max_t\{[\pi(l_1) + \pi(l_2)]t + E_q[\pi(l_1) + \pi(l_2) + \pi(l_3)]min\{T_j - t, q\} \\ +E_q[\pi(l_1) + [\pi(l_2) + \pi(l_3)]\gamma_c][max\{0, T_j - t - q\}]\}$$

However:

$$E_q[min\{T_j - t, q\}] = (T_j - t)Prob(q \geq T_j - t) + E_q[q.1\{q < T_j - t\}]$$

$$E_q[min\{T_j - t, q\}] = (T_j - t)[1 - Prob(q < T_j - t)] + E_q[q.1\{q < T_j - t\}]$$

$$E_q[min\{T_j - t, q\}] = (T_j - t)\left(1 - \int_0^{T_j - t} f(q)dq\right) + \int_0^{T_j - t} qf(q)dq$$

Recall q follows a uniform distribution on interval $[0, \bar{q}]$, So $f(q) = \frac{1}{\bar{q}}$, it follows that

$$E_q[min\{T_j - t, q\}] = (T_j - t)\left(1 - \frac{T_j - t}{\bar{q}}\right) + \frac{(T_j - t)^2}{2\bar{q}} = (T_j - t) - \frac{(T_j - t)^2}{2\bar{q}}$$

In a similar way,

$$E_q[\max\{0, T_j - t - q\}] = E_q[(T_j - t - q).1(q < T_j - t)] = \int_0^{T_j - t} (T_j - t - q)f(q)dq$$

$$E_q[\max\{0, T_j - t - q\}] = \frac{T_j(T_j - t)}{\bar{q}} - \frac{t(T_j - t)}{\bar{q}} - \frac{(T_j - t)^2}{2\bar{q}} = \frac{(T_j - t)^2}{2\bar{q}}$$

So equation 3.3.1 can be rewritten as:

$$\max_t \{E_q(\pi_j(t))\} = max_t\Bigg\{[\pi(l_1) + \pi(l_2)]t + \Big(\pi(l_1) + \pi l_2 + \pi(l_3)\Big)\left[T_j - t - \frac{(T_j - t)^2}{2\bar{q}}\right] \\ +\Big(\pi(l_1) + (\pi(l_2) + \pi(l_3))\gamma_c\Big)\frac{(T_j - t)^2}{2\bar{q}}\Bigg\} \tag{3.A.1}$$

Taking first-order condition of equation (3.A.1) with respect to t and equating to zero:

$$T_j - t = \frac{q\pi_3}{(1 - \gamma_c)(\pi_3 + \pi_3)}$$

3.A.2 Expected Revenue

From equation (3.3.5):

$$R_j(\gamma_c) = \int_{t_j^*(\gamma_c)}^{T_j} \Big((r_2 + r_3)[1 - \psi(t)] + \gamma_c(r_2 + r_3)\psi(t) \Big) \zeta_j(t)dt$$

Where $\psi(t)$ is the probability that a product is sector j will be imitated at the current time t. Let $0 < t < \bar{q}$, let $N(t) = 1$ and $N(\bar{q})$ be the number of success at time $[0, t]$ and $[0, \bar{q}]$ respectively. Denote X as the time for which product in sector j was imitated, we have that:

$$\psi(t) = P[X \leq t] = P[N(t) = 1 | N(\bar{q}) = 1] = \frac{P[N(t) = 1 \ \text{ and } \ N(\bar{q}) = 1]}{P[N(\bar{q}) = 1]}$$

$$= \frac{P[N(t) = 1 \ \text{ and } \ N(\bar{q}) - N(t) = 0]}{P[N(\bar{q}) = 1]} = \frac{P[N(t) = 1].P[N(\bar{q}) - N(t) = 0]}{P[N(\bar{q}) = 1]}$$

$$\psi(t) = \frac{\lambda t e^{-\lambda t}.e^{-\lambda(\bar{q} - t)}}{\lambda \bar{q} e^{-\lambda \bar{q}}} = \frac{t}{\bar{q}}$$

Similar method follows for $T_j - \tau(\gamma_c, l_2, l_3) < t < \bar{q}$ and the solution is:

$$\psi(t) = \frac{t - (T_j - \tau(\gamma_c, l_2, l_3))}{\bar{q}}$$

This boils down to solving

$$R_j(\gamma_c) = \int_0^{T_j} \Big((r_2 + r_3)[1 - \frac{t}{\bar{q}}] + \gamma_c(r_2 + r_3)\frac{t}{\bar{q}} \Big) \zeta_j(t)dt$$

$$R_j(\gamma_c) = (r_2 + r_3)\Big(1 - \frac{T_j}{2\bar{q}}(1 - \gamma_c) \Big)$$

and

$$R_j(\gamma_c) = \int_{T_j - \tau(\gamma_c, l_2, l_3)}^{T_j} \Big((r_2 + r_3)[1 - \frac{t - (T_j - \tau(\gamma_c, l_2, l_3))}{\bar{q}}] + \gamma_c(r_2 + r_3)\frac{t - (T_j - \tau(\gamma_c, l_2, l_3))}{\bar{q}} \Big) \zeta_j(t)dt$$

$$= \Big(\frac{r_2 + r_3}{T_j} \Big) \Big[\tau^*(\gamma_c, l_2, l_3) - \frac{\tau^*(\gamma_c, l_2, l_3)^2}{2\bar{q}} + \gamma_c \frac{\tau^*(\gamma_c, l_2, l_3)}{2\bar{q}} \Big]$$

3.A.3 Change in export quantity resulting from patent reforms:

Assume a patent reform to γ_c' such that $\gamma_c' > \gamma_c$; similar to equation (3.3.4) we have:

$$C_j(\gamma_c', l_2, l_3) = \begin{cases} 1 & \text{if} \quad T_j < \tau^*(\gamma_c', l_2, l_3) \\ \frac{\tau^*(\gamma_c', l_2, l_3)}{T_j} & \text{if} \quad T_j \geq \tau^*(\gamma_c', l_2, l_3) \end{cases} \tag{3.A.2}$$

Equation(3.A.2) - Equation (3.3.4) involves 3 cases: [1] $(T_j < \tau^*(\gamma_c, l_2, l_3))$, [2] $\tau^*(\gamma_c, l_2, l_3) \leq T_j \leq T_j < \tau^*(\gamma_c', l_2, l_3)$ and [3] $T_j > \tau^*(\gamma_c', l_2, l_3)$ and it is trivial to show its solution in equation (3.3.7). Similar derivation follows for change in export quantity resulting from change in per capita income and total change in revenue from exporting.

3.A.4 Proof of Result 5

It is enough to show that $\Delta R_j(\gamma_c', l_2, l_3)$ is increasing for some range of T_j and decreasing for some range of T_j. From equation (3.3.9):

- **Case 1**: If $T_j < \tau^*(\gamma_c, l_2, l_3)$, It is trivial to see that $\frac{d\Delta R_j(\gamma_c', l_2, l_3)}{dT_j} > 0$
- **Case 2**: If $\tau^*(\gamma_c, l_2, l_3) \leq T_j \leq \tau^*(\gamma_c', l_2, l_3)$, then $\frac{d\Delta R_j(\gamma_c', l_2, l_3)}{dT_j} = \frac{H}{2\bar{q}}\Bigg[-(1-\gamma_c') + \frac{\tau^*(\gamma_c', l_2, l_3)}{T_j^2}\Bigg(2\bar{q} - \tau^*(\gamma_c', l_2, l_3)(1-\gamma_c)\Bigg)\Bigg]$. At $\tau^*(\gamma_c, l_2, l_3) = T_j$ or $\tau^*(\gamma_c', l_2, l_3) = T_j$, $\frac{d\Delta R_j(\gamma_c', l_2, l_3)}{dT_j} > 0$
- **Case 3**: If $T_j > \tau^*(\gamma_c', l_2, l_3)$, Trivially, $\frac{d\Delta R_j(\gamma_c', l_2, l_3)}{dT_j} < 0$

3.A.5 Proof of Result 6

It is enough to show that $\Delta R_j(\gamma_c, l_2, l_3')$ is increasing for some range of T_j and decreasing for some range of T_j. From equation (3.3.10):

- **Case 1**: If $T_j < \tau^*(\gamma_c, l_2, l_3)$, It is trivial to see that $\frac{d\Delta R_j(\gamma_c, l_2, l_3')}{dT_j} = 0$
- **Case 2**: If $\tau^*(\gamma_c, l_2, l_3) \leq T_j \leq \tau^*(\gamma_c, l_2, l_3')$, then $\frac{d\Delta R_j(\gamma_c, l_2, l_3')}{dT_j} = \frac{H}{2\bar{q}}\Bigg[-(1-\gamma_c) + \frac{\tau^*(\gamma_c, l_2, l_3)}{T_j^2}\Bigg(2\bar{q} - \tau^*(\gamma_c, l_2, l_3)(1-\gamma_c)\Bigg)\Bigg]$. At $\tau^*(\gamma_c, l_2, l_3) = T_j$, $\frac{d\Delta R_j(\gamma_c', l_2, l_3)}{dT_j} > 0$
- **Case 3**: If $T_j > \tau^*(\gamma_c', l_2, l_3)$, then

$$\frac{d\Delta R_j(\gamma_c, l_2, l_3')}{dT_j} = -\frac{H}{2\bar{q}T_j^2}\Bigg[\underbrace{[2\bar{q} - (1-\gamma_c)\tau^*(\gamma_c, l_2, l_3')]\tau^*(\gamma_c, l_2, l_3')}_{A} - \underbrace{[2\bar{q} - (1-\gamma_c)(\tau^*(\gamma_c, l_2, l_3))]\tau^*(\gamma_c, l_2, l_3)}_{B}\Bigg]$$

Our aim is to show that $A > B$. Recalling that: $\tau^*(\gamma_c, l_2, l_3) = \frac{\bar{q}}{1-\gamma_c}\left(\frac{l_3}{l_2+l_3}\right)$, so

$$-\frac{H}{2\bar{q}T_j^2}\left(\frac{\bar{q}^2}{1-\gamma_c}\right)\left[\left(\frac{l_3'+2l_2}{l_2+l_3'}\right)\left(\frac{l_3'}{l_3'+l_2}\right) - \left(\frac{l_3+2l_2}{l_2+l_3}\right)\left(\frac{l_3}{l_3+l_2}\right)\right]$$

Let $f(l_2, l_3) = \left(\frac{l_3+2l_2}{l_2+l_3}\right)\left(\frac{l_3}{l_3+l_2}\right)$ if $\frac{\delta f(l_2, l_3)}{\delta l_3} > 0$ then $A > B$. It is trivial to show that this is true which completes the proof.

10.14754/CEU.2018.12

Appendix 3.B Data Description

Table 3.7: Countries, Quartile of Average Patent Protection Index and Average HDI

Countries in 1st Quartile Avg PPI. Avg. PPI =1.69 Avg. HDI = 0.48	Countries in 2nd Quartile Avg. PPI Avg. PPI =2.36 Avg. HDI = 0.51	Countries in 3rd Quartile Avg. PPI Avg. PPI = 2.99 Avg. HDI = 0.64	Countries in 4th Quartile Avg. PPI Avg. PPI =4.07 Avg. HDI = 0.82
ANGOLA	BOLIVIA	ALGERIA	AUSTRAL
BENIN	BRAZIL	ARGENT	AUSTRIA
BNGLDSH	BURKINA	BULGARIA	BEL_LUX
BURMA	CAMEROON	CYPRUS	CANADA
BURUNDI	CHAD	GHANA	CHILE
COS_RICA	CHINA	HAITI	CZECHREP
EGYPT	COLOMBIA	HONGKONG	DENMARK
ETHIOPIA	CONGO	ICELAND	FINLAND
GUATMALA	C_AFRICA	ISRAEL	FRANCE
GUYANA	DOM_REP	JAMAICA	GERMAN
INDIA	ECUADOR	KENYA	GERMAN_E
INDONES	FIJI	LITHUANI	GREECE
IRAN	GABON	MALAYSIA	HUNGARY
IRAQ	HONDURA	NEW_ZEAL	IRELAND
JORDON	IVY_CST	NIGERIA	ITALY
LIBERIA	MALI	PHIL	JAPAN
MADAGAS	MALTA	POLAND	KOREA_S
MALAWI	MAURITN	PORTUGAL	NETHLDS
MOZAMBQ	MEXICO	ROMANIA	NORWAY
MRITIUS	MOROCCO	SALVADR	RUSSIA
NEPAL	PANAMA	SIER_LN	SINGAPR
NEW_GUIN	PERU	SLOVAKIA	SPAIN
NICARAGA	SENEGAL	SRI_LKA	SWEDEN
NIGER	SUDAN	TAIWAN	SWITZLD
PAKISTAN	TANZANIA	TRINIDAD	S_AFRICA
PARAGUA	TOGO	TURKEY	UKINGDOM
RWANDA	TUNISIA	UGANDA	UKRAINE
SD_ARAB	URUGUAY		
SOMALIA	VENEZ		
SYRIA	VIETNAM		
THAILAND	ZIMBABWE		
USSR			
ZAIRE			
ZAMBIA			

[a] HDI is human capital development data from.For each country, I took average of its HDI for years 1990-2005 consistent with the original data in this article. Finally I took the average of the averages for countries within each quartile of Average Patent Protection Index.
[b] PPI implies patent protection index.

10.14754/CEU.2018.12

Table 3.8: Product Lifecycle length by Industry

SIC	Sector Name	Life-cycle length of Products (years)
281	Industrial Inorganic Chemicals	9.06
283	Drugs	9.11
284	Soap, Detergents, Cosmetics	9.22
285	Paints, Varnishes, Lacquers, Enamels	9.81
287	Agricultural Chemicals	8.69
289	Miscellaneous Chemical Products	9.73
331	Steel Works, Blast Furnaces, Mills	9.46
335	Rolling, Drawing, Extruding Of Metals	9.87
341	Metal Cans And Shipping Containers	10.63
342	Cutlery, Handtools, And General Hardware	10.41
343	Heating Equipment, Except Electric	10.89
344	Fabricated Structural Metal Products	10.25
345	Screw Machine Products, Bolts, Nuts, Screws	10.42
346	Metal Forgings And Stampings	9.63
349	Miscellaneous Fabricated Metal Products	10.08
351	Engines And Turbines	9.91
352	Farm And Garden Machinery And Equipment	9.78
353	Construction, Mining, And Materials Handling	10.05
354	Metalworking Machinery And Equipment	9.81
355	Special Industry Machinery, Except Metalworking	9.56
356	General Industrial Machinery And Equipment	9.44
357	Computer And Office Equipment	8.38
358	Refrigeration And Service Industry Machinery	9.98
359	Miscellaneous Industrial And Commercial	9.68
363	Household Appliances	9.78
364	Electric Lighting And Wiring Equipment	9.33
366	Communications Equipment	9.94
367	Electronic Components And Accessories	8.83
369	Miscellaneous Electrical Machinery, Equipment	9.88
371	Motor Vehicles And Motor Vehicle Equipment	9.64
379	Miscellaneous Transportation Equipment	9.6
381	Detection and Navigation Instruments, Equipment	9.42
384	Surgical, Medical, Dental Instruments And Supplies	9.75
386	Photographic Equipment And Supplies	9.61
387	Watches, Clocks, Clockwork Operated Devices	7.37

This table was taken from Bilir (2014a)

10.14754/CEU.2018.12

Appendix 3.C Full Specifications of Flexible Regression

Table 3.9: Destination Country Patent Laws and US Exports:Flexible Regression

Dependent Variable	*Value of Exports*		*Quantity of Exports*	
	(1)	(2)	(3)	(4)
Patent×Q_2	-0.035		0.038	
	(0.028)		(0.038)	
Patent×Q_3	0.065		0.148	
	(0.025)*		(0.043)**	
Patent×Q_4	-0.126		-0.076	
	(0.035)**		(0.051)	
log GDPpc×Q_2		-0.011		0.025
		(0.033)		(0.049)
log GDPpc×Q_3		0.100		0.147
		(0.030)**		(0.049)**
log GDPpc×Q_4		-0.128		-0.121
		(0.038)**		(0.054)*
Industry FE	yes	yes	yes	yes
Country FE, Year FE	yes	yes	yes	yes
N	65249	60041	63122	58163
r2	0.841	0.848	0.800	0.806

Standard errors in parentheses

$^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 3.10: Destination Country Patent Laws and US Exports Flexible Regression

Dependent Variable	*Value of Exports* (1)	*Quantity of Exports* (2)
Patent×D_2	0.232	-0.077
	(0.044)**	(0.068)
Patent×D_3	0.011	-0.018
	(0.047)	(0.059)
Patent×D_4	0.111	0.077
	(0.044)*	(0.064)
Patent×D_5	0.099	0.126
	(0.043)*	(0.051)*
Patent×D_6	0.196	0.312
	(0.049)**	(0.069)**
Patent×D_7	0.152	0.140
	(0.037)**	(0.055)*
Patent×D_8	-0.023	-0.165
	(0.040)	(0.054)**
Patent×D_9	-0.148	-0.131
	(0.058)*	(0.075)+
Patent×D_{10}	0.027	0.004
	(0.044)	(0.078)
Industry FE	yes	yes
Country FE, Year FE	yes	yes
Observations	65249	63122
R^2	0.842	0.801

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 3.11: Destination Country Patent Laws and US Exports Flexible Regression

Dependent Variable	*Value of Exports* (1)	*Quantity of Exports* (2)
GDPpc×D_2	0.184	-0.111
	(0.050)**	(0.078)
GDPpc×D_3	0.077	0.101
	(0.049)	(0.070)
GDPpc×D_4	0.209	0.139
	(0.046)**	(0.068)*
GDPpc×D_5	0.134	0.083
	(0.055)*	(0.077)
GDPpc×D_6	0.221	0.259
	(0.057)**	(0.084)**
GDPpc×D_7	0.230	0.216
	(0.041)**	(0.065)**
GDPpc×D_8	0.041	-0.173
	(0.050)	(0.077)*
GDPpc×D_9	-0.094	-0.135
	(0.068)	(0.091)
GDPpc×D_{10}	0.070	0.014
	(0.056)	(0.092)
Industry FE	yes	yes
Country FE, Year FE	yes	yes
Observations	60041	58163
R^2	0.849	0.807

Standard errors in parentheses

$^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

10.14754/CEU.2018.12

Appendix 3.D Additional Results

Table 3.12: Destination Country Patent Laws and US Exports

Dependent Variable	*Log Value of Exports*			*Log Quantity of Exports*		
	(1)	(2)	(3)	(4)	(5)	(6)
Patent$\times T$	1.017		0.480	1.440		0.460
	(0.334)**		(0.172)**	(0.541)**		(0.743)
Patent$\times T^2$	-0.059		-0.030	-0.082		-0.030
	(0.018)**		(0.009)**	(0.029)**		(0.040)
log GDPpc$\times T$		0.922	0.657		1.478	1.208
		(0.345)**	(0.155)**		(0.546)**	(0.673)$^+$
log GDPpc$\times T^2$		-0.051	-0.034		-0.080	-0.063
		(0.018)**	(0.008)**		(0.029)**	(0.036)$^+$
Industry-year FE	yes	yes	yes	yes	yes	yes
Country-year FE	yes	yes	yes	yes	yes	yes
Observations	65249	60041	60041	63122	58163	58163
R^2	0.862	0.867	0.867	0.824	0.829	0.829

Notes: This table shows least-squares estimates of equation (3.4.1) and other different specifications. The sample period is 1989 - 2006, standard errors are clustered at the country level and appears below each estimate. † $p < 0.10$, * $p < .05$, ** $p < .01$ respectively

10.14754/CEU.2018.12

Table 3.13: Destination Country Patent Laws and US Exports

Dependent Variable	*Log Value of Exports* (1)	(2)	(3)	*Log Quantity of Exports* (4)	(5)	(6)
Patent×T	0.045		0.070	0.003		0.062
	(0.011)**		(0.023)**	(0.034)		(0.034)$^{+}$
Patent×T^2	-0.003		-0.006	0.002		-0.004
	(0.001)**		(0.002)*	(0.003)		(0.003)
log GDPpc×T		0.178	0.061		-0.076	-0.137
		(0.086)*	(0.091)		(0.149)	(0.172)
log GDPpc×T^2		-0.008	0.004		0.023	0.028
		(0.008)	(0.009)		(0.014)	(0.016)$^{+}$
Year FE	yes	yes	yes	yes	yes	yes
Country-Sector FE	yes	yes	yes	yes	yes	yes
Observation	65249	60041	60041	63122	58163	58163
R^2	0.915	0.921	0.921	0.877	0.882	0.882

Notes: This table shows least-squares estimates of equation (3.4.1) and other different specifications. The sample period is 1989 - 2006, standard errors are clustered at the country level and appears below each estimate. † $p < 0.10$, * $p < .05$, ** $p < .01$ respectively

Table 3.14: Destination Country Patent Laws and US Exports

Dependent Variable	*Quantity of Exports* (1)	(2)
Patent×T	0.472	7.722
	(0.221)*	(4.449)$^{+}$
Patent×T^2		-0.382
		(0.225)$^{+}$
Sector Dummies	yes	yes
Country-Year Dummies	yes	yes
Observation	65246	65246
R^2	0.817	0.827

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

10.14754/CEU.2018.12

Bibliography

Ackerberg ,D. A., Caves ,K., and Frazer ,G. Identification properties of recent production function estimators. *Econometrica*, 83(6):2411–2451, 2015.

Ahn ,J. and McQuoid ,A. F. Capacity constrained exporters: micro evidence and macro implications. 2012.

Ahn ,J. and McQuoid ,A. F. Capacity constrained exporters: Identifying increasing marginal cost. *Economic Inquiry*, 2017. ISSN 1465-7295. URL `http://dx.doi.org/10.1111/ecin.12429`.

Ahn ,J., Khandelwal ,A. K., and Wei ,S.-J. The role of intermediaries in facilitating trade. *Journal of International Economics*, 84(1):73–85, 2011.

Almunia ,M., Antras ,P., Lopez-Rodriguez ,D., and Morales ,E. Venting out: Exports during a domestic slump. 2018.

Armenter ,R. and Koren ,M. Economies of scale and the size of exporters. *Journal of the European Economic Association*, 13(3):482–511, 2015.

Atkin ,D., Khandelwal ,A. K., and Osman ,A. Exporting and firm performance: Evidence from a randomized experiment. *The Quarterly Journal of Economics*, 132(2):551–615, 2017.

Auriol ,E., Biancini ,S., and Paillacar ,R. Intellectual property rights protection in developing countries. In *Fourteenth Annual of the Conference European Trade Study Group (ETSG 2012), University of Leuven, Leuven*, pages 13–15, 2012.

Bai ,X., Krishna ,K., and Ma ,H. How you export matters: Export mode, learning and productivity in china. *Journal of International Economics*, 104:122–137, 2017.

Békés ,G., Muraközy ,B., and Harasztosi ,P. Firms and products in international trade: Evidence from hungary. *Economic Systems*, 35(1):4–24, 2011.

Berman ,N., Berthou ,A., and Héricourt ,J. Export dynamics and sales at home. *Journal of International Economics*, 96(2):298–310, 2015.

Bernard ,A. B., Eaton ,J., Jensen ,J. B., and Kortum ,S. Plants and productivity in international trade. *The American Economic Review*, 93(4):1268–1290, 2003.

Bilir ,L. K. Patent laws, product life-cycle lengths, and multinational activity. *The American Economic Review*, 104(7):1979–2013, 2014a.

Bilir ,L. K. Patent laws, product life-cycle lengths, and multinational activity: Online appendix. *The American Economic Review*, 104(7):1979–2013, 2014b.

Bisztray ,M. Indirect effects of international investment and trade. 2016.

Bloom ,N., Propper ,C., Seiler ,S., and Van Reenen ,J. The impact of competition on management quality: evidence from public hospitals. *The Review of Economic Studies*, 82(2):457–489, 2015.

Blum ,B. S., Claro ,S., and Horstmann ,I. J. Occasional and perennial exporters. *Journal of International Economics*, 90(1):65 – 74, 2013. ISSN 0022-1996. doi: https://doi.org/10.1016/j.jinteco.2012.11.002. URL `http://www.sciencedirect.com/science/article/pii/S0022199612001717`.

Bond ,S. and Söderbom ,M. Adjustment costs and the identification of cobb douglas production functions. Technical report, IFS Working Papers, Institute for Fiscal Studies (IFS), 2005.

Bresnahan ,T. F. and Suslow ,V. Y. Short-run supply with capacity constraints. *The Journal of Law and Economics*, 32(2, Part 2):S11–S42, 1989.

Bustos ,P. Trade liberalization, exports, and technology upgrading: Evidence on the impact of mercosur on argentinian firms. *The American economic review*, 101(1):304–340, 2011.

Chin ,J. C. and Grossman ,G. M. Intellectual property rights and north-south trade, 1988.

Dai ,M., Yotov ,Y. V., and Zylkin ,T. On the trade-diversion effects of free trade agreements. *Economics Letters*, 122(2):321–325, 2014.

De Loecker ,J. Do exports generate higher productivity? evidence from slovenia. *Journal of international economics*, 73(1):69–98, 2007.

De Loecker ,J. Product differentiation, multiproduct firms, and estimating the impact of trade liberalization on productivity. *Econometrica*, 79(5):1407–1451, 2011.

De Loecker ,J. Detecting learning by exporting. *American Economic Journal: Microeconomics*, 5(3):1–21, 2013.

De Loecker ,J. and Warzynski ,F. Markups and firm-level export status. *The American Economic Review*, 102(6):2437–2471, 2012.

De Loecker ,J., Goldberg ,P. K., Khandelwal ,A. K., and Pavcnik ,N. Prices, markups, and trade reform. *Econometrica*, 84(2):445–510, 2016.

Deardorff ,A. V. Welfare effects of global patent protection. *Economica*, pages 35–51, 1992.

Demidova ,S., Kee ,H. L., and Krishna ,K. Do trade policy differences induce sorting? theory and evidence from bangladeshi apparel exporters. *Journal of International Economics*, 87(2):247–261, 2012.

Dix-Carneiro ,R. Trade liberalization and labor market dynamics. *Econometrica*, 82(3): 825–885, 2014.

Duggan ,M., Garthwaite ,C., and Goyal ,A. The market impacts of pharmaceutical product patents in developing countries: Evidence from india. *American Economic Review*, 106(1):99–135, 2016.

Eckel ,C., Iacovone ,L., Javorcik ,B., and Neary ,J. P. Multi-product firms at home and away: Cost-versus quality-based competence. *Journal of International Economics*, 95 (2):216–232, 2015.

Feenstra ,R. C. Us exports, 1972-1994: with state exports and other us data. Technical report, National bureau of economic research, 1997.

Feenstra ,R. C., Inklaar ,R., and Timmer ,M. The next generation of the penn world table. *The American Economic Review*, 105(10):3150–3182, 2015.

Fernandes ,A. M. Trade policy, trade volumes and plant-level productivity in colombian manufacturing industries. *Journal of international economics*, 71(1):52–71, 2007.

Ferrantino ,M. J. The effect of intellectual property rights on international trade and investment. *Weltwirtschaftliches Archiv*, 129(2):300–331, 1993.

Foellmi ,R., Legge ,S., and Tiemann ,A. Innovation and trade in the presence of credit constraints. 2015.

Foster ,L., Haltiwanger ,J., and Syverson ,C. Reallocation, firm turnover, and efficiency: Selection on productivity or profitability? *The American economic review*, 98(1): 394–425, 2008.

Foster ,L., Haltiwanger ,J., and Syverson ,C. The slow growth of new plants: Learning about demand? *Economica*, 83(329):91–129, 2016.

Gandhi ,A., Navarro ,S., and Rivers ,D. A. On the identification of production functions: How heterogeneous is productivity? 2011.

Gaulier ,G. and Zignago ,S. Baci: international trade database at the product-level (the 1994-2007 version). 2010.

Ginarte ,J. C. and Park ,W. G. Determinants of patent rights: A cross-national study. *Research policy*, 26(3):283–301, 1997.

Glass ,A. J. and Saggi ,K. Licensing versus direct investment: implications for economic growth. *Journal of International Economics*, 56(1):131–153, 2002.

Goh ,A.-T. Opportunity cost, trade policies and the efficiency of firms. *Journal of Development Economics*, 62(2):363–383, 2000.

Goldberg ,P. K. and Maggi ,G. Protection for sale: An empirical investigation. *American Economic Review*, 89(5):1135–1155, 1999.

Goldberg ,P. K., Khandelwal ,A. K., Pavcnik ,N., and Topalova ,P. Imported intermediate inputs and domestic product growth: Evidence from india. *The Quarterly Journal of Economics*, 125(4):1727–1767, 2010.

Grossman ,G. M. and Helpman ,E. Quality ladders and product cycles. *Journal of International Business Studies*, 106(2):557–586, 1991.

Grossman ,G. M. and Helpman ,E. Protection for sale. *The American Economic Review*, 84(4):833–850, 1994. ISSN 00028282. URL `http://www.jstor.org/stable/2118033`.

Hall ,B. H., Jaffe ,A. B., and Trajtenberg ,M. The nber patent citation data file: Lessons, insights and methodological tools. Technical report, National Bureau of Economic Research, 2001.

Halpern ,L., Koren ,M., and Szeidl ,A. Imported inputs and productivity. *The American Economic Review*, 105(12):3660–3703, 2015.

Hsieh ,C.-T., Li ,N., Ossa ,R., and Yang ,M.-J. Accounting for the new gains from trade liberalization. Technical report, National Bureau of Economic Research, 2018.

Hummels ,D., Jørgensen ,R., Munch ,J., and Xiang ,C. The wage effects of offshoring: Evidence from danish matched worker-firm data. *The American Economic Review*, 104 (6):1597–1629, 2014.

Ivus ,O. Do stronger patent rights raise high-tech exports to the developing world? *Journal of International Economics*, 81(1):38–47, 2010.

Ivus ,O. Does stronger patent protection increase export variety [quest] evidence from us product-level data. *Journal of International Business Studies*, 46(6):724–731, 2015.

Javorcik ,B. S. The composition of foreign direct investment and protection of intellectual property rights: Evidence from transition economies. *European economic review*, 48 (1):39–62, 2004.

Johnson ,R. C. Trade and prices with heterogeneous firms. *Journal of International Economics*, 86(1):43–56, 2012.

Khandelwal ,A. The long and short (of) quality ladders. *The Review of Economic Studies*, 77(4):1450–1476, 2010.

Klette ,T. J. and Griliches ,Z. The inconsistency of common scale estimators when output prices are unobserved and endogenous. *Journal of Applied Econometrics*, pages 343–361, 1996.

Koren ,M. and Csillag ,M. Machines and machinists: Importing skill-biased technology. Technical report, mimeo, Central European University, 2016.

Koren ,M. and Csillag ,M. Machines and machinists: Importing skill-biased technology. Technical report, Technical report, mimeo, Central European University, 2017.

Krugman ,P. Scale economies, product differentiation, and the pattern of trade. *The American Economic Review*, 70(5):950–959, 1980.

Levinsohn ,J. and Melitz ,M. Productivity in a differentiated products market equilibrium. *Unpublished manuscript*, 9:12–25, 2002.

Levinsohn ,J. and Petrin ,A. Estimating production functions using inputs to control for unobservables. Technical report, National bureau of economic research, 2000.

Lileeva ,A. and Trefler ,D. Improved access to foreign markets raises plant-level productivity… for some plants. *The Quarterly Journal of Economics*, 125(3):1051–1099, 2010.

Lin ,J. X. and Lincoln ,W. F. Pirate's treasure. *Journal of International Economics*, 109: 235–245, 2017.

Lin ,J. X., Lincoln ,W., and Welcome ,P.-C. Pirate's treasure. 2015.

Liu ,Y. Capital adjustment costs: Implications for domestic and export sales dynamics. 2015.

Lucas Jr ,R. E. Making a miracle. *Econometrica: Journal of the Econometric Society*, pages 251–272, 1993.

Marin ,A. G. and Voigtländer ,N. Exporting and plant-level efficiency gains: It's in the measure. Technical report, National Bureau of Economic Research, 2013.

Maskus ,K. E. and Penubarti ,M. How trade-related are intellectual property rights? *Journal of International Economics*, 39(3):227–248, 1995.

Maskus ,K. E. and Penubarti ,M. Patents and international trade: an empirical study. *Quiet pioneering: Robert M. Stern and his international economic legacy*, pages 95–118, 1997.

Mayer ,T. and Ottaviano ,G. I. The happy few: The internationalisation of european firms. *Intereconomics*, 43(3):135–148, 2008.

McCalman ,P. Foreign direct investment and intellectual property rights: evidence from hollywood's global distribution of movies and videos. *Journal of International Economics*, 62(1):107–123, 2004.

Melitz ,M. J. The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6):1695–1725, 2003.

Mitra ,D., Thomakos ,D. D., and Ulubaşoğlu ,M. A. "protection for sale" in a developing country: democracy vs. dictatorship. *Review of Economics and Statistics*, 84(3):497–508, 2002.

Mollisi ,V. and Rovigatti ,G. Theory and practice of tfp estimation: the control function approach using stata. 2017.

Olley ,G. S. and Pakes ,A. The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, 64(6):1263–1297, 1996. ISSN 00129682, 14680262. URL `http://www.jstor.org/stable/2171831`.

Park ,W. G. International patent protection: 1960–2005. *Research policy*, 37(4):761–766, 2008.

Rafiquzzaman ,M. The impact of patent rights on international trade: Evidence from canada. *Canadian Journal of Economics/Revue canadienne d'économique*, 35(2):307–330, 2002.

Rho ,Y. and Rodrigue ,J. Firm-level investment and export dynamics. *International Economic Review*, 57(1):271–304, 2016.

Silva ,J. S. and Tenreyro ,S. On the existence of the maximum likelihood estimates in poisson regression. *Economics Letters*, 107(2):310–312, 2010.

Smith ,P. J. Are weak patent rights a barrier to us exports? *Journal of International Economics*, 48(1):151–177, 1999.

Soderbery ,A. Market size, structure, and access: Trade with capacity constraints. *European Economic Review*, 70:276–298, 2014.

Stokey ,N. L. Human capital, product quality, and growth. *The Quarterly Journal of Economics*, 106(2):587–616, 1991.

Suslow ,V. Y. Estimating monopoly behavior with competitive recycling: an application to alcoa. *The RAND Journal of Economics*, pages 389–403, 1986.

Topalova ,P. and Khandelwal ,A. Trade liberalization and firm productivity: The case of india. *Review of economics and statistics*, 93(3):995–1009, 2011.

Trefler ,D. The long and short of the canada-us free trade agreement. *The American Economic Review*, 94(4):870–895, 2004.

UNESCAP . Building the productive capacity of the least developed countries. united nations economic and social commission for asia and the pacific. pages 153–185, 2011.

Vannoorenberghe ,G. Firm-level volatility and exports. *Journal of International Economics*, 86(1):57–67, 2012.

Young ,A. Learning by doing and the dynamic effects of international trade. *The Quarterly Journal of Economics*, 106(2):369–405, 1991.