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Yifan Li and Zhuang Miao

McGill University, Central University of Finance and Economics

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Globalization, Import Penetration and Markup*

Yifan Li[†]

Zhuang Miao[‡]

JOB MARKET PAPER

Abstract

The rise of market power in recent decades has received increased attention, but the determinants of such a rise remain unclear. This paper studies whether and how increasing import penetration of inputs leads to a more concentrated market structure and the associated rise of markups. The use of quadratic preferences in combination with the inclusion of the firm's choice to import create a link between the use of imported inputs and markups. A reduction in importing costs induces non-importers to start importing intermediates. Yet, the effect on profits is shaped by a trade-off between the potential marginal cost advantage and the fixed cost incurred from importing. As a result, only the most productive firms benefit from globalization, while existing importing firms do not fully pass through the reduction in trade costs using prices. The selection of importers, cost-savings from imported inputs and industry firm turnover jointly explain the rise of average markups in the market. Guided by this theoretical framework, we combine firm-level panel data, sector-level trade data and input-output tables to present empirical evidence on the relationship between the increase in imported input penetration and the rise of market power in the US over the last four decades. Using six-digit sectors as the unit of observation, we show that imported input penetration is positively associated with the size of markups. We test the model predictions on both the import decisions of heterogeneous firms and its implications for market structure. A difference-in-difference exercise that exploits China's accession to the WTO and the use of input tariffs as a proxy for imported input penetration provide additional supporting evidence. Overall, we find that average industry markups would have been around 1.4% lower each year in the absence of imported inputs.

Keywords: globalization, import penetration, markups

JEL Codes: F14, F15, L13

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[†]yifan.li4@mail.mcgill.ca (corresponding author). Department of Economics, McGill University, Leacock Building 414, 855 Sherbrooke St. West, Montreal, QC, Canada H3A 2T7.

[‡]zhuang.miao@mail.mcgill.ca, Department of Economics, School of International Trade and Economics, Central University of Finance and Economics, 39 South College Road, Haidian District, Beijing, P.R.China 100081

1 Introduction

Discussions about the rise of market power and its macroeconomic impacts prevail in the most recent economic literature (Kwoka et al. 2015, Barkai 2016, Gutiérrez and Philippon 2016, Azar et al. 2017, Ganapati 2017, Traina 2018). The particularly evident decline in the labor share in the United States since 2000 is primarily attributed to the rise of 'superstar' firms (Autor et al. 2017). Firm-level evidence shows that average markup has increased sharply since 1980, from 18% above marginal cost to 67% in 2014 (De Loecker and Eeckhout 2017). These studies present the rise of concentration in the market over time and have led to heated policy debates. However, the determinants of such an increase in market power remain unclear.

Importantly, another critical trend in the past several decades is globalization and the accompanied global sourcing. Dramatic removal of trade barriers and a substantial decrease of tariffs as well as advances in communication, information, and transportation technologies have revolutionized how and where firms source their input for production. Indeed, there has been a substantial increase in industry openness and imports in the United States in the last few decades: the ratio of imports to GDP went up from 4.2 percent in 1960 to around 16.5 percent in 2014.¹ How do firms use imported inputs in their production? How does the use of foreign imports affect industry concentration? How are markups impacted by firms' import decisions and the change of market concentration?

Given the transformative impact of globalization, it is natural to consider the effect that import penetration may have had on the market structure and on a firm's decisions to set the markup. The conventional wisdom underlines the intensified foreign competition as the process of globalization continues, which thereby alleviates the distortions associated with monopoly power. But, globalization also transforms the way firms in developed countries procure their inputs, although the ability of firms to select into importing might be limited to only a few firms (Antras et al. 2017). Despite the rapid expansion of global sourcing and widespread policy interest, the existing literature in trade has so far mainly focused on exporting instead of importing and has

¹IMF Databank, USA Imports of goods and services (% of GDP), url: <https://data.worldbank.org/indicator/>

paid relatively little attention to this facet of the interaction between imported input penetration and market concentration.

This paper aims to contribute to our understanding of the relationship between trade openness and market structure. On the one hand, import penetration increases competition from foreign producers, which implies pressure for the firms to decrease their markup. On the other hand, trade liberalization also leads to cost reduction due to improved access to imports of foreign intermediate inputs. If trade liberalization benefits only the most productive firms in each industry, the market concentration will rise as industries become increasingly dominated by large firms with high profits and low shares of labor in firm value-added and sales. To study these mechanisms, we provide a theoretical framework which relates the change in markup to the change in the extensive margin of sourcing decisions. We then look at how change in average markups is associated with imported input penetration in the process of globalization over 40 years. We combine firm-level micro panel data, sector-level trade data, and input-output tables and present empirical evidence on the relationship between the increasing trend of imported inputs penetration and the rise of market power over the last four decades. At the six-digit industry level, we find that the increase in imported input penetration is associated with increased market concentration, implying that only the most productive firms benefit from trade liberalization.

Our analysis proceeds in three steps. First, we developed a simple theoretical model that links market structure to global outsourcing. We extend Melitz and Ottaviano (2008) to include the firm's input procurement decision and highlight the firm's choice on importing foreign input in the spirit of Amiti et al. (2014), where the change of markup change with the extensive margin of sourcing decisions. As we work with quadratic preferences with the inclusion of the firm's choice to import intermediate inputs, the model generates linear equations that relate changes in the variable markup with changes in the imported input penetration. A reduction in importing costs induces non-importers to start importing intermediates. Yet, the capability to profit from importing foreign inputs depends on a firm's trade-off between the potential marginal cost advantage and the fixed cost incurred from importing. Since it requires a fixed cost of

importing to select cost-efficient intermediate inputs, the capability to benefit from the reduction of trade costs and to employ imported inputs into production depends on the level of productivity. High-productivity firms that can pay the associated fixed cost and import intermediate inputs will be thereby able to magnify their cost advantage relative to less productive firms.

Second, we illustrate some descriptive facts on rising import penetration and markups since 1970 before proceeding onto empirical analysis. We show that the ratio of imports to GDP went up from 4.2% in 1960 to around 16.5% in 2014, while the average markup increased from around 1.2 to over 1.6 in the same period. Import penetration has an ambiguous relationship with markup. Standard trade theory would predict reduced markup due to more imported output competition. But, if the market is imperfectly competitive, a reduction in trade costs due to globalization will have heterogeneous impacts on the markup of firms that import inputs and firms that rely only on domestic input. Therefore we distinguish import penetration in output and input and measure them separately. Indeed, when we look at imported *input* penetration, we find a strong correlation between the rise of imported input penetration ratio at the level of 2-digit sector weighted average markup based on firm-level sales, while the overall import penetration ratio shows an ambiguous relationship with the change of markup. This is because the import penetration ratio mixed the effect of competition from the final goods with the effect of employment of cheaper/better inputs on market structure. Making use of imported inputs contributes to the decrease in the firm's marginal cost and increases the firm's potential of higher markup. But it may require some level of firm ability to take advantage of imported inputs.

Third, we present empirical evidence on the relationship between the rise of market power and the increase in imported inputs penetration over the last four decades. We use firm-level panel data that contain critical balance-sheet variables such as sales, the number of employees and capital for production function estimation from WRDS-Compustat Database. By applying the production-based approach (De Loecker et al. 2016), we estimate markups at firm level from 1972 to 2014. We then measure direct import penetration level from industry-level trade data from the United States import and export Data of the Center for International Data, UN COMTRADE, and USA Trade Online. Combining input-output benchmark table at the 6-digit industry level

from the Bureau of Economic Analysis (BEA), we measure indirect intermediates import penetration by weighting the direct import penetration ratio with the degree of interdependence of each industry pair. We find that a 10% increase in the rise of imported input penetration is associated with a 0.2% increase in market concentration, implying that only the most productive firms benefit from trade liberalization. We further test our predictions of heterogeneous firms' decisions on intermediates importing and the implications on the market structure using output and input tariffs as proxies for import: a 10 percent increase of input penetration induces roughly 1.2 percent increase of markup on average. This finding is robust to different model specifications at both the firm and industry levels. It also survives from various concerns of the model including alternative markup measure, alternative benchmark weighting in accounting for input penetration, and the use of derived input tariff as a proxy for input penetration. We also applied a difference-in-difference approach taking China's accession into the WTO as a trade shock to provide additional support to our main predictions.

This paper explores the mechanism that links the globalization process to the trend of rising markups over the last four decades. The contributions of this paper are twofold. First, we construct a theoretical model that links the rise of the input imports and the increase of average markups, and also distinguishes the changes of the market structures during this process, i.e., the entry-exit decisions, outsourcing decisions, and price strategies made by heterogeneous firms. Second, we provide empirical evidence that supports these predictions and the mechanisms identified in theory. A difference-in-difference exercise that exploits China's accession to the WTO and the use of input tariffs as a proxy for imported input penetration provide additional supporting evidence to the theory.

Our paper contributes to several strands of the literature. We add to the vibrant empirical research that looks at the ambiguous effects of trade liberalization on markups (Burstein and Gopinath 2014). There is empirical evidence of reduction of markups due to more competition following dramatic trade liberalization for some countries. For example, Badinger (2007) finds a decrease of markups in aggregate manufacturing sectors following the EU's Single Market Programme. Some literature discovers that trade liberalization of intermediates inputs may lead

to markup increase due to various reasons. Ludema and Yu (2016) explain the incomplete pass-through of foreign tariff reductions with firms' quality-upgrading strategies, which are estimated to be greater for high productivity firms. Amiti et al. (2014) develop an oligopoly framework with variable markups and imported inputs, and find that firms with top import shares have low exchange rate pass-through. Brandt et al. (2017) find that cuts in output tariffs reduce markups while cuts in input tariffs raise both markups and productivity by examining China's WTO accession and the performance of Chinese manufacturing firms.²

These case studies focus on the impacts of striking shocks such as trade liberalizations for a relatively short period. They link markup variation exclusively to a market share of the firm, neglecting the effect that exogenous change of variable cost has on industry reallocation in the long run. Instead, our paper looks at the impact on the industry that the broad process of globalization brings over 40 years, which combines short-run effects of trade cost reduction on marginal cost and competition with the impact on industry reallocation in the relative long term.

Our theoretical framework is closely related to and is built upon Melitz and Ottaviano (2008) and Halpern et al. (2015). Melitz and Ottaviano (2008) develop a monopolistic competition model of trade with firm heterogeneity which has been a workhorse model that predicts intra-industry reallocation between firms with different mark-ups following trade liberalization. Halpern et al. (2015) estimate the productivity gain from the improved access to foreign input. They assume a constant elasticity of substitution (CES) utility function and provide a static model of industry equilibrium where firms use both domestic and imported intermediates goods for production. However, CES utility directly implies constant markup and make it unsatisfactory to analyze variable markup changes concerning aggregate shocks. We instead employ the linear demand system as in Melitz and Ottaviano (2008) and trace in detail how imported input penetration plays a role in the pricing of firms that have better ability to utilize sourcing opportunities. If firm heterogeneity interacts with fixed sourcing costs, the firm's decision to import from one

²Other case studies include Fan et al. (2018) for China, De Loecker et al. (2016) for India, Altomonte and Barattieri (2015) for Italy, Moreno and Rodríguez (2011) for Spain, Konings et al. (2005) for Bulgaria and Romania and Harrison (1994) for Cote d'Ivoire.

market will also affect market structure. In our model, a reduction in global sourcing costs induces a firm to increase imports of low-cost input and to increase the markup. But the access to foreign inputs is restricted to the firms that can pay the fixed importing cost and use imported intermediates. Our model predicts that, as the cost of importing decreases, existing importing firms will import more foreign intermediate varieties, leading to even better advantages in both product quality and production cost. These two effects will magnify existing strengths that more productive firms have relative to less productive firms. This, in turn, implies that trade liberalization has asymmetric impacts on the market share of existing market players.

Our paper also relates to the literature that looks at the global trend of market power and its consequences. De Loecker and Eeckhout (2018) document the rising trend of global market power. While it is more salient in the developed world than in the emerging areas, the average global markup increased from 1.1 to 1.6 between 1980 and 2016. For the U.S in particular, the average mark-up has been increasing dramatically since the 1980s, and it is believed to be associated with several other macroeconomic trends such as the decline in labor and capital share, the decrease of low skill labor wage, and the slow down in aggregate output (De Loecker and Eeckhout 2017). Autor et al. (2017) reassess the secular trend of labor share through micro panel data since 1982 and interpret the fall in the labor share to be the result of the rise of “superstar firms” that dominate the market with high profits and low share of labor in firm value-added and sales. They also notice the potential role that globalization and technological changes might have played but are skeptical as the fall in labor’s share also appears in non-traded sectors like retail and wholesale, not just in traded industries like manufacturing. There is other circumstantial evidence in this story of rising market power.³ A paper that is closely related to ours is that of Elsby et al. (2013), who consider the potential impact consider the possible effects of globalization and rising imports on the decline of labor share. They provide a set of simple cross-industry regressions and graphs and show that the variation in the change in import exposure explains 22 percent of the cross-industry variation in payroll-share changes.

³For example, increased profits (Barkai 2016), decreased investment (Gutiérrez and Philippon 2016), decreased wages in concentrated markets (Azar et al. 2017), weakened antitrust enforcement (Kwoka et al. 2015), and restricted output (Ganapati 2017).

While these studies try to link the rise of market power of superstar firms as the cause for the decline of labor share, our purpose is to propose a mechanism that drives this rising market concentration and to illustrate how less-frictional international trade enables more efficient firms to be rewarded with higher market shares today than in the past. Our paper looks not only at the direct impact, i.e., the substitution effect, which depresses the labor share of domestic income and reduces the marginal cost of firms that employ cheap foreign inputs, but also the indirect impact, which changes the market structure to be more concentrated as only some firms can pay the fixed cost and utilize global opportunities. We also provide direct empirical evidence of these mechanisms.

Finally, our paper complements a large body of literature that evaluates welfare gains from trade by estimating its impact on markup heterogeneity and allocative efficiency. Epifani and Gancia (2011) document several stylized facts about markup dispersion across industries over time and in a relationship with exposure to trade. They provide an oligopoly framework with CES utility and find that markup heterogeneity entails significant costs and that asymmetric trade liberalization may reduce welfare when there exists restricted entry. Feenstra and Weinstein (2017) consider symmetric translog preferences and structurally estimate the welfare gain of globalization into variety-increase and markup-decline channels. There are two critical differences between the theoretical framework in these papers and the model we present here. First, our paper adopts monopolistic competition with linear demand system which allows markup variability to depend not only on market share but also on imported input substitution and product/industry characteristics. Second, in our framework, a change in the trade costs induces marginal cost change directly and induces price change indirectly through both general equilibrium effects (the number of active firms) that shift or rotate the firm's demand curve.

The rest of the paper is organized as follows. Section 2 presents a general theoretical framework that encompasses monopolistic competition and variable markup to examine the impact of trade cost reductions on firms' markups and associated intra-industry reallocation. Section 3 describes the datasets and measurements used. Section 4 presents our econometric specifications and report the main results, followed by an interpretation of the underlying mechanisms. Section 5

provides a series of robustness checks. The last section concludes.

2 Theoretical Framework

In this section, we develop our theoretical framework of global sourcing and markup. Our model is based on an extension of Melitz and Ottaviano (2008). Building upon Halpern et al. (2015), we incorporate Amiti et al. (2014)'s way to model the firm's cost structure and its choice to import intermediate inputs. We extend the model by relating the option of importing to productivity and analyze its comparative statistics. In sections below, we present the model and derive equilibrium prices, sourcing strategies, marginal cost, and markups. Since our model is similar to Amiti et al. (2014), we relegate most of the derivations to the Appendix and examine here in more detail the impact of increasing import penetration on markups.

2.1 Consumers

Preferences are defined over a continuum of differentiated varieties indexed by $i \in \Omega$, and a homogeneous good chose as numeraire. As in Melitz and Ottaviano (2008), consumers share the same quasi-linear utility function given by

$$U = q_0^c + \alpha \int_{i \in \Omega} q_i^c di - \frac{1}{2} \gamma \int_{i \in \Omega} (q_i^c)^2 di - \frac{1}{2} \eta \left(\int_{i \in \Omega} q_i^c di \right)^2 \quad (1)$$

where q_0^c and q_i^c represent the quantities of the numeraire good and the differentiated variety i respectively. The demand parameters α , η , and γ are all positive. The parameters α and η index the substitution pattern between the differentiated varieties and the numeraire good, and the level of competition intensity among differentiated varieties. The parameter γ indexes the decreasing rate of the marginal utility for each variety. Given the price for variety i , consumers

decide their quantity demand as followings.

$$q_i \equiv Lq_i^c = \frac{\alpha L}{\eta N + \gamma} - \frac{L}{\gamma} p_i + \frac{\eta N}{\eta N + \gamma} \frac{L}{\gamma} \bar{P} \quad (2)$$

where L denotes the population of the economy, N measures the mass of varieties in Ω (which is also the number of active firms) and $\bar{P} = \frac{1}{N} \int_{i \in \Omega^*} p_i di$ is the average price of all varieties existing in the market. The set Ω^* is the collection of the varieties that exist in the market. In other words, the variety which belongs to the set Ω^* must satisfy

$$p_i \leq \frac{1}{\eta N + \gamma} (\gamma \alpha + \eta N \bar{P}) \equiv p_{max} \quad (3)$$

This inequality suggests that all firms' prices will be up-bounded by the price level charged by the lowest productivity firm. This is because low-productivity firms need to charge relatively high level of prices in order to cover their high variable cost. Among the surviving firms, the demand is limited to the price that the lowest productivity firm charges.

2.2 Producers

For simplicity, we assume that final-good varieties are prohibitively costly to trade across borders. We do this in order to highlight the trade of intermediate input as the relevant mechanism.⁴ Similar to Amiti et al. (2014), we model the cost structure of the firm and its choice to import intermediate inputs. Consider firm i , indexed by its productivity A_i , uses labor Z_i and a composite intermediate input X_i to produce output Y_i according to the production function:

$$Y_i = A_i X_i^\phi Z_i^{1-\phi} \quad (4)$$

⁴The model could be extended to accommodate trading of final goods and the extensive margins of both exports and imports will be jointly determined.

The composite intermediate input X_i consists of two types of intermediate goods, one of which could be purchased either locally or imported from the foreign market and the other one of which could only be procured domestically. D_i represents the quantity of the domestic-specific input which can only be purchased domestically, and M_i represents the amount of intermediate inputs which could be sourced from either the domestic or the foreign markets. Let ξ be the elasticity of substitution between D_i and M_i .

$$X_i = \left[D_i^{\frac{\xi}{1+\xi}} + aM_i^{\frac{\xi}{1+\xi}} \right]^{\frac{1+\xi}{\xi}} \quad (5)$$

Intuitively, a measures the productivity advantage of the foreign variety. Although production is still possible without the use of imported inputs, imported inputs are useful due to (i) their potential productivity advantage a , and (ii) the love-of-variety feature of the production function. The prices of imported inputs and domestic inputs are denoted by P_M and P_D respectively, and we assume the firms are price takers in these input markets.

For each imported intermediate good, firm i must incur a fixed cost $f_i(A_i)$, which depends on firm productivity A_i . Examples for the fixed importing costs include the information gathering and search cost, management cost, cost for an import permit, and the production adjustment for various inputs. We believe the high productivity firms pursue cost advantage in both the production and importing processes. For example, the high productivity firms hire the high productivity workers who will lower the management cost. They are more likely to export to more markets and pursue widely international connections, which will lower the search cost. In section 2.5, we relax the assumption on the dependence of the fixed cost while assuming a complementary form of the production function. The main predictions of that model are consistent with the one with the fixed cost endogenous to the productivity.

The presence of fixed costs have been founded empirically and have been widely assumed (Amiti et al. 2014; Antras et al. (2017); Gopinath and Neiman (2014); Halpern et al. (2015)). Here we further assume that the fixed sourcing cost a firm has to pay to start importing intermediate inputs is decreasing with productivity. If we think of the fixed cost as the searching and informa-

tion cost a firm pays to find the most cost-efficient external input supplier, then it is reasonable to believe that high-productivity firms are likely to find the desired trading partner easier.⁵ Following this setting, we compute the variable cost index for importers and non-importers as follows

$$V_i = \begin{cases} \left[1 + \left(\frac{\tau_m P_{Mf}}{a} \right)^{\frac{1}{1+\xi}} \right]^{1+\xi} & \text{importer} \\ \left[1 + (P_{Md})^{\frac{1}{1+\xi}} \right]^{1+\xi} & \text{non - importer} \end{cases} \quad (6)$$

where P_{Mf} and P_{Md} are the prices for the foreign and domestic intermediates respectively; τ_m captures the trade cost of purchasing the foreign intermediates.

The marginal cost of firm i is equal to:

$$c_i = \varsigma \varphi_i \left(\frac{W}{1-\phi} \right)^{1-\phi} \left(\frac{V_i}{\phi} \right)^\phi = \varsigma \varphi_i V_i^\phi \bar{D} \quad (7)$$

where W measures the domestic labor cost, thus $\bar{D} \equiv \left(\frac{W}{1-\phi} \right)^{1-\phi} \left(\frac{1}{\phi} \right)^\phi$ is a common cost factor for both importers and non-importers. φ_i is the inverse productivity of firm i , i.e. $A_i = \frac{1}{\varsigma \varphi_i}$, where ς is a parameter. φ_i is assumed to follow a Pareto distribution, i.e. $\varphi \sim \left(\frac{\varphi - \bar{\varphi}}{\underline{\varphi} - \bar{\varphi}} \right)^k$ with support $[\underline{\varphi}, \bar{\varphi}]$.⁶

Notice that the term \bar{D} is identical across all the firms. Moreover, firms only differ in their productivity levels and the term V_i , depending on how much the foreign inputs they use.

In a closed economy, firm i only sources from the domestic market, so the profit maximization problem is:

$$Max_{p_i} \pi^D = (p_i - c_i) * q_i$$

⁵Alternatively, this assumption could be replaced by a quantitative constrain on the relative scale of fixed cost and net profit of being an importer. Moreover, we relax this assumption and consider a constant fixed cost case in the following section 2.5.2.

⁶Recall that the productivity level for firm i is denoted as A_i , thus $\varsigma \varphi_i = \frac{1}{A_i}$.

Profit maximization implies the following results:

$$\begin{aligned}
p_{iD} &= \frac{1}{2} (c_i + c_d) \\
\mu_{iD} &= \frac{(c_i + c_d)}{2c_i} \\
q_{iD} &= \frac{L(c_d - c_i)}{2\gamma} \\
r_{iD} &= \frac{L(c_d - c_i)(c_d + c_i)}{4\gamma} \\
\pi_{iD} &= \frac{L(c_d - c_i)^2}{4\gamma}
\end{aligned} \tag{8}$$

where $p_i(c_d) = p_{\max} = \frac{1}{2}(c_{\max} + p_{\max})$, therefore, $p_{\max} = c_d$, and c_d is the cut-off cost value for the firms to be able to survive in the market with their exact variable cost, i.e, all the firms whose variable cost is higher than this value will not be able to survive in the market. To simplify our analysis, we assume the firms' entry decision and the reveal of the productivity information take place during the same period.

Assume the firm's variable cost c is drawn from a known distribution $G(c)$ with support $[\underline{c}, \bar{c}]$.

⁷ The cost (productivity) cut-off is thus determined by the free-entry condition:

$$\int_{\underline{c}}^{c_d} \pi(c_i) dG(c) = f_E \tag{9}$$

The mass of surviving firms is determined using c_d and the zero demand price condition:

$$c_d = \frac{\gamma\alpha + \eta N \bar{P}}{\eta N + \gamma} \tag{10}$$

which implies

$$N = \frac{\gamma}{\eta} \frac{\alpha - c_d}{c_d - \bar{P}} \tag{11}$$

and the mass of entrants

$$N_E = \frac{N}{G(c_d)} \tag{12}$$

⁷Under the case of closed economy, the variable c follows the same type of distribution as the inverse productivity.

From which it follows

$$\bar{P} = \int_{\omega \in \Omega} p(\omega) d\omega = \int_{\underline{c}}^{c_d} \frac{c_i + c_d}{2} dG(c_i)/G(c_d) \quad (13)$$

2.3 The Equilibrium

2.3.1 Determination of importing productivity cutoff

For simplicity, we keep the number of entrants N_E and the productivity distribution $G(\cdot)$ fixed. The number of survived firms is thus $N = N_E G(\varphi_d)$, where φ_d is the cut-off value of productivity, i.e. $c_d = \varsigma \varphi_d V_i^\phi \bar{D}$. Recall that the inverse productivity is assumed to be drawn from a Pareto distribution, $\varphi \sim \left(\frac{\varphi - \underline{\varphi}}{\bar{\varphi} - \underline{\varphi}}\right)^k$ with support $[\underline{\varphi}, \bar{\varphi}]$. Following Antras et al. (2017), we assume that importing intermediate from the foreign market requires a fixed cost f_m , whose value is identical to all firms. Firm i decides whether to import the intermediates based on the expected profits it faces. As we assume that the firm only imports one type of input from one foreign country, the index V_i^ϕ should be identical across all importing firms, i.e. $V_i^\phi = V^\phi$. For simplicity, we further define $\Psi = \Psi_i \equiv \varsigma V_i^\phi \bar{D}$ for importing firms (where $\bar{D} \equiv (\frac{W}{1-\phi})^{1-\phi} (\frac{1}{\phi})^\phi$) and normalize $\varsigma V_i^\phi \bar{D} = 1$ for all non-importing firms. The firm will import intermediates if $H(\varphi_i) \equiv \pi(\varphi_i|importer) - \pi(\varphi_i|non - importer) > f_m$, where $\pi(\varphi_i|importer) = (p_i^f - \varphi_i \Psi) * q_i^f$ with $\Psi < 1$ and $\pi(\varphi_i|non - importer) = (p_i^d - \varphi_i) * q_i^d$.

This mechanism is presented in the illustrative Figure 1. The unit cost savings that importing brings is constant. When a firm is the most productive (inverse productivity is 0), it can charge highest price, sell most products and get highest profits. Importing foreign inputs brings no change to its unit cost due to the cost structure, so to the price and quantity. Thus the profit difference curve cross the origin. As a firm becomes less productive, it prices relatively lower, sell less and profit decreases. But at the same time importing starts to bring in advantage because it decrease unit cost by a certain amount, counteracting the decrease in productivity, and brings positive profit difference. Until reaching a point where the negative effect that the decreases in productivity brings on profit, exceeds the positive effects that the constant unit cost savings

that importing brings on profits. And the profit difference curve starts to become downward sloping.

Proposition 1. *Given the highest inverse productivity of the survived firms in the market and the following assumptions. (i) Importing fixed cost f_m is identical to all firms, and (ii) the fixed cost satisfies the conditions $\underline{\varphi} > \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}$ and $\bar{\varphi} < \frac{2}{1-\Psi} \sqrt{\frac{\gamma f_m}{L}}$, then there exists a unique solution φ_m which solves $H(\varphi_m) = 0$ in the definition range $\varphi_m \in [\underline{\varphi}, \bar{\varphi}]$, and it follows that $H(\varphi) \geq 0$ for $\varphi < \varphi_m$ and $H(\varphi) < 0$ for $\varphi > \varphi_m$.*

Proposition 1 implies that only high productivity firms make importing, and the firms whose inverse productivity is higher than a critical value, then they won't make importing. Specifically, this critic value is solved as:

$$\varphi_m = \frac{\varphi_d + \sqrt{\varphi_d^2 - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1 + \Psi} \quad (14)$$

When the value of φ_m is less than φ_d , for the firms whose inverse productivity is lower than φ_m will choose to import the inputs, and the firms with higher inverse productivity will choose to use domestic inputs only. If $\varphi_m \geq \varphi_d$, then all the firms in the market will not choose to import the intermediate inputs.

2.3.2 Determination of the number of active firms and productivity cut-off

In the open economy case, equation (13) becomes:

$$\bar{P} = \int_{\underline{\varphi}}^{\varphi_m} \left(\frac{\varphi\Psi + \varphi_d}{2} \right) dG(\varphi)/G(\varphi_d) + \int_{\varphi_m}^{\varphi_d} \left(\frac{\varphi + \varphi_d}{2} \right) dG(\varphi)/G(\varphi_d) \quad (15)$$

As $\varphi \sim \left(\frac{\varphi - \underline{\varphi}}{\bar{\varphi} - \underline{\varphi}} \right)^k$, we can simplify the equation above as:

$$\bar{P} = \int_{\underline{\varphi}}^{\varphi_m} k \left(\frac{\varphi \Psi + \varphi_d}{2} \right) \left(\frac{\varphi - \underline{\varphi}}{\varphi_d - \underline{\varphi}} \right)^{k-1} \left(\frac{1}{\varphi_d - \underline{\varphi}} \right) d\varphi + \int_{\varphi_m}^{\varphi_d} k \left(\frac{\varphi + \varphi_d}{2} \right) \left(\frac{\varphi - \underline{\varphi}}{\varphi_d - \underline{\varphi}} \right)^{k-1} \left(\frac{1}{\varphi_d - \underline{\varphi}} \right) d\varphi \quad (16)$$

The example with the uniform distribution function is solved as:

$$\bar{P} = \left(\frac{4}{\varphi_d - \underline{\varphi}} \right) \left[3\varphi_d^2 - (1 - \Psi) \varphi_m^2 - (\Psi \underline{\varphi} + 2\varphi_d) \underline{\varphi} \right] \quad (17)$$

Then the firm number is solved as:

$$N = \frac{\gamma}{\eta} \frac{\alpha - \varphi_d}{\varphi_d - \left(\frac{4}{\varphi_d - \underline{\varphi}} \right) \left[3\varphi_d^2 - (1 - \Psi) \varphi_m^2 - (\Psi \underline{\varphi} + 2\varphi_d) \underline{\varphi} \right]} \quad (18)$$

Equation (18) shows that the number of survived firms N is negatively correlated with the cut-off value φ_d . Recall from equation (12) that we have another relation between N and φ_d , i.e. $N_E = \frac{N}{G(\varphi_d)}$, which indicates a positive relation between N and φ_d when the entrant mass N_E is fixed in short-run. Equations (12), (14), and (18) uniquely determine the inverse productivity cut-off φ_d and firm number N , which is illustrated in Figure 3. The positive relation between N and φ_d (equation (12)) represented by curve S suggests that the market will be able to support more active firms when the productivity cut-off is low (high φ_d), while the negative relation between N and φ_d (equation (18)) represented by curve D implies that only a limited number of firms could survive in the market due to high choke price induced by low productivity cut-off (high φ_d).

2.4 The Impact of Globalization

The process of globalization suggests a continuous reduction of trade costs between countries. According to Equation (14), a reduction of variable trade cost will induce a lower price level of intermediate input Ψ , making it more profitable for a firm to engage in intermediate input

trading. Equation (14) shows that the inverse productivity cut-off to import foreign input φ_m will be higher. This implies that there are more firms engage in importing cost-efficient intermediate input. This is illustrated in Figure 2, where the expected profit curve moves outward when there is a reduction in trade cost, leading to a higher inverse productivity cut-off value to become an importing firm.

Equations (18) and (12) determine the equilibrium level of N and φ_d as shown in Figure 3. It is clear that when the trade cost V^ϕ decreases, the curve D1 shifts downwards while the S curve remains unchanged. This is because the relation between N and φ_d in Equation (12) is uncorrelated with trade cost this is not the case for Equation (18). Solving the new equilibrium gives a lower level of N and φ_d as shown in Figure 4. This indicates that the number of active firms in the market shrinks following the reduction of trade costs. Moreover, a smaller φ_d suggests that the productivity cut-off level to survive in the market also increases.

From simple differentiation of equations (14), (18) and (12) it follows that:⁸

Proposition 2. *A decrease in variable trade cost τ induces the number of active firms in the market N and the inverse productivity cut-off to survive φ_d to decrease, i.e. $\frac{\partial N}{\partial \Psi} > 0$ and $\frac{\partial \varphi_d}{\partial \Psi} > 0$; furthermore, if the change of cut-off value is small enough, i.e. $\frac{\partial \varphi_d}{\partial (1+\Psi)} \frac{1+\Psi}{\varphi_d} < 1$, in response to a reduction of the trade cost τ the importing critical value φ_m will increase.*⁹

The average markup across all firms that survive is derived as:¹⁰

$$\bar{\mu} = \int_{\underline{\varphi}}^{\varphi_m} k \left(\frac{\varphi \Psi + \varphi_d}{2\varphi \Psi} \right) \left(\frac{\varphi - \underline{\varphi}}{\varphi_d - \underline{\varphi}} \right)^{k-1} \left(\frac{1}{\varphi_d - \underline{\varphi}} \right) d\varphi + \int_{\varphi_m}^{\varphi_d} k \left(\frac{\varphi + \varphi_d}{2\varphi} \right) \left(\frac{\varphi - \underline{\varphi}}{\varphi_d - \underline{\varphi}} \right)^{k-1} \left(\frac{1}{\varphi_d - \underline{\varphi}} \right) d\varphi \quad (19)$$

An example with the uniform distribution is written as:

⁸The details of the derivation are presented in Appendix A2.

⁹The condition $\frac{\partial \varphi_d}{\partial \Psi} < \frac{4\gamma\kappa\Psi + \varphi_d L(1-\Psi)^2(1+\Psi)}{L(1-\Psi)^2(1+\Psi)}$ is easy to satisfy if the value of Ψ is closed to one.

¹⁰The details of the derivation are presented in Appendix A3.

$$\bar{\mu} = \underbrace{\frac{\varphi_d}{2(\varphi_d - \underline{\varphi})}}_{(1)} \left(\underbrace{\frac{1}{\Psi} \ln \frac{\varphi_m}{\underline{\varphi}}}_{(2)} + \underbrace{\ln \frac{\varphi_d}{\varphi_m}}_{(3)} \right) - \frac{1}{2} \underline{\varphi} \quad (20)$$

where k is the parameter for the distribution of inverse productivity; φ_d is the surviving cut-off value of the inverse productivity; φ_m is the critical value of the inverse productivity to import; and Ψ captures the variable cost of importing the inputs.

Combining the latter with equation (14), we observe that if $\frac{\partial \varphi_d}{\partial (1+\Psi)} \frac{1+\Psi}{\varphi_d} < 1$, then $\frac{\partial \varphi_m}{\partial \Psi} < 0$, which means that when importing cost decreases, more firms will use the imported inputs. This condition also implies that the average markup $\bar{\mu}$ decreases in the importing cost Ψ , i.e., $\frac{\partial \bar{\mu}}{\partial \Psi} < 0$. In other words, a lower importing intermediate price index leads to a higher average markup. Specifically, based on the equation (20), we observe that the link between trade cost and average markup materializes via two different channels. First, there is a higher share of high productivity firms. The first term of (20) captures the exit of low productivity firms and then the sales reallocate to the high productivity firms with high markup. The second term of (20) captures the fact that in response to a reduction of importing cost, the importing firms will obtain higher markup, where $\ln \frac{\varphi_m}{\underline{\varphi}}$ indexes the share of the importing firms out of all survived firms. The third term measures the increase of market competition due to that the importing firms charge a lower price in response to a reduction of input price. When the first and second effects dominate the third effect, then the average markup will increase in response to the reduction of importing cost.

Proposition 3. *In response to a reduction of the trade cost, if the change of the surviving cut-off value is small enough, i.e. $\frac{\partial \varphi_d}{\partial \Psi} \frac{\Psi}{\varphi_d} < \ln \underline{\varphi}$, the industry's average markup $\bar{\mu}$ will increase. This is due to the Cost Reduction Effect and the Reallocation Effect.*

2.5 Extensions

This section completes our theoretical framework by altering a few dimensions of our modeling setup and see how the results change. First, we allow the entry mass to be endogenously determined by the free entry condition and discuss the conditions under which that our model main predictions remain. Second, we turn the fixed sourcing costs that are previously increasing in the firm's inverse productivity into a constant independent one, and we show that the relevant expressions would all be very similar. Third, to highlight the importance of importing, we have assumed that final goods cannot be traded across borders. We relax this assumption and study the joint determination of the extensive margins of both exports and imports.

2.5.1 Endogenous Number of Entrants

In the model so far we kept the entry mass N_E constant. It could be endogenously determined by the entry condition and supply of the entry firms, i.e.

$$\begin{cases} \int_{\underline{\varphi}}^{\varphi_m} \frac{LD^{-2}(\varphi_d - \Psi\varphi)^2}{4\gamma} dG(\varphi) + \int_{\varphi_m}^{\varphi_d} \frac{LD^{-2}(\varphi_d - \varphi)^2}{4\gamma} dG(\varphi) = f_E \\ N = N_E G(\varphi_d) \end{cases} \quad (21)$$

Both equations together determine the supply side of the entry firms. From equation (14), we know that φ_m is an increasing function of φ_d , given the value of Ψ . In this way, the value of φ_d is determined by the entry cost f_E and independent of the firm number N . In this case, the curve which illustrates the supply side of the entry firms is drawn as a horizontal line in the Figure 6 below (the curve S_1). It is easy to prove that when the trade cost Ψ decreases, the demand curve D_1 shifts down to the position of the curve D_2 , and the supply curve S_1 shifts down to the position of the curve S_2 . In this case, the inverse productivity φ_d decreases but the change in the cut-off value for the firm number N depend on the relative associated change of both the supply and demand curve. Although we are not able to make quantitative statement

on the changes of the importing critical value φ_m in this case, it is qualitatively clear that our min prediction on average markup \bar{M} remains as long as the firm entry incurred by the rise of imported input penetration remains in a relatively small scale over the observation period.

2.5.2 Independent Fixed Sourcing Cost

One might be concerned with the seemingly strong assumption that the fixed sourcing cost a firm has to pay to start importing intermediate inputs is decreasing with productivity, though it is well-justified by the fact that the searching and information cost it incurs to find the most cost-efficient trading partner is likely to fall with productivity. To address this issue, we relax this assumption and assume an independent fixed sourcing cost. We make the following assumptions on the production function. It requires two types of inputs in the production, i.e., labor and intermediate input. One unit of composite intermediate input can be transformed into ϕ units of the final output. It requires at least $\frac{1}{A_i}$ unites of labors to complete the transformation of one unit of output, where the parameter A_i captures the labor productivity for the firm i .

$$Y_i = \min \{A_i L_i, \phi X_i\} \quad (22)$$

The marginal cost of firm i is computed as:

$$c_i = \varphi_i W + \phi V_i$$

where V_i and W are price for the intermediate input and wage of the labor respectively; ς and ϕ are parameters with given values; and φ_i is inverse productivity of firm i , which is assumed to follow a Pareto distribution, i.e. $A_i = \frac{1}{\varsigma \varphi_i}$ and $\varphi \sim \left(\frac{\varphi}{\bar{\varphi}}\right)^k$ with support $[0, \bar{\varphi}]$. We can then prove the following lemma:

Lemma 1. *When the importing fixed cost is small enough, i.e. $f_m < \frac{(W \varphi_d - \frac{\phi \Psi + 1}{2})}{2\Upsilon}$, there exists*

a $\varphi_m \in [0, \varphi_d]$ which solves $H(\varphi_m) = 0$; and $H(\varphi) \geq 0$ for $\varphi < \varphi_m$ and $H(\varphi) < 0$ for $\varphi > \varphi_m$.

In this case, the survived firm who has lowest productivity won't choose to import the intermediates.

Specifically, the critical value φ_m is given by:

$$\varphi_m = \frac{1}{W} \left[W\varphi_d + \frac{1 - \Psi}{2} - \frac{2\Upsilon f_m}{L(1 - \Psi)} \right] \quad (23)$$

According to Lemma 1 , the firms whose inverse productivity is lower than φ_m will choose to import and the firms with higher inverse productivity will choose to use domestic inputs only.

Similar derivations give the average markup as:¹¹

$$\bar{\mu} = \int_0^{\varphi_m} \left[\frac{W\varphi + \Psi + W\varphi_d + 1}{2(W\varphi + \Psi)} \right] dG(\varphi)/G(\varphi_d) + \int_{\varphi_m}^{\varphi_d} \left[\frac{W\varphi + 2 + W\varphi_d}{2(W\varphi + 1)} \right] dG(\varphi)/G(\varphi_d) \quad (24)$$

Assuming that the inverse productivity follows uniform distribution, i.e. $k = 1$ and $\bar{\varphi} = 1$, the average markup across all firms that survive is derived as:

$$\bar{\mu} = \frac{1}{2} \left[1 + \underbrace{\left(\frac{W\varphi_d + 1}{W\varphi_d} \right)}_{(1)} \ln \left(\underbrace{\frac{W\varphi_m + \Psi}{\Psi(W\varphi_m + 1)}}_{(2)} \right) + \underbrace{\left(\frac{W\varphi_d + 1}{W\varphi_d} \right) \ln(W\varphi_d + 1)}_{(3)} \right] \quad (25)$$

It follows that the average markup $\bar{\mu}$ increases in the importing critical value φ_m . Similar to the results in the case of Cobb-Douglous productivity function, we observe two channels for the rise of the average markup in reacting to the reduction of Ψ , i.e. the reallocation effect and cost reduction effects. Term (1) of 25 captures the reallocation effect such that lowering importing cost reduces the surviving cut-off φ_d , which increases the proportion of high productivity firms

¹¹See Appendix A.5

in the market. Term (2) reveals the fact that lower importing cost reduces the variable cost of the importing firms directly, which enhances the competition capacity of these firms. Term (3) increases in φ_d , which reveals that the firms that never import inputs will face higher intense of market competition after the importing cost reduces, and thus their markups will be lower than before. When the effects of terms (1) and (2) dominates the effect of term (3), the average markup will increase in react to a reduction of the importing cost. As a result, a reduction in variable trade costs increases the average markup due to these two effects. Next, we will show that in response to a reduction of importing cost, the average markup will increase when some conditions satisfy. Recall that from 10, the change of φ_d is very small in response to the varying of importing cost when the parameter η is small enough. If we set $\eta = 0$, φ_d will be constant in the importing cost Ψ . Given this property, when the importing cost Ψ decreases, the importing critical value φ_m will increase according to 23. That means more firms will enter the international input market. Given all these properties, we observe that, terms (1) and (2) of 25 are constant in Ψ while term (2) decreases in Ψ . In this case, we will observe an increase of average markup in response to a reduction of importing cost Ψ . Actually, when the parameter η is small enough (not necessary to be zero), the change of term (3) will be very small and the average markup still decreases in Ψ .

3 Data and measurement

Our theoretical framework shows that a decrease in trade cost and the associated rise in input import penetration is associated with a surge in the markup. It is due to both a cost reduction and reallocation effect. The remainder of the paper aims to find empirical evidence that supports this claim. To uncover the relationship between input import penetration and markups, we use Compustat data of US public firms to generate markup, and we combine US trade data and Input-Output tables to test the impacts of import penetration on markups. The empirical exercise is based on three main types of data for the empirical analysis: firm's balance-sheet

data, trade data, and input-output tables at detailed commodity level.

3.1 Firm Balance-Sheet Data

We use Compustat (North America) Fundamental Annual database to derive firm-level balance sheet information. Compustat has variables that are needed for production function estimation including annual sales, wages, capital stock, as well as the labor of all the US publicly traded firms available from 1950 to 2014 in Wharton Research Data Services (WRDS). We restrict the sample as follows: First, we only consider and identify firms incorporated in the United States based on Stock Exchange Code (EXCH) and Foreign Incorporation Code (FIC); Second, we exclude observations with obviously mis-measured variables of interests, such as negative sales or employment. The final sample counts 504,319 firms-year observations covering the years from 1972 to 2014. The common GDP deflator comes from the Bureau of Economic Analysis's National Income and Product Accounts (NIPA) tables of the United States. Therefore we obtain firm-level markup by applying the so-called cost-based production approach as in De Loecker and Warzynski (2012).

Constrained by the data availability of import penetration measures, we focus on the sample from 1972 to 2014, that we match with industrial level import penetration ratios in the firm-level regression. It reduces our sample to 412,565 firms-year observations with an average of 9,822 firm-level observations per year. Compustat assigns each firm a North American Industry Classification System (NAICS) 2012 6-digit sector code based on the firm's operation reported as required by Financial Accounting Standards Board (FASB). The 2012 NAICS codes have 1,065 disaggregate industries. To match it with the industrial classification in the Input-Output table, we first converted the different versions of NAICS codes to the 2007 version and then assigned each 2007 NAICS code with one of the 389 6-digit IO industries used in the Input-Output table from Bureau of Economic Analysis (BEA). Table 2 shows the IO industrial distribution of the firm-year observations at the most aggregate level between 1972 to 2014. While Compustat only

includes publicly traded companies, our sample covers firms across most of the industries and matches closely with the industrial distribution across the economy. A large portion of firms is in the Manufacturing and Finance sector, accounting for 35.5% and 21.8% of the observations respectively in the sample. We are interested in how imported inputs penetration is related to markup at the firm level, but Compustat does not contain information on how much each firm employ foreign inputs. Therefore in the industry-level regression, we compute the sales-weighted markup at the 6-digit BEA I-O industry level to match with industry-level import penetration measures.

3.2 Markup Estimation

Defined as the ratio of price over marginal cost, markups can be estimated by a few different methods prevailing in the field of empirical industrial organization. As detailed data on price and marginal cost data is usually unavailable, markup estimation depends on the granularity of the available data and the choice of assumptions. On the one hand, the “demand-based” estimation requires assumptions on the form of demand function and market structure, therefore marginal cost and markups are estimated with the associated demand elasticity and firms’ optimal pricing behavior as in Bresnahan (1982) and Berry et al. (1995). On the other hand, the “production-based” method proposed in De Loecker and Warzynski (2012) builds upon the insight of Hall (1988) where markups are inferred by estimating the production function with assumptions on the firms’ optimal input choice from total cost minimization. Markup is then derived as the product of the input revenue share and output elasticity of any chosen variable input. Intuitively, it is measured as technology-adjusted cost share. As the input cost shares are often available in the accounting data, it is easy to estimate markup by having an estimate of the input elasticity. The input elasticity is estimated using various production function estimation methods including OLS, Olley-Pakes, and Levin-Petrin methods. And our baseline results are based on Olley-Pakes method.

We adopt the “production-based” method in our markup estimation for several reasons. First, one of our model prediction is that imported input penetration is associated with rising markup through the change of market structure. Therefore it is reasonable to impose as least assumptions as we can on the market structure in markup estimation. Second, Compustat data is firm-level balance sheet accounting data, from which input share is directly calculated. Last, following the same method of markup estimation would make our results comparable to De Loecker et al. (2016). As we are following the same manner, we relegate the necessary derivation of markup in Appendix 6.

3.3 Trade Data

The trade data are used to compute direct import penetration measures. The data is divided into three parts: 1972-1988; 1989-2006; and 2007-2014. The first two parts of data come from U.S. trade data assembled by Feenstra (1996). For the period 1972 to 1988, the data are by year at the level of 4-digit 1972-revision SIC industry and the level of 1987 SIC version for the years from 1989 to 2006.¹² The other part of trade data comes from USA Trade Online, which contains data on US (down to district-level) export, import, and total trade value at various industrial classification such as 10-digit HTS and 6-digit NAICS for different versions covering from 2007-2014. USA Trade Online always starts using the new NAICS revision the year after the change. So for 2008-2012, the data report the 2007 NAICS codes and for 2013-2017 the 2012 NAICS codes and so on. To match with other sources of data, we harmonized the different industrial classifications and different versions based on the concordance table provided by the Census Bureau and Bureau of Economic Analysis.

¹²There are 533 unique 4-digit SIC 1972 version industries appear in the 1972-1988 sample, converted to 507 NAICS 2007 industry codes. For 1989-2006 sample, there are 459 unique SIC 1987 version industries converted to 456 NAICS 2007 industry codes.

3.4 Input-Output Table

A crucial component of our empirical analysis is the derivation of a measure of import penetration of intermediate products or vertical import penetration. To build this measure, we take advantage of input-output tables that provide information on the level of interdependence and input use between industries. All the industry and I-O data come from the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. The I-O tables along with industry economic accounts provide detailed information on the interrelationships between producers and users and the contribution to production across industries. The data are available at three levels: sector (15 industry groups), summary (71 industry groups), and detail (389 industry groups). To get the highest level of disaggregation, we make use of the I-O data at a detail level that is available for each 5-year benchmark years between 1947-2007. We calculate the weights measuring how much each industry's production is relying on the products of another sector by the use values shares of the industry pair appear in detail I-O use table in 1972 in the baseline regression. For example, the weight d_{js} represents the value share of the input used by industry s from industry j of the total inputs utilized by industry s in the benchmark year, i.e., $d_{js} = \frac{use_{js}}{\sum_{j \in s} use_{js}}$. To keep the potential impact of the change of relative input use between different industry due to the shift in trade policy to the minimum, we keep using the year 1997 as the baseline for the calculation of such weights.¹³

3.5 Measures of import penetration

This section describes how our main import penetration variables are constructed. We look at the impact of import penetration both directly and indirectly. Horizontal import penetration measures the direct effect of imported product and within-sector competition. By contrast,

¹³We assume that the input mix remains unchanged over the entire sample period, so ideally we need to use the earliest available benchmark year, 1972. However, there are admittedly significant structural change of industries due to technology and innovation in the 42 years our sample covers. To avoid potential bias caused by the change of industrial classifications, we use year 1997 in the middle of our sample period to be the benchmark year. We also proceed manual industry classification mapping between years and use the weights calculated from 1972 benchmark I-O table to corroborate our main results in section 6.

vertical import penetration takes the interdependence and input use between sectors into consideration. Horizontal and vertical import penetration is measured for the period 1974–2014 and each of the 389 benchmark I-O industries based on the 1997 benchmark I-O table classification.

The horizontal import penetration (HIMP) for industry s in year t is calculated as:

$$himp_{st} = \frac{imp_{st}}{imp_{st} + prod_{st} - exp_{st}}$$

where imp_{st} is the value of imports from the world to US in industry s at time t , and $prod_{st}$ is the production value of industry s in year t .

Similar to the way of separating input tariffs from output tariffs in Amiti and Konings (2007), we measure the cumulative impact of foreign input penetration in the industry s that is supplied by sector j by defining a measure of vertical import penetration ratio (VIMP). We define this for industry s as the weighted average of the import penetration of its inputs:

$$vimp_{st} = \sum_{j \in s} d_{js} himp_{jt}$$

where $himp_{jt}$ is the horizontal import penetration of intermediate inputs coming from industry j whose goods are used as inputs in the production processes of industry s . The weights d_{js} are computed as described in section 4.3 from the I-O tables as discussed above.

Horizontal and vertical import penetrations have a different impact on both firms' marginal costs and markup. On the one hand, higher horizontal import penetration leads domestic firms to face tougher final goods competition directly. This implies that an increase in horizontal import penetration leads domestic firms to lower their production and prices, and thus reduce their markup, assuming constant marginal costs. On the other hand, higher vertical import penetration will not affect the competitive environment faced by domestic firms, but it leads to a reduction in firms' marginal costs and thus allowing more room for firms to raise markups.

Table 1 summarizes the features of our key variables, i.e., markup, horizontal and vertical importing penetration rates for the industry level 1972-2014. Figure 8 provide our measure

of vertical import penetration with average industry markup between 1974 to 2014.

4 Results

In this section, we test the main predictions of our theoretical model: vertical import penetration is positively associated with average markups across industries and over time. We estimate our baseline specification at the industry level and firm level respectively for a full combined sample from 1972 to 2014.

4.1 Import penetration and markups: baseline results

We start by presenting how average markup increase with import penetration across the US economy in the last four decades. Figure 7 reports the time evolution of import exposure along with the sales-weighted markup. Measured as the value of imports of goods and services to GDP, the import exposure ratio has been steadily increasing in the first and half decade (1960s-1970s) despite the slightly drop of markup in the same period. Following the sharp increase in import exposure since 1970, the markup has been increasing since the next decade (1980s) till the present. As noted by De Loecker et al. (2016), there has been a sharp rise from a markup of around 1.2 in 1980 to a markup of 1.6 in 2014, while the import exposure ratio has doubled in the same period: it increase from around 10% in 1980 to 20% in 2014. This figure suggests that import exposure may have changed markup in some ways other than only output competition. In Figure 8, we report the VIMP ratio calculated as described in Section 3.5 with average markup from 1974 to 2014.¹⁴Recall that this VIMP ratio is the average of direct import penetration ratio in each industry (HIMP), weighted by the ratio of how each industry uses the other industry's output in the production. The VIMP ratio thus indicates the import penetration ratio of input. Remarkably, the pattern of VIMP is very much aligned with the average markup since 1970s: it

¹⁴We would like to extend this to years before 1974 but we are constrained by trade data availability.

increased from 0.05 to around 0.2 by 2014. These figures provide suggestive evidence consistent with predictions in the theoretical model. Next, we show the empirical test of these conjectures.

4.1.1 Sector-Level Analysis

With the import penetrations and industry level markup measures in hand, we can implement the following regression specification.

$$\ln\mu_{st} = \beta_1 \ln HIMP_{st-1} + \beta_2 \ln VIMP_{st-1} + \mathbf{X}'_{st} \gamma + \sigma_s + \delta_t + \varepsilon_{st} \quad (26)$$

where $\ln\mu_{st}$ is the log of estimated average markup in the 6-digit US Input-Output industry s weighted by sales in year t . $\ln HIMP_{st-1}$ and $\ln VIMP_{st-1}$ are the horizontal and vertical import penetration ratios in the same sector s . They are lagged for one period to accommodate the time it takes to adjust markups accordingly as described in the model and they also serve to attenuate potential simultaneous bias between import penetration and markup. \mathbf{X}_{st} is a vector of industry-level control including industrial level capital intensity (KL) and average wage ($WAGE$), who serve to capture the factors that could also potentially influence average markups. σ_s and δ_t are industry and time fixed effects, respectively, to control for time-invariant industry-related effect and time effect. ε_{st} is an iid error term. We clustered the standard errors at the industry level in our following regressions to accommodate non-independent residuals across observations within industries. Based on our theoretical framework, we expect β_2 to be significant and positive.

Table 4 reports the baseline regression results. Results from the unweighted from the unweighted sample in column (1) and (2) shows that an increase in one-year lagged vertical import penetration is associated with increase in markup, while horizontal import penetration negatively affects sale-weighted industry markup. In terms of magnitude, a 10% increase in lagged vertical import penetration is associated with a 0.43% increase in markup. Adding industry-level controls has little impact on the significance and size of the estimated beta, equal to 0.40% in column (2).

4.1.2 Firm-Level Analysis

In column (3) and (4), we implement a weighted regression specification having as weight the number of observations in each 6-digit BEA Input-Output industry that are used in the estimation of production function in each 2-digit sector. And this magnitude stays stable for these weighted regressions in columns (3) and (4): the coefficient of vertical import penetration increases to 1.23 and remains unchanged when including controls. We test our primary hypothesis further using firm-level observations. In particular, we regress firm-level markups over 6-digit industrial import penetration ratios as in Acemoglu et al. (2016) and Olper et al. (2017),¹⁵

$$\ln\mu_{ist} = \beta_1 \ln HIMP_{st-1} + \beta_2 \ln VIMP_{st-1} + \mathbf{Z}'_{ist} \gamma + \beta_4 \mathbf{I}_{st} + \theta_i + \sigma_s + \delta_t + \varepsilon_{st} \quad (27)$$

where $\ln\mu_{ist}$ is the markup of the firm i , who operates in industry s at year t in equation 27. The firm characteristic vector \mathbf{F}_{it} is added to account for time-variant firm-level factors including the number of employment, capital-labor ratio, and productivity that could also influence a firm's capacity of adjusting markups. We also include firm fixed-effects as captured by θ_i .

Table 5 reports the results from the firm level regressions. We find a positive and strongly significant correlation between both types of penetration ratios and the value of markup. According to the results from the unweighted regression specification estimation, implies that a 10% increase of vertical import penetration contributes to .62% and .25% increase of firm-level markup without and with other firm and industry controls. Columns (3) and (4) in Table 5 further reports the firm-level baseline results of weighted regression. Our results show a more significant positive correlation between the vertical import penetration ratio and the markup and they increase in scale comparing to unweighted regressions in column (1) and (2).

¹⁵In these regressions, we still use the industrial level data for the variables horizontal and vertical penetration ratios due to the lacking of firm level data for these variables.

4.2 Mechanisms

Here we further verify the main results presented above by looking into the specific mechanisms that operate in our theoretical model.

4.2.1 Production Frontier

Our model predicts that firms are motivated to employ more foreign inputs when variable sourcing cost decreases, but only firms with relatively high initial productivity can pay the fixed sourcing costs, import foreign intermediate goods and obtain the corresponding market advantage. Therefore, we should be able to observe that the positive effect of vertical import penetration is more substantial for firms that are initially at the fringe of the productivity frontier. We interact vertical import penetration ratio with a measure of the firm’s position relative to the production frontier. We define a firm’s proximity to the frontier as the ratio of its initial estimated productivity λ_{it}^{ini} to the highest productivity of that year in the industry the firm belongs to as in Amiti and Khandelwal (2013): $PF_{it} = \frac{\lambda_{it}^{ini}}{\max_{i \in s}(\lambda_{it}^{ini})}$. Table 6 column (1) shows a significant positive effect of the vertical import penetration ratio to markup and the significant positive coefficient of the interaction term between vertical import penetration and production frontier measure indicates the impact is more profound for firms initially at the fringe of productivity frontier. This relationship remains stable with the addition of firm and industry level controls as shown in column (2).

4.2.2 Industry Concentration

To fully understand the impacts of vertical import penetration on domestic market structure, we use HHI index as a measure of market concentration and look at how vertical import penetration may contribute to the reshaping of market structure. Table 6 shows a positive effect of the vertical import penetration ratio but a negative effect of the horizontal import penetration

intensity on the market concentration. The reports from Table 6 column (3) and (4) indicate that when the high productivity firms use more ratio of foreign inputs, the low productivity firms will face higher competition pressure from the high productivity firms and the market exiting ratio rises as well.

4.2.3 Industry Exit ratio

The rest of Table 6 relates the percentage of firms' exit in each industry with the import penetration measures. The central prediction on the relationship between vertical import penetration and markup relies on the differential impacts that import penetration has on heterogeneous firms. We thus expect to observe more firms exiting the market as high productivity firms retain cost advantage through importing intermediate inputs. The positive coefficients of vertical import penetration on industry exit ratio reported in Table 6 column (5) and (6) indicate that when the high productivity firms use more foreign inputs, the low productivity firms will face higher competition pressure from the high productivity firms and the market exiting ratio thus rises.

To sum up our results, we test the predicted mechanism of our model: the effect on markup is more profound for firms initially at the fringe of the productivity frontier. This is expected in the model as only firms with relatively high productivity could pay the fixed cost of sourcing intermediate goods from foreign countries and benefit more in the process of globalization. After this, we look at the change of both HHI and firms' exit ratio of each industry concerning the shift of import penetration. They further validate our expectation: the industry's sales are more concentrated to the advantageous firms, and the low productivity firms are forced to exit the market and so the firms' exit ratio of the industry increases.

5 Robustness Checks

5.1 Alternative Weighting

As described in Section 4, the measure of VIMP is a weighted average of the HIMP. In the measure of VIMP above, the weights being used are the shares of use values of each industry pair appear in detail input-output table in 1972. One possible concern is that these weights are based on a far distant year to cover the entire sample. It is likely that the structure of the economy has changed structurally and thus the initial industry classification and the associated weights cannot account for these structural changes. Moreover, the use of weights derived from 1972 benchmark input-output table requires re-classifications of secondary products definitions used in I-O tables over different benchmark years. Furthermore, I-O tables from 1972 to 1992 are based on the SIC classification while they are based on NAICS for later years. The concordance between SIC and NAICS as well as the concordance within different versions of each classification are thus unavoidable. To address these issues, we hereby first construct VIMP using use value shares from 1972 I-O table. We then split the sample into two parts, 1972-1988 and 1989-2014, and assign different weights for each sample. We employ the use value shares from 1972 I-O table and that from 1997 I-O table for these two split sample respectively.

The results are reported in Table 7. Our baseline results still hold for the entire sample using weights from 1997 I-O table as in column (1). The VIMP turns out to be insignificant in the first split 1972-1988 sample, but the results hold for the sample of 1989-2014 using weights from 1992 I-O table. This could be well explained by the fact that the observed sharp increase of markup only started in the late 1980s and the impact of VIMP is more significant when large developing economies like China just joined WTO and actively participated in the global value chain in 1990s. Also, the magnitude remains comparable with baseline regressions: a 10% increase in lagged vertical import penetration contributes to the rise in markup by .07%.

5.2 Output and Input Tariff

Presumably, the input and output tariff will determine the profitability of importing one product and thus influence the magnitude of trade flow. In this subsection, we circumvent the measurement issues of VIMP as described in the previous sections by using output tariff as a proxy for HIMP and derive input tariff the same way as deriving VIMP. The data for output tariffs are drawn from WTO trade analysis and information system (TRAINS) combined with tariffs collected by Feenstra et al. (2002). Moreover, the tariff measures are based on SIC which is consistent with 1972 I-O table and makes it more reliable when calculating input tariff using the use value share derived as weights from I-O table. The measure to compute input tariffs are adapted from the approach to measuring VIMP as in section 4:

$$\tau_{st}^{in} = \sum_{j \in s} d_{js} \tau_{jt}^{out}$$

where the input tariff of industry s , τ_{st}^{in} , is calculated as the weighted average of de jure output tariffs τ_{jt}^{out} in any industry k at time t . Similar to the measure of VIMP, d_{js} remains the use value shares of industry j to the production of industry s as in section 4.4. A small difference, however, is that the input tariffs are calculated at 4-digit SIC codes, and the use value shares are concorded using the concordance table between I-O table and SIC provided in the 1972 benchmark I-O table. Next, we replace HIMP and VIMP with output tariff and input tariff in our baseline regressions (26) and (27).

The results are displayed in columns (1) - (3) in Table 9. We still find a negative relationship between input tariff and markup, suggesting that lowering input tariff leads to rising markup. To get a sense of the magnitude, a 10% increase in lagged vertical import penetration contributes to the rise of markup by .17% and a markup increase by .57% and .41% when we split the sample at 1997. Compared with the baseline results using HIMP and VIMP directly as in section 5.1, the estimation results using output and input tariffs have larger coefficients for their impacts on the markup in scale, yet still confirming the same relationship that our theoretical model predicts: the increase of intermediate inputs penetration contributes positively to the rise of markup in

the long run.

5.3 A Difference-in-Difference Exercise: China’s WTO Accession

In Section 4.1, we presented evidence showing the association between import penetration and markup. Here, we are able to exploit a specific exogenous policy that changes import penetration to address the potential issue of endogeneity. As China entered WTO in 2001, the trade between the US and China has experienced impressive growth (Autor et al. 2018). We adopt a Difference-in-Difference approach based on the China’s accession into WTO in 2001, which eliminated both fixed trade barriers and variable trade costs. A number of researchers have considered this so-called ‘China Shock’ and have examined its impacts on the US economy in various aspects (Dorn et al. 2016, Acemoglu et al. 2016, Autor et al. 2018, 2016). We consider a sample of industry-level import penetration from China between 1997 to 2006 and begin with a specification in the spirit of Guadalupe and Wulf (2010) as follows,

$$\mu_{st} = \beta_1 AVH_{s98-00} * POST_{2000} + \beta_2 AVV_{s98-00} * POST_{2000} + \mathbf{X}'_{st} \Gamma + \sigma_s + \delta_t + \sigma_s \times t + \varepsilon_{st} \quad (28)$$

The measures of import penetrations are similar to above but here we consider only tariff with China. AVH_{s98-00} and AVV_{s98-00} , are the average output and input tariff with China in each industry respectively, taking the averages of the three years prior to the accession. These measures are interacted with post dummy, $POST_{2000}$, a dummy variable equal to 1 in each year after 2001. And \mathbf{X}_{st} is a matrix industry-level control variables to controls for industry size (as the natural logarithm of sales, employment and capital) and the endogeneity of import penetration through interactions of industry fixed effects with a time dummy. Standard errors are clustered at the industry level. Identification in the model thus comes from comparing the average markup of each industry that has different levels of initial tariffs before this China shock in 2001. We are interested in the question that if industries with relatively low levels in initial tariffs changed markup differently after WTO than industries facing high initial levels of tariffs.

Table 12 reports the results of the effect of tariff reduction due to China’s WTO accession and the impacts on average markups. In the baseline regression results as shown in the Column (1), we find statistically significant coefficients on the two interaction terms. As expected, the negative coefficient of $AVH_{s98-00} * POST_t$ suggests that industries with higher output tariff prior to 2001 decreased average markup more the period as they faced greater competition due to this China Shock. The positive coefficient of $AVV_{s98-00} * POST_t$ indicates that industries with lower vertical import penetration levels prior to 2001 increase average markup more over the period as they have improved access to input and concentrated market structure due to China’s WTO accession in 2001. Column (2) and (3) extend the baseline regression with industry size controls and industry trend interaction respectively. The results remains consistent with the baseline results. As a placebo test, in Column (4) we replace the post dummy variable with the fake year 1999 and recalculating the average tariffs before the fake shock using year 1997 and 1998. The coefficients of the two interaction terms turn to be insignificant.

5.4 Alternative Markup Measure and Sensitivity

The estimation of firm-level markup described in Section 3.2 relies on strict assumptions on the production function such as perfect competition in input markets and constant output elasticity over time. We here adopt an alternative measure of markup. We use economic profits over sales as an indicator for price-cost margin directly and perform the same regression as in section 5.1 to see how the ratio of imports penetration is correlated with the firm’s profitability. This approach enables us to circumvent potential measurement error in markup estimation. The results from Table 10 with firm-level panel data show the same results: The coefficients of industry level vertical import penetration ratio remain positive and significant, indicating that higher exposure to intermediate import penetration is associated with higher price-cost margins. In addition, the magnitude of the coefficients is close to results obtained before.

6 Conclusion

The value of imports to annual GDP in the US went up from 4.2 percent to around 16.5 percent from 1960 to 2014. The rapid increase in US exposure to trade over this period indicates that both foreign competition and input penetration may have grown considerably relative to earlier decades. Much previous research has studied the effects of imports on firm strategies after dramatic removal of trade barriers in specific periods of time. But the question of how and to what degree is increasing import penetration contributes to the more concentrated market structure and the associated rise of markups remain unclear. By analyzing heterogeneous firms that respond differently to the reduction of trade costs according to the initial productivity within each industry, our paper extends the analysis of the consequences of trade liberalization beyond change in export participation and average productivity. Specifically, we relate changes in market structure with firms' sourcing decisions and we relate average markups across US industries to the changes in imported input exposure.

In our analysis, we propose and test this relationship. First, we construct a theoretical framework to explicitly flesh out how vertical import penetration impacts the market concentration and the firms' markups. We obtain the following main predictions: increased input import penetration is associated with (i) higher average markups; (ii) higher market concentration; and (iii) higher exiting ratio at the industrial level. Second, we test these predictions and find empirical evidence that supports them. Our research contributes to and improves on the existing literature along two dimensions: First, we look at the structural impact on industry that the broad process of globalization brings over 40 years, which will not only nest the short-run effects of trade cost reduction on marginal cost and competition but also on industry reallocation in the relatively long-term. Second, we trace in detail how imported input penetration plays a role in the pricing of firms who have a better ability to utilize sourcing opportunities.

This paper does not incorporate the decisions in the boundaries firms such as outsourcing to contracting firms and offshoring to foreign countries. Quantifying the combinatorial effects on markups of these factors both theoretically and empirically is an essential avenue for further

research. The consequences of import penetration for market power may contribute to public ambivalence toward globalization and specific anxiety about resources redistribution between workers, consumers and owners of firms.

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Tables and Figures

Table 1: Summary Statistics

Variables	N	Mean	Min	Max
<i>Markup_{OLS}</i>	384,069	1.476711	.0017906	5.767589
<i>Markup_{OP}</i>	384,069	1.438996	.0017449	5.620286
<i>Markup_{ACF}</i>	348,026	1.757911	.0021316	6.865868
Horizontal Import Penetration Ratio	15,990	.1100257	0	1
Vertical Import Penetration Ratio	15,990	.1910009	1.22e-06	5.586

Notes: The table reports the summary statistics for the main independent and dependent variables used throughout the empirical analysis. The unit of observation for Markups is the production unit in the sector under investigation in each day from 1972 to 2014. *Markup_{OLS}*, *Markup_{OP}*, and *Markup_{ACF}* are estimated firm-level markups by OLS regression, by Olley and Pakes (1996) Method, and by Akerberg et al. (2015) corrections respectively. Horizontal and Vertical Import Penetration Ratio are calculated by the methods described in Section 4 using weights from 1972 BEA I-O benchmark table.

Table 2: Sample Firm Distribution by Broad Industry

IO Code	IO Description	Firms(%)	Freq(%)
11	Agriculture, forestry, fishing, and hunting	1,513	0.4
7	Arts, entertainment, recreation, accommodation, and food services	10,132	2.5
23	Construction	5,824	1.4
6	Educational services, health care, and social assistance	6,924	1.7
FIRE	Finance, insurance, real estate, rental, and leasing	89,734	21.8
51	Information	35,155	8.5
31G	Manufacturing	146,914	35.6
21	Mining	32,971	8
81	Other services, except government	1,624	0.4
PROF	Professional and business services	21,838	5.3
44RT	Retail trade	17,374	4.2
48TW	Transportation and warehousing	10,572	2.6
22	Utilities	18,015	4.4
42	Wholesale trade	13,941	3.4
	Total	412,565	100

Notes: The table reports the industry distributions for the firms in the firm-level data from Compustats from 1972-2014. The IO Code is based on BEA industry classification at sector level.

Table 3: Change of Import Penetration Ratios in Manufacturing Sectors: 1980-2014

Industry Code	Industry Description	Δ HIMP	Δ VIMP
311FT	Wood products	-0.032	0.035
313TT	Nonmetallic mineral products	0.259	0.086
315AL	Primary metals	0.556	0.154
321	Fabricated metal products	-0.182	0.031
322	Machinery	0.189	-0.035
323	Computer and electronic products	0.197	-0.015
324	Electrical equipment, appliances, and components	-0.131	0.05
325	Motor vehicles, bodies and trailers, and parts	-0.835	-0.402
326	Other transportation equipment	0.687	0.014
327	Furniture and related products	0.146	-0.002
331	Miscellaneous manufacturing	0.436	0.279
332	Food and beverage and tobacco products	0.049	0.05
333	Textile mills and textile product mills	0.08	0.095
334	Apparel and leather and allied products	-3.219	0.542
335	Paper products	0.399	0.093
3361MV	Printing and related support activities	-0.314	-0.136
3364OT	Petroleum and coal products	-0.156	0.067
337	Chemical products	0.021	-0.004
339	Plastics and rubber products	0.564	-0.007

Notes: The table reports the change of calculated horizontal and vertical import penetration ratios for manufacturing sectors at BEA industry classification summary level, 1980-2014, taking 1997 Input Output table as benchmark.

Table 4: Import Penetration and Markup: Baseline Industry Regression

	Industry-level Markup			
	Panel A: Unweighted Regression		Panel B: Weighted Regression	
	(1)	(2)	(3)	(4)
$\ln\text{Himp}_{t-1}$	-0.326** (0.158)	-0.316** (0.156)	-0.308 (0.686)	-0.356** (0.178)
$\ln\text{Vimp}_{t-1}$	0.044* (0.024)	0.039* (0.022)	0.123* (0.065)	0.117* (0.061)
Industry FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Other Firm-level controls	NO	YES	NO	YES
Industries	356	356	356	356
Observations	12,336	12,280	12,264	12,208
R-squared	0.638	0.655	0.804	0.813

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The robust standard errors are corrected by clustering variables at the 6-digit industry level. Sample is restricted to the 6-digit I-O benchmark industries during 1972-2014. Dependent variable is industry-level markup estimations corrected by Olley-Pakes Method. $\ln\text{Himp}_{t-1}$ is 1-year lagged industry horizontal import penetration ratio in log form. $\ln\text{Vimp}_{t-1}$ is 1-year lagged industry vertical import penetration ratio in log form. Specifications (1) - (2) report unweighted regressions and specifications (3) - (4) report the regression results that uses the number of firms that are being used in the production function estimation of each 2-digit industry as weight in the regressions. Other industry-level controls include industry capital-labor ratio.

Table 5: Import Penetration and Markup: Baseline Firm Regression

	Firm-level Markup			
	Panel A: Unweighted Regression		Panel B: Weighted Regression	
	(1)	(2)	(3)	(4)
$\ln\text{Himp}_{t-1}$	0.066 (0.070)	0.276*** (0.067)	-0.565*** (0.150)	0.715*** (0.134)
$\ln\text{Vimp}_{t-1}$	0.062*** (0.011)	0.024** (0.011)	0.191*** (0.017)	0.057*** (0.016)
Industry FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Other Industry-level controls	NO	YES	NO	YES
Other Firm-level controls	NO	YES	NO	YES
Firms	27,445	24,146	27,387	24,093
Observations	286,884	236,095	284,885	234,267
R-squared	0.681	0.717	0.706	0.747

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The robust standard errors are corrected by clustering variables at the firm level. Sample is restricted to the firms that appears during 1972-2014 merged with 6-digit industry code. Dependent variable is firm-level markup estimations corrected by Olley-Pakes Method. $\ln\text{Himp}_{t-1}$ is 1-year lagged industry horizontal import penetration ratio in log form and $\ln\text{Vimp}_{t-1}$ is 1-year lagged industry vertical import penetration ratio in log form. Specifications (1) - (2) report unweighted regressions and specifications (3) - (4) report the regression results that uses the number of firms that are being used in the production function estimation of each 2-digit industry as weight in the regressions. Other firm-level controls include the number of employees, and capital-labor ratio. Other industry-level controls include industry capital-labor ratio.

Table 6: Mechanism: Production Frontier, HHI, Exit Ratio

	Dependent Variables					
	Firm-level Markup		Herfindahl Index		Exit Ratio	
	(1)	(2)	(3)	(4)	(5)	(6)
lnHimp _{t-1}	-0.928*** (0.051)	-0.795*** (0.048)	-0.033 (0.044)	0.005 (0.046)	0.166 (0.290)	-1.321*** (0.327)
lnVimp _{t-1}	0.255*** (0.012)	0.214*** (0.012)	0.019** (0.007)	0.025*** (0.009)	0.128** (0.053)	0.205*** (0.057)
PF*Vimp _{t-1}	0.005* (0.002)	0.016*** (0.009)				
PF	0.0006*** (0.000)	0.0008*** (0.000)				
Industry FE	NO	NO	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Other controls	NO	YES	NO	YES	NO	YES
Observations	283,197	217,168	12,336	12,280	11,654	11,593
R-squared	0.681	0.689	0.854	0.861	0.536	0.549

Notes: * p<0.10, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. All variables are in logs. Sample is restricted to the firms that appears during 1972-2014 merged with 6-digit industry code. Dependent variables are: firm-level markup estimations corrected by Olley-Pakes Method in column (1)-(2); 6-digit industry Herfindahl Index in column (3)-(4); and Firm Exit Ratio calculated by the number of firms that appeared in last year but disappear in current year divided by total number of firms in the last year at 6-digit industry level. lnHimp_{t-1} is 1-year lagged industry horizontal import penetration ratio in log form and lnVimp_{t-1} is 1-year lagged industry vertical import penetration ratio in log form. PF is the variable that indicates a firm's initial distance to the productivity frontier within its main industry. PF equal to 1 if it is the top productivity firm at its initial year in its main industry. Other firm-level controls include the number of employees and capital-labor ratio. Other industry-level controls include industry capital-labor ratio and the Herfindahl index.

Table 7: Robustness: Using Different Benchmark Weighting: Industry Level

	Industry-level Markup			
	A: Pooling Sample		B: Sample I	C: Sample II
	(1)	(2)	(3)	(4)
$\ln\text{Himp}_{t-1}$	-0.009 (0.014)	-0.009 (0.006)	-0.009 (0.022)	-0.010 (0.011)
$\ln\text{Vimp}_{t-1}$	0.004 (0.009)	0.002 (0.003)	0.013 (0.016)	0.014* (0.007)
Other Industry-level controls	NO	YES	NO	NO
Industry FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Observations	15,406	12,938	3073	12,332
R-squared	0.766	0.673	0.927	0.744

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The robust standard errors are corrected by clustering variables at the 6-digit industry level. Sample is restricted to the detail level industries during 1972-2014. Dependent variable is industry-level markup estimations corrected by Olley-Pakes Method. $\ln\text{Himp}_{t-1}$ is 1-year lagged industry horizontal import penetration ratio in log form and $\ln\text{Vimp}_{t-1}$ is 1-year lagged industry vertical import penetration ratio in log form. Specifications (1) - (2) report regressions results on the full sample from 1972-2014 where VIMP is calculated using weights based on 1997 benchmark I-O table. Column (3) - (4) report the regression results from splitted samples of 1972-1982 and 1983 - 2014, and VIMP is calculated using weights based on 1997 benchmark I-O table. Other industry-level controls include industry capital-labor ratio.

Table 8: Robustness: Using Different Benchmark Weighting - Firm Level

	Firm-level Markup			
	A: Pooling Sample		B: Sample I	C: Sample II
	(1)	(2)	(3)	(4)
$\ln\text{Himp}_{t-1}$	-0.253*** (0.058)	-0.123** (0.060)	0.086 (0.062)	-0.012*** (0.004)
$\ln\text{Vimp}_{t-1}$	0.011 (0.007)	0.018** (0.007)	0.001 (0.010)	0.006*** (0.001)
Other Industry-level controls	NO	YES	YES	YES
Industry FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Observations	296,791	245,083	139,902	110,153
R-squared	0.679	0.716	0.733	0.780

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The robust standard errors are corrected by clustering variables at the 6-digit industry level. Sample is restricted to the detail level industries during 1972-2014. Dependent variable is industry-level markup estimations corrected by Olley-Pakes Method. $\ln\text{Himp}_{t-1}$ is 1-year lagged industry horizontal import penetration ratio in log form and $\ln\text{Vimp}_{t-1}$ is 1-year lagged industry vertical import penetration ratio in log form. Specifications (1) - (2) report regressions results on the full sample from 1972-2014 where VIMP is calculated using weights based on 1997 benchmark I-O table. Column (3) - (4) report the regression results from splitted samples of 1972-1988 and 1989 - 2014. Other industry-level controls include industry capital-labor ratio.

Table 9: Robustness: Input Tariff

	Industry-level Markup		
	A: 1972	B: 1972	C: 1997
	Weight (1)	Weight (2)	Weight (3)
Output Tariff $_{t-1}$	0.021* (0.011)	0.006 (0.004)	0.020 (0.045)
Input Tariff $_{t-1}$	-0.016* (0.010)	-0.057*** (0.018)	-0.041** (0.017)
Other Industry-level controls	YES	YES	YES
Industry FE	YES	YES	YES
Time FE	YES	YES	YES
Observations	4,472	1,572	1,813
R-squared	0.752	0.877	0.843

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The robust standard errors are corrected by clustering variables at the 6-digit industry level. Sample is restricted to the detail level manufacturing industries during 1972-2014. Dependent variable is industry-level markup estimations corrected by Olley-Pakes Method. Output Tariff $_{t-1}$ is 1-year lagged industry Output Tariff in log form and Input Tariff $_{t-1}$ is 1-year lagged industry input tariff in log form. Specifications (1) report regressions results on the full sample from 1972-2014 where Input Tariff is calculated using weights based on 1972 benchmark I-O table. Column (2) - (3) report the regression results from splited samples of 1972-1988 and 1989 - 2014. And Input Tariff is calculated using weights based on 1972 and 1988 benchmark I-O table respectively. Other industry-level controls include industry capital-labor ratio.

Table 10: Alternative Markup: Profit Margin

	Dependent variable: Firm Level Profit Margin			
	Panel A: Unweighted Regression		Panel B: Weighted Regression	
	(1)	(2)	(3)	(4)
lnHimp _{t-1}	0.084 (0.053)	0.088 (0.053)	0.031 (0.104)	0.118 (0.105)
lnVimp _{t-1}	0.036*** (0.008)	0.031*** (0.008)	0.060*** (0.014)	0.047*** (0.014)
Other Industry-level controls	NO	YES	NO	YES
Other Firm-level controls	NO	YES	NO	YES
Industry FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Observations	253,833	252,580	252,047	250,746
R-squared	0.499	0.517	0.517	0.545

Notes: * p<0.10, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. The robust standard errors are corrected by clustering variables at the firm level. Sample is restricted to the firms that appears during 1972-2014 merged with 6-digit industry code. Dependent variable is firm-level profit margin measured by profit over sales. lnHimp_{t-1} is 1-year lagged industry horizontal import penetration ratio in log form and lnVimp_{t-1} is 1-year lagged industry vertical import penetration ratio in log form. Specifications (1) - (2) report unweighted regressions and specifications (3) - (4) report the regression results that uses the number of firms that are being used in the production function estimation of each 2-digit industry as weight in the regressions. Other firm-level controls include the number of employees, capital-labor ratio, and average wage. Other industry-level controls include industry capital-labor ratio.

Table 11: Sensitivity to Outliers

Dependent variable:	Industry-level Markup		Firm-level Markup	
	Panel A: Industry Regression		Panel B: Firm Regression	
	(1)	(2)	(3)	(4)
$\ln\text{Himp}_{t-1}$	-0.846*** (0.321)	-0.803*** (0.307)	-0.488*** (0.104)	-0.256*** (0.097)
$\ln\text{Vimp}_{t-1}$	0.098** (0.043)	0.092** (0.037)	0.084*** (0.014)	0.028** (0.013)
Other Industry-level controls	NO	YES	NO	YES
Other Firm-level controls	NO	NO	NO	YES
Industry FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Observations	11513	11467	253735	210074
R-squared	0.743	0.757	0.679	0.721

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The robust standard errors are corrected by clustering variables at the 6-digit industry level for columns (1) and (2) and clustering at the firm level for columns (3) and (4). Dependent variable is industry-level markup estimations corrected by Olley-Pakes Method. $\ln\text{Himp}_{t-1}$ is 1-year lagged industry horizontal import penetration ratio in log form. $\ln\text{Vimp}_{t-1}$ is 1-year lagged industry vertical import penetration ratio in log form. Only observations that fall between the top and bottom 2.5 percentile of industry markup and firm markup are kept for column (1)-(2) and column (3)-(4) respectively. Specifications (1) - (4) report the weighted regression results that uses the number of firms that are being used in the production function estimation of each 2-digit industry as weight in the regressions. Other firm-level controls include the number of employees and capital-labor ratio. Other industry-level controls include industry capital-labor ratio.

Table 12: A Difference-in-Difference Exercise: China's WTO Accession

Dependent variable:	Industry-level Markup			
	(1)	(2)	(3)	(4)
	Baseline	With Control	With Trend	Placebo 1999
$AVH_{s98-00} * POST_{2000}$	-0.029** (0.014)	-0.037** (0.015)	-0.013*** (0.000)	
$AVV_{s98-00} * POST_{2000}$	0.406** (0.165)	0.413** (0.202)	0.485*** (0.007)	
$AVH_{s97-98} * POST_{1999}$				-0.062 (0.039)
$AVV_{s97-98} * POST_{1999}$				0.678 (0.485)
Industry Trend	NO	NO	YES	NO
Industry Controls	NO	YES	YES	YES
Industry FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Observations	3373	3118	3118	3118
R-squared	0.848	0.845	1.000	0.845

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The robust standard errors are corrected by clustering variables at the 6-digit industry level. Dependent variable is industry-level markup estimations in log form corrected by Olley-Pakes Method. AVH_{s98-00} and AVH_{s97-98} are the average horizontal import penetration ratio from China in sector s between 1998 to 2000 and between 1997-1998 respectively. AVV_{s98-00} and AVV_{s97-98} are the average vertical import penetration ratio from China in sector s between 1998 to 2000 and between 1997-1998 respectively. $POST_{2000}$ and $POST_{1999}$ are dummy variables which takes 1 only if year is 2000 and 1999 respectively. Industry-level controls include industry labor, sales and fixed capital in log form.

Figure 1: Inverse Productivity Cut-off of Importing Firms

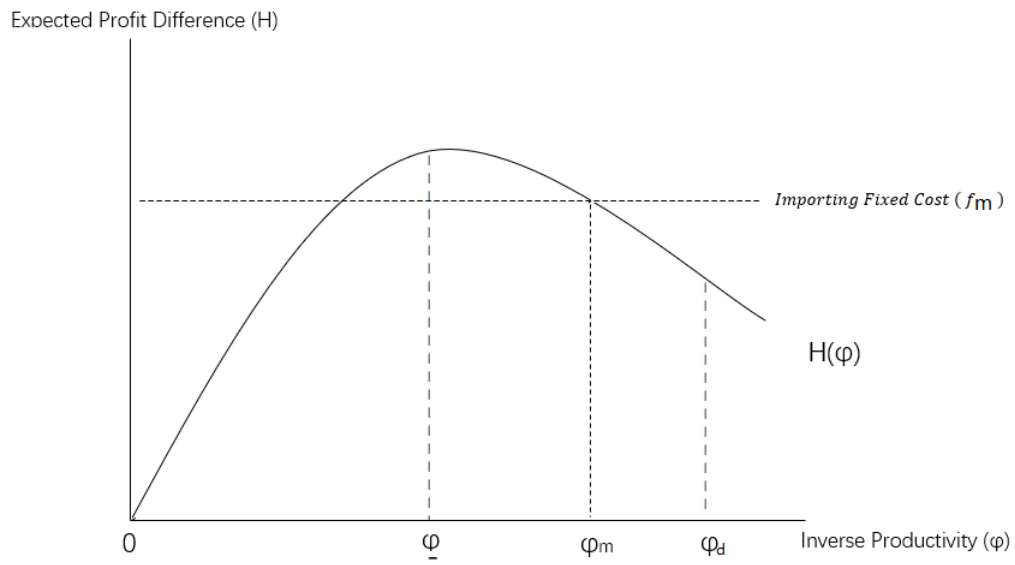


Figure 2: Inverse Productivity Cut-off of Importing Firms: A Reduction of Trade Cost

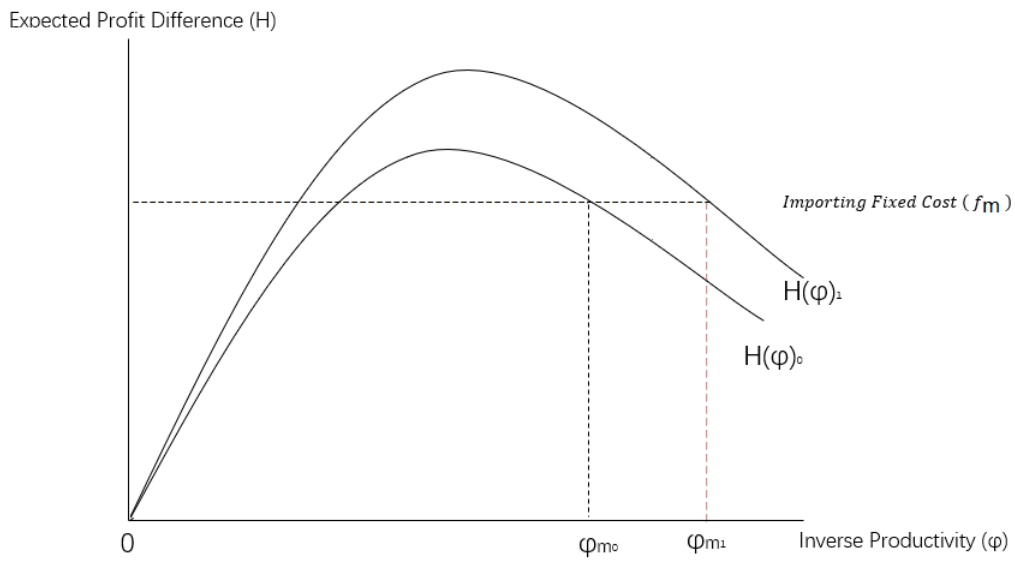


Figure 3: Inverse Productivity and the Firm Number

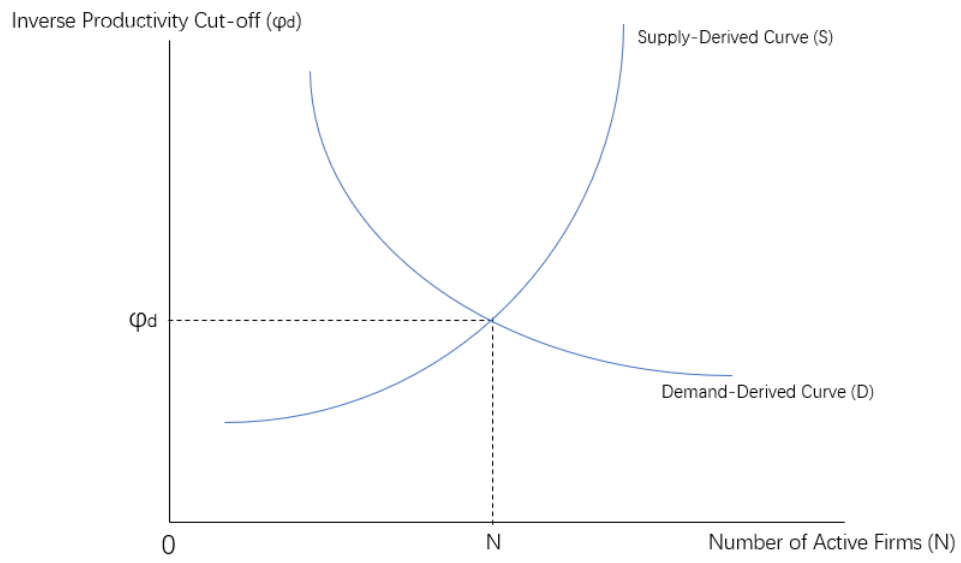


Figure 4: Inverse Productivity and the Firm Number: A Reduction of Trade Cost

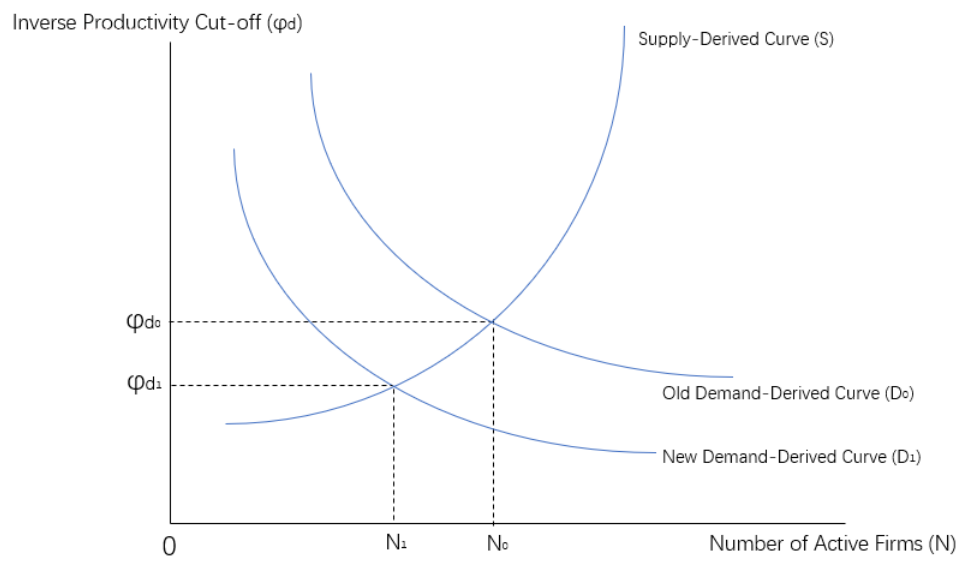


Figure 5: Import Productivity Cut-off: Constant Fixed Cost

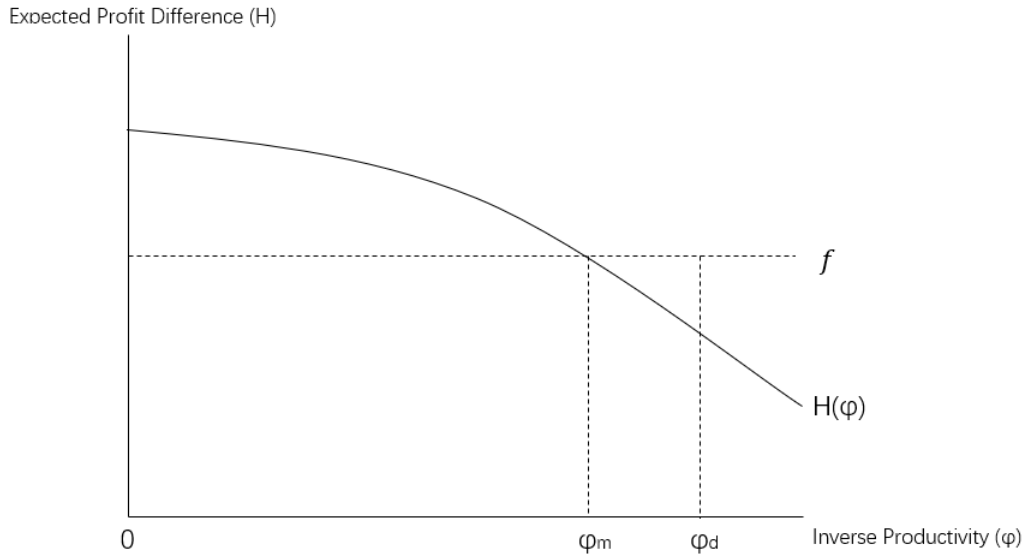


Figure 6: Inverse Productivity and Firm Number, Endogenous Entrants

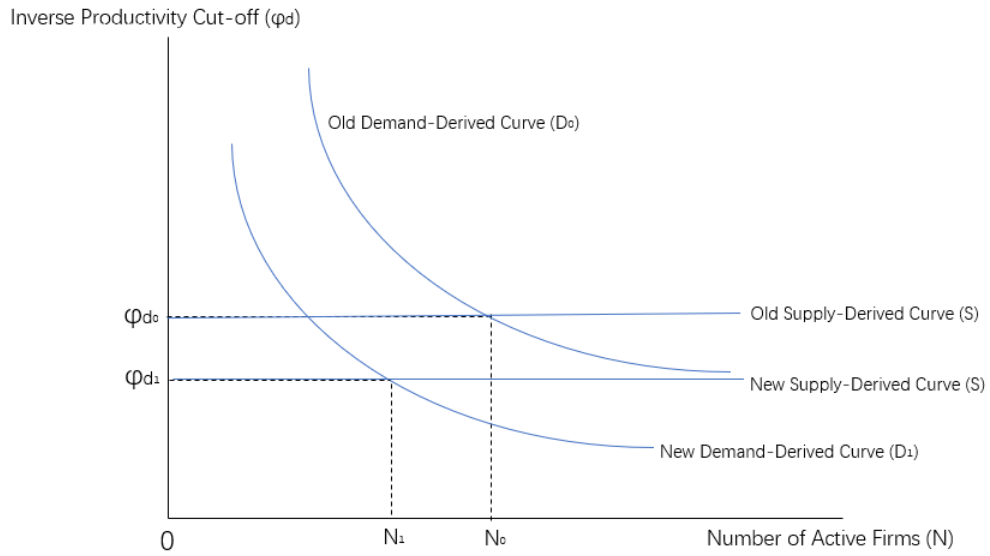


Figure 7: The Evolution of Average Markups and Import to GDP Ratio in the US (1960 - 2014)

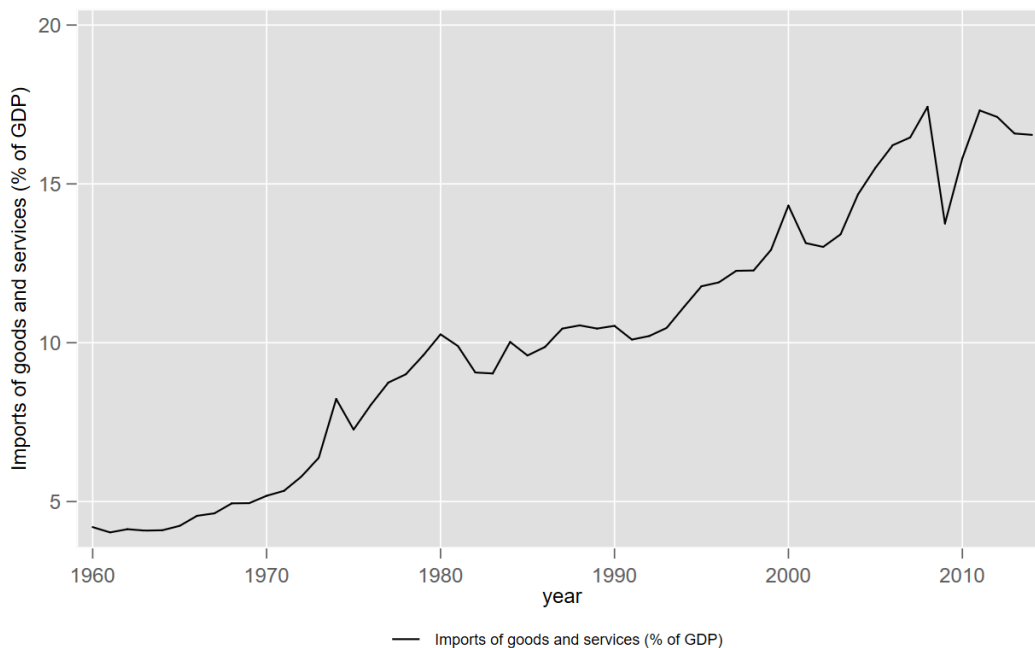


Figure 8: The Evolution of Average Markups and Imported Input Penetration in the US (1974 - 2014)

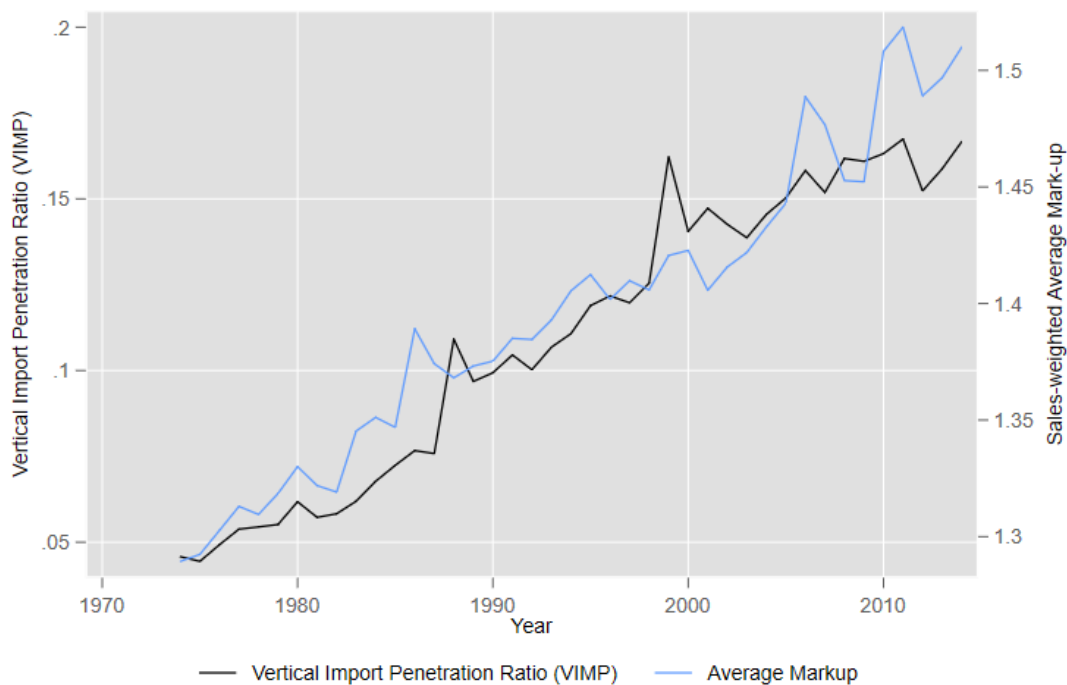


Figure 9: The Change of Average Markups and the Change in Import Penetration in the US (1980 - 2014)



Appendix A

A.1 Proof of Proposition 1

Claim 1 is equivalent to the following conditions: φ_m is the unique solution to the equation $H(\varphi_m) \equiv \frac{[2\varphi_d - (V^\phi + 1)\varphi_m](1 - V^\phi)\varphi_m \bar{D}^{-2}}{4\gamma} - f_m = 0$ in the definition range $[\underline{\varphi}, \bar{\varphi}]$; $H(\varphi_i) > 0$ for $\varphi_i < \varphi_m$; and $H(\varphi_i) < 0$ for $\varphi_i > \varphi_m$.

The solutions to the equation $H(\varphi_m) = 0$ in the definition range $\varphi_m \in R$ are: $\varphi_{m1} = \frac{\varphi_d - \sqrt{\varphi_d^2 - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1+\Psi}$ or $\varphi_{m2} = \frac{\varphi_d + \sqrt{\varphi_d^2 - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1+\Psi}$. Moreover, when $\varphi < \varphi_{m1}$ or $\varphi > \varphi_{m2}$, then $H(\varphi) < 0$; when $\varphi_{m2} \geq \varphi \geq \varphi_{m1}$, then $H(\varphi) \geq 0$. As follows and the assumptions in proposition 1, we get the following properties: (i) $\underline{\varphi} > \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}$ and $\bar{\varphi} < \frac{2}{1-\Psi} \sqrt{\frac{\gamma f_m}{L}}$; (ii) $\varphi_d \in [\underline{\varphi}, \bar{\varphi}]$; (iii) $\frac{2}{1-\Psi} \sqrt{\frac{\gamma f_m}{L}} > \sqrt{\frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}$; (iv) $\frac{\varphi_d - \sqrt{\varphi_d^2 - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1+\Psi}$ decreases in φ_d ; and (v) $\frac{\varphi_d - \sqrt{\varphi_d^2 - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1+\Psi}$ increases in φ_d . So we have $\underline{\varphi} > \frac{\sqrt{\frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}} - \sqrt{\frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)} - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1+\Psi} > \frac{\varphi_d - \sqrt{\varphi_d^2 - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1+\Psi}$ and $\frac{\varphi_d + \sqrt{\varphi_d^2 - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1+\Psi} \leq \frac{\bar{\varphi} + \sqrt{\bar{\varphi}^2 - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1+\Psi} < \bar{\varphi}$. Thus, we get a unique solution $\varphi_m = \frac{\varphi_d + \sqrt{\varphi_d^2 - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1+\Psi}$ such that $H(\varphi_m) \equiv \frac{[2\varphi_d - (V^\phi + 1)\varphi_m](1 - V^\phi)\varphi_m \bar{D}^{-2}}{4\gamma} - f_m = 0$ in the definition range $[\underline{\varphi}, \bar{\varphi}]$; $H(\varphi_i) > 0$ for $\varphi_i < \varphi_m$; and $H(\varphi_i) < 0$ for $\varphi_i > \varphi_m$.

Q.E.D.

A.2 Proof of Proposition 2: change of φ_m , φ_d and N

Proof of $\frac{\partial N}{\partial \Psi} > 0$ and $\frac{\partial \varphi_d}{\partial \Psi} > 0$:

Given the value of Ψ , equation (18) describes a negative relation while equation (12) shows a positive relation between N and φ_d . (See 3) In 3, the intercept of the curves for equation (18) and equation (12) determines the values for both N and φ_d . A decrease of Ψ will shift the curve for equation (18) to move downwards, which leads to lower values for both

N and φ_d .

Proof of $\frac{\partial \varphi_m}{\partial \Psi} < 0$:

Recall that the equation for φ_m is $\varphi_m = \frac{\varphi_d + \sqrt{\varphi_d^2 - \frac{4\gamma f_m(1+\Psi)}{L(1-\Psi)}}}{1+\Psi} = \frac{\varphi_d}{1+\Psi} + \sqrt{\frac{\varphi_d^2}{(1+\Psi)^2} - \frac{4\gamma f_m}{L(1-\Psi^2)}}$. If $\frac{\partial \varphi_d}{\partial(1+\Psi)} \frac{1+\Psi}{\varphi_d} < 1$, then the terms $\frac{\varphi_d}{1+\Psi}$ and $\frac{\varphi_d^2}{(1+\Psi)^2}$ decreases in Ψ . Also, we observe that the term $-\frac{4\gamma f_m}{L(1-\Psi^2)}$ decreases in Ψ , thus $\frac{\partial \varphi_m}{\partial \Psi} < 0$.

Q.E.D.

A.3 Derivative of equation (20)

$$\begin{aligned}\bar{\mu} &= \int_{\underline{\varphi}}^{\varphi_m} k \left(\frac{\varphi\Psi + \varphi_d}{2\varphi\Psi} \right) \left(\frac{\varphi - \underline{\varphi}}{\varphi_d - \underline{\varphi}} \right)^{k-1} \left(\frac{1}{\varphi_d - \underline{\varphi}} \right) d\varphi + \int_{\varphi_m}^{\varphi_d} k \left(\frac{\varphi + \varphi_d}{2\varphi} \right) \left(\frac{\varphi - \underline{\varphi}}{\varphi_d - \underline{\varphi}} \right)^{k-1} \left(\frac{1}{\varphi_d - \underline{\varphi}} \right) d\varphi \\ \bar{\mu} &= \int_{\underline{\varphi}}^{\varphi_m} \left(\frac{\varphi\Psi + \varphi_d}{2\varphi\Psi} \right) \left(\frac{1}{\varphi_d - \underline{\varphi}} \right) d\varphi + \int_{\varphi_m}^{\varphi_d} \left(\frac{\varphi + \varphi_d}{2\varphi} \right) \left(\frac{1}{\varphi_d - \underline{\varphi}} \right) d\varphi \\ \bar{\mu} &= \frac{1}{2(\varphi_d - \underline{\varphi})} \left[\left(\varphi + \frac{\varphi_d}{\Psi} \ln \varphi \right) \Big|_{\underline{\varphi}}^{\varphi_m} + \left(\varphi + \varphi_d \ln \varphi \right) \Big|_{\varphi_m}^{\varphi_d} \right] \\ \bar{\mu} &= \frac{\varphi_d}{2(\varphi_d - \underline{\varphi})} \left(\underbrace{\frac{1}{\Psi} \ln \frac{\varphi_m}{\underline{\varphi}}}_{(2)} + \underbrace{\ln \frac{\varphi_d}{\varphi_m}}_{(3)} \right) - \frac{1}{2} \underline{\varphi}\end{aligned}$$

Q.E.D.

A.4 Proof of Proposition 3

As $\bar{\mu} = \frac{\varphi_d}{2(\varphi_d - \underline{\varphi})} \left(\frac{1}{\Psi} \ln \frac{\varphi_m}{\underline{\varphi}} + \ln \frac{\varphi_d}{\varphi_m} \right) - \frac{1}{2} \underline{\varphi}$, we get the following properties for partial derivatives: $\frac{\partial \bar{\mu}}{\partial \varphi_d} < 0$, $\frac{\partial \bar{\mu}}{\partial \Psi} < 0$, and $\frac{\partial \bar{\mu}}{\partial \varphi_m} > 0$. If $\frac{\partial \varphi_d}{\partial \Psi} \frac{\Psi}{\varphi_d} < \ln \varphi$, we have $\frac{d\bar{\mu}}{d\Psi} = \frac{\partial \bar{\mu}}{\partial \varphi_d} \cdot \frac{\partial \varphi_d}{\partial \Psi} + \frac{\partial \bar{\mu}}{\partial \varphi_m} \cdot \frac{\partial \varphi_m}{\partial \Psi} + \frac{\partial \bar{\mu}}{\partial \Psi} < 0$, indicating that the trade reduction process leads to an increasing trend of the average markup.

Q.E.D.

A.5 Market Equilibrium in the Independent Fixed Sourcing Cost case

In the open economy case, the Equation (13) becomes :

$$\bar{P} = \int_0^{\varphi_m} \left(\frac{W\varphi + \Psi + W\varphi_d + 1}{2} \right) dG(\varphi)/G(\varphi_d) + \int_{\varphi_m}^{\varphi_d} \left(\frac{W\varphi + 2 + W\varphi_d}{2} \right) dG(\varphi)/G(\varphi_d) \quad (29)$$

As $\varphi \sim \left(\frac{\varphi_m}{\varphi_d}\right)^k$, we can simplify the equation above as:

$$\bar{P} = \frac{\Psi - 1}{2} \left(\frac{\varphi_m}{\varphi_d}\right)^k + \frac{(2k + 1)W}{2(k + 1)}\varphi_d \quad (30)$$

Substituting into Equation (11) we get

$$N = \frac{\gamma}{\eta} \frac{\alpha - \varphi_d}{\varphi_d - \left[\frac{\Psi-1}{2} \left(\frac{\varphi_m}{\varphi_d}\right)^k + \frac{(2k+1)W}{2(k+1)}\varphi_d\right]} \quad (31)$$

Combining equations (23) and (31), we get:

$$N = \frac{\gamma}{\eta} \frac{\alpha - \varphi_d}{\frac{[2k(1-W)+2-W]\varphi_d}{2(k+1)} + \frac{1-\Psi}{2} \left(\frac{1}{W}\right)^k \left(1 - \frac{(1-\Psi^2)L+4\gamma f_m}{2\varphi_d(1-\Psi)L}\right)^k} \quad (32)$$

Equation 26 shows that if k is small enough, e.g. $k=1$, the number of survived firms N decreases in the surviving critical value φ_d , and increases in Ψ . Similar to section 2.3.2, now equations 32 and $N_E = \frac{N}{G(\varphi_d)}$ uniquely determine the inverse productivity cut-off φ_d and firm number N . When variable trade cost V decreases, new equilibrium get to a lower level of N and φ_d , i.e. $\frac{\partial \varphi_d}{\partial \Psi} > 0$ and $\frac{\partial N}{\partial \Psi} > 0$. In addition, if the marginal effect of cost reduction on the surviving cut-off value is small enough such that $\frac{\partial \varphi_d}{\partial \Psi} < \frac{L(1-\Psi)^2+4\gamma f_m}{2WL(1-\Psi)^2}$, the critical value for importing will decrease in Ψ , i.e. $\frac{\partial \varphi_m}{\partial \Psi} > 0$.

A.6 Estimation of Markup

The estimation of markup follows exactly the same method as in De Loecker et al. (2016). Here we sketch out the basic ideas. Using the methodology in De Loecker and Warzynski (2012), no inference from demand or mkt structure. Starting with a production technology

$$Q_{it}(\mathbf{V}_{it}; K_{it}; \Omega_{it}) = F_{it}(\mathbf{V}_{it}; K_{it};)\Omega_{it}$$

The associated Lagrangian function (with one composite input) is

$$L(V_{it}; K_{it}; \Omega_{it}) = P_{it}^V V_{it} + r_{it} K_{it} - \lambda_{it} (Q_{it}(\cdot) - Q_{it})$$

First-Order Condition with respect to the variable input V gives

$$\frac{\partial Q_{it}(\cdot)}{\partial V_{it}} \frac{V_{it}}{Q_{it}} \equiv \theta_{it}^V = \frac{1}{\lambda_{it}} \frac{P_{it}^V V_{it}}{Q_{it}}$$

where θ_{it}^V is the output elasticity of the variable input V and the Lagrangian multiplier λ_{it} is a measure of marginal cost. Rearranging the terms we have markup μ_{it} defined as price over marginal cost

$$\mu_{it} \equiv \frac{P}{\lambda} = \theta_{it}^V \frac{P_{it} Q_{it}}{P_{it}^V V_{it}}$$

where the output elasticity θ_{it}^V is estimated from production function estimation and $\frac{P_{it} Q_{it}}{P_{it}^V V_{it}}$ is the inverse of input revenue share of the variable input V , which could be directly calculated from firm-level accounting data.