Economies of Scale and International Business Cycles*

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Abstract

Most international business cycle models assume a linear cost function and disregard variations in cost structure across industries. This paper investigates the loss of generality implied by these choices. I develop a two-country two-industry dynamic stochastic general equilibrium model with monopolistic competition and heterogeneous firms where economies of scale arise from two sources: fixed costs and sloping marginal cost curves. First, the model reproduces observed international business cycle dynamics for narrowly defined industries: in industries with decreasing marginal costs, (i) output is more volatile, but exports and imports are less volatile, and (ii) aggregate variables and trade flows are more correlated with aggregate GDP than they are in industries with increasing marginal costs. Second, the quantity anomaly is mitigated: Allowing the slopes of marginal cost curves to vary across industries increases aggregate GDP comovements across countries. The model successfully generates GDP comovements across countries that are stronger than consumption comovements. I interpret these findings as evidence that non-linear cost functions and variations in cost structure across industries improve our understanding of the international business cycle.

Keywords: Cost structure, Economies of scale, International business cycle, Quantity anomaly, Within-firm market interdependence.

JEL Classification: D24, F41, F44.

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1 Introduction

Does the slope of the marginal cost curve play a major role in macro and trade dynamics? Economies of scale and product differentiation are fundamental building blocks of the new trade theory introduced by Krugman (1979, 1980). Conventional new trade models and open macro models widely use a linear cost function, so fixed costs solely generate economies of scale because marginal costs are constant in output. The flat marginal cost curve yields that individual firm's problems and decisions in a domestic market are independent of an export market, and vice versa. In contrast, the recent firm-level international trade studies such as Vannoorenberghe (2012), Soderbery (2014), Berman et al. (2015), and De Loecker et al. (2016) have documented that each firm's domestic and export market maximization problems and decisions are not separable. Economies of scale derived from a sloping marginal cost curve endogenously produce within-firm level interdependence between the domestic and export markets because changes in one market sales have impacts on marginal costs for the both markets. In the data, industry heterogeneous international business cycle patterns vary with their marginal cost structures.

A fundamental idea of my paper is allowing industry heterogeneity of marginal cost structure, which is empirically plausible. The first evidence for the existence of sloping marginal cost curve is observed diseconomies of scale in many industries. Both sloping marginal cost and fixed cost determine the degree of economies of scale. However, fixed costs cannot generate diseconomies of scale. Second, U.S. manufacturing industry data show that economies of scale are more strongly associated with slopes of marginal costs than are fixed costs. Hence, these results suggest that the conventional new trade model assumption – fixed costs with a flat marginal cost curve – is too strict for multi-industry models. Furthermore, I find that the slope of the marginal cost curve is strongly associated with different patterns of macro and trade flows across narrowly defined U.S. manufacturing industries.

To study heterogenous industry dynamics and their role in the aggregate dynamics, I construct a two-country two-industry dynamic stochastic general equilibrium model with industry heterogeneity of cost structure along the line of the new trade open economy macroeconomic model introduced by Ghironi and Melitz (2005): monopolistic competition with endogenous entry and heterogeneous firms with an endogenous export decision. The distinct feature of my model is allowing different slops of marginal cost curves across industries. The model contributes to our understanding of the role of marginal cost structure in the observed industry-level international business cycles. Furthermore, understanding the marginal cost structure contributes to the aggregate-level international business cycle literature on explaining the quantity anomaly (also called the consumption-output anomaly) introduced by Backus et al. (1995).[1]

[1]Multi-country (or multi-region) dynamic general equilibrium models tend to have lower cross-country comovements than the data. More precisely, the output comovements are smaller than the productivity comovements and also the consumption comovements across countries, which is the opposite of what the data show. That is because of an incentive to shift resources and production to a more productive economy from a less productive economy. Hence, the conventional models need additional interdependence mechanisms between domestic and export markets to generate more correlated outputs across countries. See Ambler et al. (2004) for the recent international business cycle empirical findings related to the quantity anomaly. See Rebelo (2005) for low comovements across multi-regions.

My empirical work illustrates how U.S. manufacturing industrial international business cycles vary with industry cost structure characteristics. To investigate business cycle fluctuations, I use filtered four-digit Standard Industrial Classification U.S. manufacturing industry data.[2] To investigate impacts of marginal and fixed costs on the business cycle, I decompose sources of economies of scale into a sloping marginal cost curve and fixed cost. As I found, industry-level economies of scale are more strongly associated with marginal costs than fixed costs in the data. I find that industries with larger economies of scale derived from a sloping marginal cost curve have a more volatile output (value of shipments), but less volatile exports and imports than do industries with smaller economies of scale from a sloping marginal cost curve. In the former industries, the output, exports, and imports are more positively correlated to GDP. However, I cannot find a statistically robust association between the industrial international business cycle and economies of scale derived from fixed costs. Thus, I conclude that economies of scale derived from the sloping marginal cost curve play a vital role in different international business cycles across industries.

I construct an open macro model with industry-heterogenous marginal cost curves where firms established with a fixed sunk entry cost can access monopolistically competitive domestic and export markets. There are fixed export costs; thus, more productive firms export, but less productive firms do not. With a flat marginal cost curve, a firm only exports when its profit in the export market is higher than the fixed export cost. Its export decision is independent of its decisions in the domestic market because the profit functions in each market are linearly separable. Thus, there is no within-firm market interdependence. However, a sloping marginal cost curve generates export gains or losses that cause this separation to fail. Export market decisions and profitability have impacts on domestic market decisions and profitability through changes in marginal costs and vice versa. Thus, export decisions (to export or not) and foreign demands become more important in an individual firm's decisions: profits, sales, prices, and productions. When a marginal cost curve is decreasing in individual firm's production level, some firms export even if their profit in the export market is negative, because their export gains from lower marginal costs increase profits in the domestic market. Conversely, an increasing marginal cost causes some firms to forgo entry despite positive profits in the export market.

My model successfully generates empirically plausible business cycle comovements of aggregate GDP, consumption, and labor across countries. Allowing industry heterogeneity in a sloping marginal cost structure increases GDP and labor comovements across countries, which mitigates the quantity anomaly. The benchmark model with different sloping marginal cost curves performs better than the conventional model with identical flat marginal cost curves across industries to match observed cross-country comovements. Further, the model qualitatively performs well at matching the observed heterogeneous patterns of international business cycles across industries. In my model, there are only aggregate productivity shocks. The absence of sectoral specific shocks implies that all different patterns of indus-

[2] I use Hodrick and Prescott (1997)'s high-pass filter (HP filter). Baxter and King (1999)'s bandpass filter proposed is also widely used in business cycle research. Both filters provide similar results.

tries are endogenous.

A negative sloping marginal cost curve means that marginal costs decrease when production increases. It generates economies of scale and export efficiency gains because exports need more production to decrease marginal costs in both domestic and export markets. Such export gains make export markets more important in a less productive economy than in a more productive economy. The opposite holds for a positively sloping marginal cost curve. Consider two countries, home and foreign, and two industries, LEOS (Large Economies of Scale) and SEOS (Small Economies of Scale) industries. The LEOS and SEOS industries have a decreasing and increasing marginal cost curve, respectively. Thus, the LEOS industry generates larger economies of scale when both industries have the same fixed costs.[3] Suppose that a home favorable productivity shock is realized. Then, there are the following two propagation mechanisms. The first channel is a productivity channel that home LEOS and SEOS industries have cost advantages and disadvantages, respectively. This is because a large domestic market lowers marginal costs in the LEOS industry but increases marginal costs in the SEOS industry. Therefore, the LEOS industry becomes more profitable than the SEOS industry, which implies higher LEOS industry investment than SEOS industry investment in the home country. Thus, output, exports, and imports are more procyclical in the home LEOS industry than in the home SEOS industry. The second channel is from export gains and losses. The LEOS industry has larger export gains than the SEOS industry, and the gains are more important in the foreign country than in the home country due to low domestic demand in the foreign country. Thus, an individual foreign firm is more willing to export in the LEOS industry to enjoy large export gains. That causes industry reallocations from the SEOS to LEOS industry in the foreign country: more firms and exporters in the foreign LEOS industry. It implies more home imports in the LEOS industry than in the SEOS industry. In contrast, the home country is concentrated and exports more than before in the SEOS industry. In sum, that channel generates more procyclical imports but less procyclical output and exports in the home LEOS industry than in the home SEOS industry.

The first channel in the previous paragraph disappears over time due to the continuing entry of firms. Cost advantages and large profits in the LEOS industry are from increases in production of individual firms, which increases the entry of firms although this increase slowly over time. A large number of firms in the LEOS industry lowers an individual firm's output, so cost advantages shrink. Thus, a large level of friction in firm entry – slow changes in the number of firms – makes the first channel strong. The second channel exists through reallocations of firms across industries. At the early stage after the shocks, the second channel is limited because the number of firms changes slowly. Fast changes in the number of firms imply a stronger second channel. Thus, an increase in firm entry friction decreases the second channel. Hence, the relative size of two channel hinges on the firm entry friction quantitatively. Under empirically plausible parameters, the first channel is larger than the second channel. Thus, output,

[3]To focus on the marginal cost structure, I assume identical fixed costs structure across industries. For convenience, I assume decreasing and increasing marginal cost curve. A relatively negative slope of the marginal cost curve for the LEOS industry is enough, for example, a constant and positive slope for LEOS and SEOS, respectively.

exports, and imports are more procyclical in industries with decreasing marginal costs than in industries with increasing marginal costs.

A negatively sloped marginal cost curve generates positive within-firm market interdependence between domestic and export markets. In other words, domestic and export sales are compliments for individual firms, which implies more strongly positive output comovements across countries. Thus, industries with decreasing marginal costs contribute to mitigating the quantity anomaly. In contrast, there is negative within-firm market interdependence in industries where the slope of the marginal cost curve is positive. Thus, these industries lower cross-country output comovements that worsen the quantity anomaly. To investigate the aggregated impacts, my model considers two industries, the LEOS and SEOS industries. I calibrate parameters satisfying that the aggregate level marginal cost curve is flat, which is consistent with U.S. manufacturing sector data. Does the SEOS industry exactly offset the positive impact of the LEOS industry on business cycle output comovements? The answer is no. Due to export gains and losses, the LEOS industry's volume of trade is larger than that of the SEOS industry. Thus, the positive within-firm market interdependence in LEOS industry is quantitatively larger than the SEOS industry's negative within market interdependence.[4] Hence, the model generates positive aggregate level within-firm market interdependence despite its aggregate marginal cost curve being flat. The model reproduces stronger cross-country output correlation than does a model with a homogenous flat marginal cost curve across industries.

This paper relates to a wide range of international business cycle research. Many papers have studied the quantity anomaly in line with the international real business cycle model developed by Backus et al. (1992). Fattal-Jaef and Lopez (2014) show that it is hard to fix the quantity anomaly in new trade open macro models, even though they allow for endogenous labor, capital accumulation, and various entry and export structures. A large number of studies have introduced various structures to bridge the gap between model predictions and empirical patterns. For example, Heathcote and Perri (2002) and Kehoe and Perri (2002) investigate the role of capital market structures in international co-movements. Baxter and Farr (2005) and Ambler et al. (2002) introduce factor utilization and intermediate goods to generate strong positive cross-country output correlations, respectively. Lastly, Head (2002) investigates impacts of national and international returns to scale on business cycle comovements.

Industry-level empirical studies have documented significant heterogeneity in economies of scale across industries, for examples, Basu and Fernald (1997), Chang and Hong (2006), and Basu et al. (2006).[5] The recent empirical papers such as Lee (2007) support the above results based on firm-level data. However, economies of scale do not directly mean that a marginal cost is decreasing in production because fixed costs can generate economies of scale. De Loecker et al. (2016) directly estimate

[4]The theoretical prediction is also consistent with the data. The ratio of trade volume to output of the U.S. manufacturing industries tends to increase with economies of scale and a sloping marginal cost curve coefficient (the inverse of marginal cost curve slope).

[5]Chang and Hong (2006) and I use NBER CES database that tends to estimate relatively larger economies of scale than estimates based on KLEM data in Basu and Fernald (1997) and Basu et al. (2006).

an individual firm's marginal cost and find a negative correlation between marginal costs and quantities produced, which supports the decreasing marginal cost structure in some industries. Tybout (1993), Harrigan (1994), and Antweiler and Trefler (2002) study empirical patterns between economies of scale and international trade. They conclude that introducing economies of scale contributes to a better understanding of international trade.

Another strand of literature studies the within-firm relationship between domestic and export sales. They find that firms' sales interact across markets. However, their results, especially the direction of the relationship, are rather mixed. First, Berman et al. (2015) conclude that an exogenous increase in foreign sales causes increases in domestic sales. di Giovanni et al. (2016) document that internationally connected firms generate a positive relationship between an individual firm and foreign economy. Thus, domestic and export sales are complements, which can be derived from decreasing marginal cost, learning by doing, export efficiency gain, multi-national firms, or global supply chains. In contrast, some papers find that sales access markets are substitutes. Vannoorenberghe (2012) constructs a Melitz (2003) type trade model with increasing marginal cost to explain firm-level volatilities. Soderbery (2014) and Rho and Rodrigue (2016) assume constant returns to scale with capacity constraints, which induces increasing marginal costs in the short run. Both at the theoretical and empirical levels, the relationship between exports and domestic sales is not clear cut. My empirical findings of industry heterogeneity of marginal cost structure suggest complementary relationships for some industries and substitute relationships for some industries.

This paper is organized as follows. Section 2 documents industry-level cost structures and international business cycles of U.S. manufacturers. In Section 3, I investigate an individual firm's problem with a sloping marginal cost curve and illustrate the analytical mechanism behind the results of the following sections. Section 4 develops a two-industry two-country dynamic stochastic general equilibrium model based on Section 3. Section 5 presents a quantitative analysis of international trade and macro dynamics. These results guide my interpretation of international business cycles associated with a cost structure. The last section concludes.

2 Cost Structure and International Business Cycles

This section documents stylized facts of cost structure and the international business cycle of narrowly defined U.S. manufacturing industries. First, I describe cost structure heterogeneity across manufacturing industries. I collect a four digit Standard Industrial Classification (SIC) manufacturing industry data from NBER-CES Manufacturing Industry Database (annual from 1958 through 2011). Second, I illustrate how international business cycle fluctuations vary with a cost structure, for which I use Schott (2008)'s four digit SIC international trade flows annual data from 1974 through 2011. My empirical business cycle research is based on annual data, which does not capture higher frequency features. Appendix C describes the details of data sources, sample construction, variables, and measurements.

2.1 Sources of Economies of Scale: Sloping Marginal Cost Curves and Fixed Costs

To investigate a source of economies of scale, suppose that firms in an industry have the identical cost function with three factors, the production labor, capital, and material, denoted by l, k, and m with prices w, r, and p_m, respectively. f_C is the non-production labor in terms of unit of efficiency labor. To produce, the firm has to hire non-production workers, which generate fixed costs. The total, variable, and fixed costs are denoted by tc, vc, and fc, respectively. An individual firm's cost function is

$$\mathrm{tc} = \underbrace{\Theta w^{\vartheta_l} r^{\vartheta_k} (p_m)^{\vartheta_m} \left(\frac{y}{Z}\right)^{\frac{1}{\alpha}}}_{=\mathrm{vc}} + \underbrace{\frac{w}{Z^{\frac{1}{\alpha}}} f_C}_{=\mathrm{fc}}, \tag{1}$$

where y and Z are the output and the productivity, respectively. $\Theta = 1/\left[\prod_{x=l,k,m} (\vartheta_x)^{\vartheta_x}\right]$. The cost share parameters ϑ_x satisfy $\sum_{x=l,k,m} \vartheta_x = 1$. The corresponding production function is $y = Z\left(l^{\vartheta_l} k^{\vartheta_k} m^{\vartheta_m}\right)^{\alpha}$. The fixed cost is $\mathrm{fc} = f_C w/Z$. The number of non-production worker is $f_C Z^{-1/\alpha}$. I assume that capital and material are flexible in the long-run: zero non-production capital and materials. If $\alpha = 1$, then the cost function is linear.

The marginal cost is

$$\mathrm{mc} = \frac{\Theta}{\alpha Z} w^{\vartheta_l} r^{\vartheta_k} (p_m)^{\vartheta_m} \left(\frac{y}{Z}\right)^{\frac{1}{\alpha}-1}, \tag{2}$$

where α represent the degree of sloping marginal cost curve. Henceforth, I will call α the marginal cost coefficient. $\alpha = 1$ implies a flat marginal cost curve: the marginal cost is constant in output.

Economies of scale are measured by the inverse elasticity of total cost, denoted by eos. The cost minimization implies that

$$\mathrm{eos} = \left(\frac{\mathrm{tc}}{y}\right)\left(\frac{1}{\mathrm{mc}}\right) = \alpha\left(1 + \frac{\mathrm{fc}}{\mathrm{vc}}\right) = \alpha\left(1 + \vartheta_l \tilde{f}_C\right), \tag{3}$$

where $\tilde{f}_C = \left(w f_C Z^{-1/\alpha}\right)/(wl)$ is the ratio of non-production labor input to production labor input. Thus, there are two sources of economies of scale: sloping marginal cost curve and fixed costs: α and $\tilde{f}_C$.

Endogenous entry yields a difference between the industry- and firm-level production function. A wide literature such as Basu and Fernald (1997) has documented almost zero long-run profit in the U.S. manufacturing sector. Thus, the zero profit condition holds as follows.

$$\frac{1}{\zeta\mu}\rho y = \frac{w}{Z} f_C, \tag{4}$$

where ρ is the real price of output, μ is the markup, and $\zeta = 1/(\mu - \alpha)$. Then, the firm-level economies of scale are equal to the markup: $\mathrm{eos} = \mu$. The condition pins down the number of firms, denoted by N, in each industry. Let $K = Nk$, $L = Nl$, and $M = Nm$ be the industry aggregate capital, production labor, and materials, respectively. I obtain that

$$N = \left(\frac{\zeta \mu}{w} f_C \right)^{-\frac{1}{\alpha}} K^{\vartheta_k} L^{\vartheta_l} M^{\vartheta_m}. \tag{5}$$

As in Kim (2004), I introduce a parameter $\varepsilon \in [0, 1]$ that is associated with the elasticity of firm entry.[6] Large ε implies low elasticity. At $\varepsilon = 1$, the elasticity of firm entry is zero. Thus, the number of firms is fixed, which can be interpreted as the short run. At $\varepsilon = 0$, the elasticity is infinite. The number of firm is fully flexible, which represents the long run.

Define $\tilde{F}_C$ as the ratio of industry level non-production input to production input for labor in terms of effective unit: $\tilde{F}_C = Nwf_C Z^{-1/\alpha} / (wL) = \tilde{f}_C$ due to $L = Nl$. The (aggregated) industry production function is as follows.[7]

$$Y = N\rho y = \tilde{Z} \left(K^{\vartheta_k} L^{\vartheta_l} M^{\vartheta_m} \right)^{\alpha\left[1+(1-\varepsilon)\vartheta_l \tilde{F}_C\right]}, \tag{6}$$

where $\tilde{Z} = Z^{\varepsilon+(1-\varepsilon)\mu/\alpha} (\alpha/\mu) \left[\kappa (\zeta\mu)^{\varepsilon-1} \right]^{1/(\alpha\zeta)}$. At the (aggregated) industry-level, economies of scale, denoted by EOS, are

$$\mathrm{EOS} = \alpha \left[1 + (1-\varepsilon) \vartheta_l \tilde{F}_C \right]. \tag{7}$$

2.1.1 Methodology

This section presents the empirical framework, estimating the cost structure of each industry. As a first step, I estimate the ratio of non-production input to production input for labor.

$$\tilde{F}^s_{C,t} = \tilde{F}^s_C + \epsilon^s_{\tilde{F}_C,t} \tag{8}$$

The ratio of non-production input to production input for labor is calculated by the ratio of payroll for non-production workers to payroll for production workers. Considering the ratio based on the number of production and non-production workers does not change the main results.

The benchmark production function estimation follows Basu and Fernald (1997). Industry level

[6] See Appendix A for the functional form and its implications.

[7] See Appendix A for the derivation.

economies of scale (EOS^s) can be measured by γ^s in what follows. For an industry s,

$$\vartheta^s_{l,t} = \vartheta^s_l + \epsilon_{\vartheta_l,t} \tag{9}$$

$$\vartheta^s_{m,t} = \vartheta^s_m + \epsilon_{\vartheta_m,t} \tag{10}$$

$$\Delta Y^s_t = \gamma^s \left[\vartheta^s_l \Delta L^s_t + \vartheta^s_m \Delta M^s_t + \left(1 - \vartheta^s_l - \vartheta^s_m\right) \Delta K^s_t\right] + \Delta \tilde{Z}^s_t, \tag{11}$$

where ΔY^s_t, ΔL^s_t, ΔM^s_t, ΔK^s_t and $\Delta \tilde{Z}^s_t$ are the growth rates of real output, total labor, total capital, materials, and technology, respectively. The labor input is measured as the total hours for production and non-production workers. Because the NBER-CES database does not cover hours for non-production worker, the value for total hours is estimated following the method used in Baily et al. (1992). As an alternative, I use only production workers' hours as the measurement for the labor input. In the benchmark, ϑ^s_l and ϑ^s_m are the share of total labor and materials costs in the total cost, respectively. The alternative use the share of production labor and materials costs in the variable cost. respectively. The share of costs for total capital is calculated by $1-\vartheta^s_l-\vartheta^s_m$. There is no difference between the benchmark and the alternative in any of my main results.

Using Equation (7), the implied marginal cost coefficient is

$$\alpha^s = \frac{\gamma^s}{1 + (1 - \varepsilon)\, \vartheta^s_l \tilde{F}^s_C}.. \tag{12}$$

$\varepsilon = 0$ mean the firm's entry is infinitely elastic, implying a long-run. Conversely, the case where $\varepsilon = 1$ implies the short run because the number of firms is constant. I set $\varepsilon = 0$ as a benchmark. I also consider $\varepsilon = 1$. Then, industry-level economies of scale are equal to the sloping marginal cost curve coefficient: $\gamma^s = \alpha^s$.

I consider both instrumented and uninstrumented regressions. I use IV estimation to control measurement error problems that generate attenuation bias to zero. To reduce the bias, I introduce an instrument: the cost-share-weighted growth of inputs from $t+1$ to $t-2$, as in Lee (2007). If measurement errors are not serially correlated, instrumented regressions will yield consistent estimates. However, the instrument may not be valid to the endogeneity of inputs. To control for the endogeneity, demand-side instruments such as oil prices, the president's party, and government defense spending are widely used. According to Basu and Fernald (1997), the demand-side instruments are not completely exogenous and are weakly correlated to regressors. In this case, Nelson and Startz (1990) point out that IV estimates can be more biased than ordinary least squares estimates.

As Pagan (1984) and Murphy and Topel (1985) document, my approach faces generated regressor problems. In Section 2.2.2, the same problem will occur again in the second step because the second step regression uses the estimated cost structure coefficients as regressors. To handle the problem, I construct a bootstrapping algorithm.[8]

[8] See Section 2.2.2 and Appendix B for details of the bootstrap.

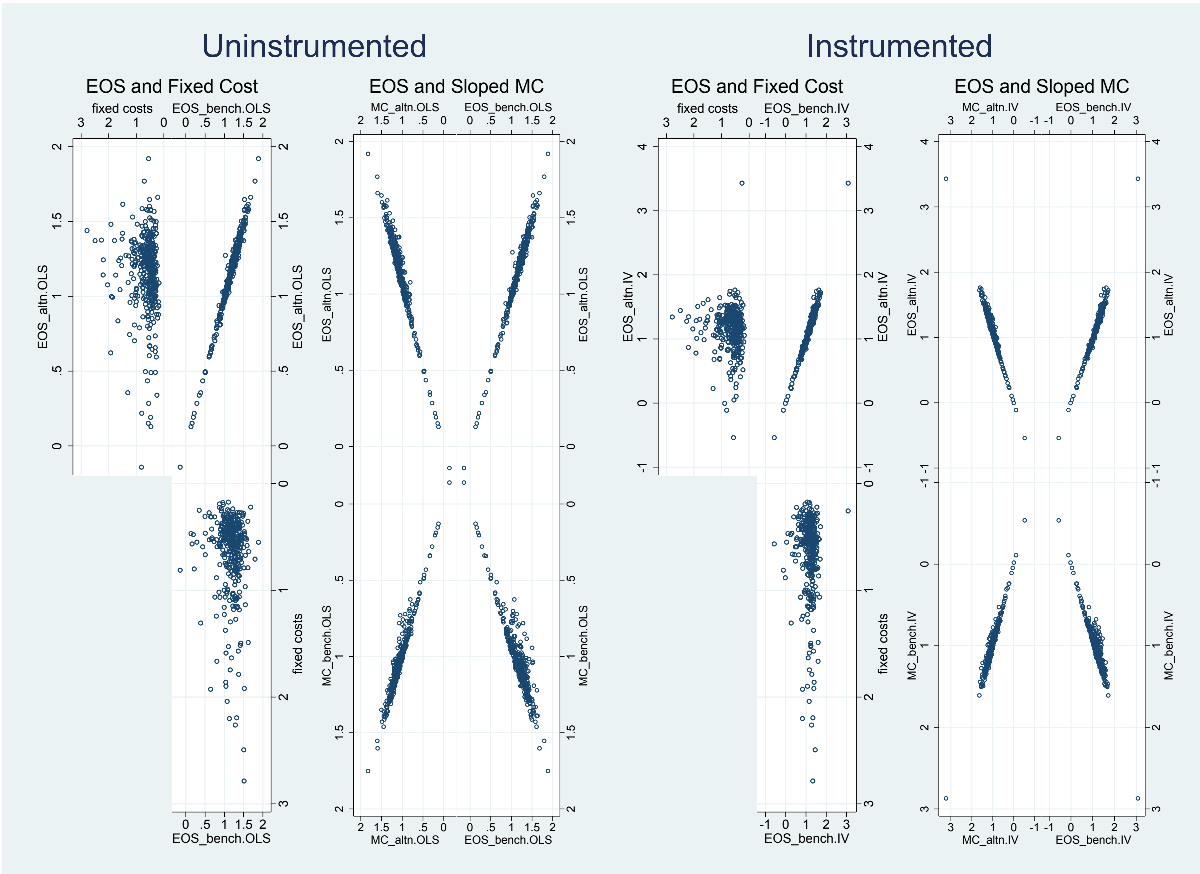

Figure 1: Estimated Economies of Scale, Sloping Marginal Costs, and Fixed Costs

2.1.2 Estimation Result: Cost Structure

Figure 1 illustrates the estimated cost structures for each industry. My data cover 364 four digit manufacturing industries. For each regression, I drop industries when their estimated economies of scale are below zero, although the number of dropped industries and their contribution in the economy is negligible.[9] Allowing negative estimates of economies of scale has no significant impact on all results. The non-production input ratio represents a fixed cost structure. In Figure 1, economies of scale have a weaker positive relationship to non-production input ratios than to the marginal cost coefficients. Also, the figure illustrates that estimated economies of scale and marginal curve coefficients are strongly correlated across the four regressions. Thus, I will focus on the benchmark OLS estimators because there is little difference between the four methods.

Even though my benchmark estimation follows Basu and Fernald (1997), Table 1 indicates statistically significant economies of scale in overall manufacturing industries, which is contrary to the findings

[9] Dropped industry's SIC codes industries are as follows: for the benchmark and alternative OLS, 2095. For the benchmark and alternative IV, 2046, 2095, and 2048. There is no impacts on results rounded off to three decimal places.

Table 1: Industry Cost Structure

		SEOS				LEOS				Total			
		EOS	α	$\bar{F}_C$	Obs.	EOS	α	$\bar{F}_C$	Obs.	EOS	α	$\bar{F}_C$	Obs.
						Panel A: Unweighted Industry							
Bench.	mean	0.988	0.885	0.659	165	1.319	1.149	0.654	198	1.168	1.029	0.656	363
OLS	stdv.	0.238	0.209	0.425		0.131	0.134	0.356		0.250	0.217	0.388	
Bench.	mean	1.071	0.951	0.650	231	1.359	1.183	0.664	130	1.175	1.034	0.655	361
2SLS	stdv.	0.295	0.261	0.389		0.123	0.137	0.390		0.283	0.250	0.389	
Altern.	mean	0.975	0.910	0.640	167	1.311	1.191	0.669	196	1.157	1.061	0.656	363
OLS	stdv.	0.236	0.212	0.413		0.131	0.125	0.366		0.251	0.221	0.388	
Altern.	mean	1.059	0.979	0.650	230	1.357	1.233	0.665	131	1.167	1.071	0.655	361
2SLS	stdv.	0.312	0.283	0.395		0.128	0.125	0.380		0.297	0.268	0.389	
						Panel B: Weighted Industry							
Bench.	mean	1.009	0.836	1.185	165	1.345	1.121	0.864	198	1.181	0.982	1.021	363
OLS	stdv.	0.355	0.238	0.933		0.112	0.117	0.551		0.310	0.234	0.778	
Bench.	mean	1.070	0.865	1.196	231	1.321	1.170	0.621	133	1.146	0.957	1.022	359
2SLS	stdv.	0.308	0.225	0.815		0.118	0.114	0.500		0.289	0.243	0.780	
Altern.	mean	0.985	0.896	1.174	167	1.330	1.185	0.873	196	1.161	1.043	1.021	363
OLS	stdv.	0.335	0.274	0.934		0.114	0.086	0.553		0.302	0.248	0.778	
Altern.	mean	1.081	0.958	1.203	230	1.308	1.204	0.620	131	1.151	1.035	1.022	361
2SLS	stdv.	0.326	0.263	0.818		0.120	0.094	0.492		0.298	0.252	0.780	

Notes: The weight is based on the over-time average of industry's fraction of unfiltered real output in each year from 1974 to 2011: $\text{weight}_Y^s = (1/38)[\sum_{t=1974}^{2011}(Y_t^s / \sum_{s'} Y_t^{s'})]$.

in Basu and Fernald (1997) and Basu et al. (2006) based on two digit industry level estimations. The result is robust on instrumented and un-instrumented regressions of the benchmark and the alternative. The reason for the difference is that the NBER CES database tends to yield larger economies of scale estimates than the KLEM data does in Basu and Fernald (1997) and Basu et al. (2006).[10] Implied marginal cost coefficients have to be lower than economies of scale, which are around one on average. The alternative specifications tends to yield both larger economies of scale and marginal cost coefficients.

In Table 1, an industry in LEOS exhibits economies of scale: the benchmark OLS estimated EOS is larger than one at 5 % significance confidence level. The SEOS industries form the remainder. SEOS and LEOS contain 165 and 198 industries in 363 four digit manufacturing industries,respectively. In the table, LEOS industries do not tend to have a higher ratio of non-production input to production input than SEOS industries even though LEOS industries exhibit larger economies of scale than SEOS industries. However, marginal cost coefficients of LEOS indstries are greater than SEOS industries robustly, which

[10]See Basu et al. (2006) and Chang and Hong (2006) for the difference between results based on KLEM and NBER CES database. They report estimated returns to scale and utilization parameters for two digit manufacturing industries: Table 1 in Basu et al. (2006) and Table 5 in Chang and Hong (2006). Chang and Hong (2006) follow Basu et al. (2006)'s estimation method, but their estimates tend to be larger than estimates in Basu et al. (2006).

implies that marginal costs are quantitatively more important than fixed costs as sources of economies of scale. These patterns hold after considering durables and non-durables.[11]

2.2 The International Business Cycle of the U.S. Manufacturers

To investigate the international business cycle of the U.S. Manufacturers, I use Hodrick and Prescott (1997)'s high-pass filtered and Baxter and King (1999)'s band-pass filtered cyclical components of logarithmic output, export, and import annual data. The results are robust to the choice of filter, so I report only HP-filtered results with a smoothing parameter 6.25 for annual frequency.

2.2.1 Descriptive Evidence: International Business Cycles Vary with Industry Cost Structure

To show how international business cycles vary with economies of scale, I classify industries into two-by-two categories. First, I consider SEOS and LEOS industries by using estimated EOS by benchmark OLS as in Section 2.1.2. LEOS and SEOS industries represent industries with large and small economies of scale, respectively. In terms of real outputs, sizes of SEOS and LEOS are 0.484 and 0.510, respectively, and 0.432 and 0.565, respectively in terms of trade.[12] LEOS is more trade intensive than SEOS because economies of scale motivate export by decreasing average costs. Second, I consider durable and nondurable industries.[13] A wide range of empirical research has reported that durables exhibit larger returns to scale than nondurables, which is consistent with my results in Table 1 in Appendix D. For this reason I introduce the two-by-two classification to check counterfactuals. Roles of economies of scale do not depend on the type of goods industries produce.

Table 2 summarizes the U.S. industry-level volatility and cyclicality of output, exports, and imports for each group and in total. There are 154 durable and 209 non-durable industries, of which durables have larger economies of scale than non-durables. Among 198 LEOS industries, 64 are non-durable and 134 are durable. Volatilities of output are measured by standard deviations in terms of percentage. Volatilities of trade flows are measured by standard deviations relative to standard deviations of industry output. Cyclicalities are measured by correlation to aggregate real GDP. As in the previous empirical literature, trade flows are more volatile than outputs. Exports and imports are both procyclical, although imports are more strongly so.

In Table 2, the differences between SEOS and LEOS industries give a rough indication of how

[11] See Table 1 in Appendix D for the evidence.

[12] In terms of real output and real trade volume, a size of each industry is calculated by

$$\text{Size of SEOS} = \sum_{s \in LEOS} \text{weight}_x^s \quad \text{and} \quad \text{Size of LEOS} = \sum_{s \in LEOS} \text{weight}_x^s \quad \text{for } x = Y_t^s,\ EX_t^s + IM_t^s$$

, where Y_t^s, EX_t^s, and IM_t^s are unfiltered sectoral real output, real export, and import, respectively. weight_x^s is the weight in terms of x_t^s, which is defined by $\text{weight}_x^s = (1/38)[\sum_{t=1974}^{2011}(x_t^s / \sum_{s'} x_t^{s'})]$.

[13] Industries with following 1987 two digit SIC codes are durables: 24, 25, 32, 33, 34, 35, 36, 37, 38, and 39. Nondurables two digit SIC code are 20, 21, 22, 23, 26, 27, 28, 29, 30, and 31.

Table 2: Summary Statistics: Volatility and Cyclicality

		SEOS				LEOS				Total			
		output	export	import	Obs.	output	export	import	Obs.	output	export	import	Obs.
						Panel A: Volatility							
ND	mean	3.850	3.374	3.341	90	5.455	2.587	2.701	64	4.231	3.187	3.189	154
	stdv.	1.590	1.791	2.440		2.309	1.272	3.369		1.908	1.711	2.695	
D	mean	7.795	2.245	2.593	75	8.275	1.789	1.854	134	8.111	1.945	2.107	209
	stdv.	2.601	2.196	2.309		2.454	1.373	1.278		2.509	1.708	1.733	
Total	mean	5.650	2.859	3.000	165	7.820	1.917	1.991	198	6.761	2.377	2.483	363
	stdv.	2.884	2.058	2.403		2.640	1.386	1.810		2.964	1.807	2.177	
						Panel B: Cyclicality							
ND	mean	0.183	0.012	0.319	90	0.311	0.155	0.418	63	0.214	0.046	0.343	153
	stdv.	0.269	0.227	0.218		0.273	0.208	0.277		0.274	0.231	0.236	
D	mean	0.349	0.127	0.234	75	0.419	0.224	0.381	134	0.395	0.191	0.330	209
	stdv.	0.189	0.132	0.182		0.263	0.228	0.219		0.242	0.205	0.218	
Total	mean	0.259	0.064	0.280	165	0.402	0.213	0.387	198	0.332	0.141	0.335	363
	stdv.	0.249	0.198	0.206		0.267	0.226	0.230		0.268	0.225	0.225	

Notes: Volatilities of output are measured by standard deviations in terms of percentage. Volatilities of imports and exports are measured by standard deviations relative to output. Cyclicalities are correlations to aggregate GDP. All results are weighted by the over-time average of industry's fraction of unfiltered real output in each year from 1974 to 2011:
$\text{weight}^s = (1/38)[\sum_{t=1974}^{2011}(Y_t^s / \sum_{s'} Y_t^{s'})]$. Unweighted results are reported in Appendix D (Table 2).

industry macro and trade dynamics vary with economies of scale. LEOS industries tend to have more volatile output but less volatile export and import flows than do SEOS industroes. Output, export, and import are more strongly correlated to aggregate GDP in LEOS industries than in SEOS industries. After considering durables and non-durables, these patterns hold generally in Panel A and B.

2.2.2 Methodology

For more statistically accurate investigation of the relation between industrial international business cycles and industry cost structures, I consider regressions as follows. To investigate pure impacts of each source of economies of scale – marginal and fixed costs –, I define economies of scale derived from marginal and fixed costs, respectively, as follows.

$$\text{EOS}^s_{MC} = \alpha^s \quad \text{and} \quad \text{EOS}^s_{FC} = 1 + (1-\varepsilon)\,\vartheta^s_l \tilde{F}^s_C,$$

which is based on Equation (7). Thus, it holds that $\text{EOS}^s = \text{EOS}^s_{MC} \times \text{EOS}^s_{FC}$. In a long run, the infinite elasticity of firm entry implies that $\varepsilon = 0$. Then, $\text{EOS}^s_{FC} = 1 + \vartheta^s_l \tilde{F}^s_C$. In a short run, the fixed number of firm implies that $\varepsilon = 1$. Thus, $\text{EOS}^s_{FC} = 1$. I consider following regression.

$$x^s = b_0 + b_1 \ln \text{EOS}^s_{MC} + b_2 \ln \text{EOS}^s_{FC} + \epsilon^s_x \tag{13}$$

where x^s is a measure of volatility or cyclicality for output, exports, and imports.[14]

Again, there are generated regressor problems (regressors are estimated in Section 2.1.1). Murphy and Topel (1985) suggest an analytical correction for the one-level two-step estimation, but my estimation strategy is multi-level and multi-step. My regressions have more complicated generated regressor problems than do conventional regressions. Thus, it is hard to impose Murphy and Topel (1985)'s correction. To address this problem, I construct a bootstrapping algorithm.[15]

2.2.3 Estimation Result: International Business Cycles

Table 3, 4, and 5 show significant evidences that industry cost-side characteristics play a fundamental role in the volatility and cyclicality of international trade and macroeconomic flows. The all regression results are weighted by industry size.

In Table 3 and 4, Column (1) reports estimated results based on $\varepsilon = 1$ where $\text{EOS}^s = \text{EOS}^s_{MC}$ and $\text{EOS}^s_{FC} = 1$. Column (3) is my benchmark estimation results for Equation (13) with $\varepsilon = 0$. Column (2) is also based on $\varepsilon = 0$, but I only use EOS^s_{MC} as a regressor.

Table 3 presents regressions of a standard deviation of industry output and trade flows on economies of scale from marginal cost coefficient and fixed costs. In Panel A, the estimated b_1 in all columns are statistically significant at the 5% level, and show that industries with larger economies of scale derived from a sloping marginal cost curve tend to have more volatile output than smaller industries with large economies of scale derived from a sloping marginal cost curve. All columns in Panel B and C report that b_1 is negative at the 1% significance level. Exports and imports are less volatile when industries have large economies of scale from marginal costs. My benchmark regression reported in Column (3) indicates that a 1% increase in economies of scale derived from marginal costs is associated with a 4.586% increase in the industry's standard deviation of output. Further, a one percent increase in economies of scale derived from marginal costs is associated with -2.036% and -2.273% decreases in the relative standard deviations of exports and imports, respectively.

Column (3) in all panels indicates the estimates for economies of scale derived from fixed costs. According to Column (3) in Panel A, the standard deviations of output are increasing in economies of scale from fixed costs, that are significant at the 5% level. Column (3) in Panel B shows that b_2 is

[14] Alternatively, I consider followings.

$$x^s = b_0 + b_1 \alpha^s + b_2 \tilde{F}^s_C + \epsilon^s_x \tag{14}$$

The alternative regression gives very similar results to those from the regression in Equation (13). Approximation with log-linearization implies that Equation (13) and (14) are very similar.

[15] See Appendix B for details.

Table 3: Weighted Regression Results: Economies of Scale and Volatility

	(1)	(2)	(3)
	Panel A: Output (stdv. %)		
	$\varepsilon = 1$	$\varepsilon = 0$	$\varepsilon = 0$
b_0	6.908***	7.928***	5.599***
	[6.033,8.082]	[6.462,8.897]	[4.386, 6.530]
b_1	6.190***	5.275**	4.586***
	[2.336,6.908]	[0.358,5.523]	[1.464,5.084]
b_2			13.194**
			[2.465,19.512]
R^2	0.416	0.234	0.506
Obs.	363	363	363

	(1)	(2)	(3)	(1)	(2)	(3)
	Panel B: Export (stdv. relative to output)			Panel C: Import (stdv. relative to output)		
	$\varepsilon = 1$	$\varepsilon = 0$	$\varepsilon = 0$	$\varepsilon = 1$	$\varepsilon = 0$	$\varepsilon = 0$
b_0	2.417***	2.026***	2.609***	2.585***	2.196***	2.512***
	[2.054,2.745]	[1.759,2.445]	[2.306,3.124]	[2.187,3.008]	[1.915,2.652]	[2.142,3.144]
b_1	-2.272***	-2.208***	-2.036***	-2.182***	-2.366***	-2.273***
	[-3.025,-0.957]	[-2.734,-0.579]	[-2.830,-0.682]	[-3.235,-0.748]	[-3.195,-0.577]	[-3.297,-0.601]
b_2			-3.304**			-1.789
			[-5.536,-0.741]			[-4.678,2.201]
R^2	0.258	0.188	0.267	0.176	0.160	0.177
Obs.	363	363	363	363	363	363

Notes: The number of bootstrap sample is $2,000 \times 2,000$. 95 percent Bootstrap confidence intervals are reported in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regression results are weighted by the over-time average of industry's fraction of unfiltered real output in each year from 1974 to 2011: $\text{weight}^s = (1/38)[\sum_{t=1974}^{2011}(Y_t^s/\sum_{s'} Y_t^{s'})]$.

negative at the 5% significance level. Exports are less volatile when industries have large economies of scale from fixed costs. In Panel C, however, the estimated result cannot reject the null of zero b_2 at the 10% significance level. Thus, fixed costs have no impact on the volatilities of imports.

Table 4 displays the relationship between cost structure and cyclicality. Panels A, B, and C show that industrial output, exports, and imports are strongly correlated with aggregate GDP when industries have large economies of scale derived from marginal costs. In Columns (2) and (3), all the estimated b_1 is significantly positive at the 5% level. The benchmark results are reported in Column (3). A 1% increases in economies of scale derived from sloping marginal costs is associated with 0.395, 0.288, and 0.185 increases in correlations of industry output, exports, and imports with aggregate GDP, respectively. I consider impacts of fixed costs on cyclical patterns of output, exports, and imports in the regression models of Column (3). In contrast to marginal costs, there are negative associations between fixed costs and cyclicality of output and imports at the 5% significance level. However, estimated b_2 for exports is insignificant.

To check the robustness of the regression results, I consider non-durables and durables for my bench-

Table 4: Weighted Regression Results: Economies of Scale and Cyclicality

	(1)	(2)	(3)
	Panel A: Output (corr. to aggregate GDP)		
	$\varepsilon = 1$	$\varepsilon = 0$	$\varepsilon = 0$
b_0	0.375***	0.421***	0.527***
	[0.322,0.440]	[0.370,0.482]	[0.438,0.571]
b_1	0.209***	0.364***	0.395***
	[0.096,0.412]	[0.185,0.538]	[0.206,0.514]
b_2			-0.923**
			[-0.814,-0.083]
R^2	0.076	0.178	0.268
Obs.	363	363	363

	(1)	(2)	(3)	(1)	(2)	(3)
	Panel B: Export (corr. to aggregate GDP)			Panel C: Import (corr. to aggregate GDP)		
	$\varepsilon = 1$	$\varepsilon = 0$	$\varepsilon = 0$	$\varepsilon = 1$	$\varepsilon = 0$	$\varepsilon = 0$
b_0	0.192***	0.236***	0.233***	0.419***	0.431***	0.549***
	[0.154,0.248]	[0.189,0.279]	[0.130,0.311]	[0.372,0.465]	[0.387,0.482]	[0.482,0.587]
b_1	0.238***	0.289***	0.288***	0.025	0.150**	0.185***
	[0.069,0.327]	[0.068,0.374]	[0.070,0.374]	[-0.038,0.185]	[0.035,0.327]	[0.071,0.278]
b_2			0.020			-0.673***
			[-0.293,0.404]			[-0.865,-0.350]
R^2	0.152	0.173	0.173	0.002	0.048	0.229
Obs.	363	363	363	363	363	363

Notes: The number of bootstrap sample is $2,000 \times 2,000$. 95 percent Bootstrap confidence intervals are reported in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regression results are weighted by the over-time average of industry's fraction of unfiltered real output in each year from 1974 to 2011: $\text{weight}^s = (1/38)[\sum_{t=1974}^{2011}(Y_t^s/\sum_{s'} Y_t^{s'})]$.

mark regression – Column (3) – in Tables 3 and 4. Table 5 illustrates robustness of impacts of cost structure on industry-level international business cycles for durable and non-durable industries. Durables and non-durables have similar patterns of impact of marginal costs on industrial business cycles. Thus, my previous results showing, the impacts of economies of scale from marginal costs on volatility and cyclicality of macroeconomic and trade flows, are robust. However, it is hard to find a clear and robust relationship between fixed costs and international business cycles. Impacts of fixed costs on industrial business cycles depend on industry goods classification. Thus, I leave these issues related to fixed costs for future research.

The regression results for economies of scale derived from fixed costs in Tables 3 and 4 are changed after allowing different coefficients for durable and non-durables. In Table 5, Panel A reports that the volatilities of exports and imports are positively associated with economies of scale derived from fixed costs in nondurables. b_2 for exports are insignificant, but b_2 for imports are significant at the 5% level. However, these associations are statistically negative in durables at the 10% level. Output volatility of durables increases when fixed costs increase at the 10% significant level. However, b_2 for output of non-

Table 5: Robustness Check: Non-durables and Durables

	Panel A: Volatilities					
	output		export		import	
	non-durable	durable	non-durable	durable	non-durable	durable
b_0	5.340***	5.921***	2.086***	2.914***	1.535***	3.019***
	[4.034,6.035]	[4.998,7.652]	[1.493,3.046]	[2.082,3.559]	[0.795,2.829]	[2.002,3.629]
b_1	2.401***	8.834*	-1.627***	-4.151**	-1.825**	-5.287**
	[0.787,2.986]	[-1.596,11.636]	[-2.626,-0.309]	[-4.852,-0.465]	[-2.894,-0.312]	[-5.771,-0.417]
b_2	-2.326	13.287*	6.729	-4.685**	14.768*	-4.033*
	[-9.513,6.831]	[-0.007,18.292]	[-3.857,14.074]	[-7.460,-1.453]	[-1.576,25.500]	[-6.944, 0.444]
R^2	0.245	0.413	0.194	0.283	0.198	0.352
Obs.	154	209	154	209	154	209

	Panel B: Cyclicality					
	output		export		import	
	non-durable	durable	non-durable	durable	non-durable	durable
b_0	0.324***	0.674***	0.135**	0.266***	0.439***	0.580***
	[0.168,0.425]	[0.579,0.727]	[0.019, 0.237]	[0.124,0.392]	[0.335,0.510]	[0.494,0.639]
b_1	0.230**	0.276**	0.222**	0.303*	0.065	0.331**
	[0.058,0.399]	[0.034,0.564]	[0.026,0.324]	[-0.051,0.419]	[-0.041,0.196]	[0.058,0.513]
b_2	0.467	-1.049***	0.879*	-0.099	-0.015	-0.764***
	[-0.467,1.953]	[-1.297,-0.505]	[-0.098,1.856]	[-0.573,0.358]	[-0.467,1.953]	[-1.014,-0.364]
R^2	0.137	0.477	0.249	0.085	0.016	0.421
Obs.	154	209	154	209	154	209

Notes: The number of bootstrap sample is $2,000 \times 2,000$. 95 percent Bootstrap confidence intervals are reported in brackets. $^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$. $\varepsilon = 0$ for all regressions. All regression results are weighted by the over-time average of industry's fraction of unfiltered real output in each year from 1974 to 2011: $\text{weight}^s = (1/38)[\sum_{t=1974}^{2011}(Y_t^s / \sum_{s'} Y_t^{s'})]$.

durables is negative and statistically insignificant at the 10% level. In Panel B, b_2 for output and imports in durables show a negative relationship with fixed costs at the 1% significant level. b_2 for exports is also negative but statistically zero at the 10% significance level. In contrast, b_2 for output and imports in non-durables are positive and negative, respectively. They are statistically zero at the 10% significance level. Cyclicality of exports in durables is positively associated with fixed costs at the 1% significant level.

In both Panel A and B, the regression results for b_1 in durables and non-durables have similar patterns to the results for economies of scale derived from a sloping marginal cost curve in Tables 3 and 4. In Panel A, industry output volatitility is increasing in $\ln \text{EOS}_{MC}^s$, however, exports and imports are decreasing in $\ln \text{EOS}_{MC}^s$. These results are statistically significant for both durables and non-durables. In Panel B, the correlation of industry output, exports, and imports to the aggregate GDP is increasing in α. Estimated b_1 for output, exports, and imports in durables is positive at the 10% significance level. In non-durables, estimated coefficients for output and imports are also statistically positive at the 10% level. A positive relation between cylcicality of imports and economies of scale from marginal costs is positive but insignificant at the 10% level.

Durable industries contribute to macro and trade business cycle properties. In Panel B of Table 5, the estimated results for b_0 imply that output, exports and import flows in durable industries are more correlated to aggregate GDP than in non-durable industries. These results are consistent with previous macro and international business cycle studies such as Baxter (1996) and Engel and Wang (2011).

3 Theoretical Framework: Sloping Marginal Cost Curve and Within-firm Market Interdependence

This section presents an individual firm's problem with a sloping marginal cost curve. Monopolistic competition implies that an individual firm's decision does not affect aggregate variables such as total demands, wages, price indices, and exchange rate. The individual firm's maximization problem is time separable. Each industry can be indexed by its marginal cost coefficient. Thus, I drop the industry (s) and time index (t) in Section 3. The section focuses on individual firm's decisions without general equilibrium effects. Thus, all aggregate variables are exogenously given. Section 4 will construct a dynamic general equilibrium model. There are two countries, home and foreign. I denote foreign variables by an asterisk.

3.1 Heterogeneous Firms with Sloping Marginal Cost Curve

There is a continuum of firms in each country and each industry. The mass of firms is given in this section. Home firms are heterogeneous in firm-specific productivity denoted by $z \in [z_{min}, \infty)$ where $z_{min} \geq 1$. Each firm produces a different variety $\omega \in \Omega$. An individual firm decides the quantity of supply to the domestic and export market denoted by $y_D \geq 0$ and $y_X \geq 0$, respectively. An exporter should ship τy_X units of the good for y_X units to reach the export market where $\tau > 1$ represents the iceberg export costs.

The real total cost function in terms of the home currency is

$$\mathrm{tc}\left(y; w, Z, z\right) = \left[\frac{w}{(Zz)^{\frac{1}{\alpha}}}\right] y^{\frac{1}{\alpha}} + f_X \frac{w}{Z^{\frac{1}{\alpha}}} \mathrm{I}\left\{y_X \in \mathbb{R}_+\right\}, \tag{15}$$

where $y = y_D + \tau y_X \geq 0$ is the total quantity produced, w is the real wage, $Z > 0$ is the aggregate industry productivity, and $f_X > 0$ is the fixed export costs in unit of efficiency labor. $\mathrm{I}\left\{\cdot\right\}$ is the indicator function.[16] Allowing a sloping marginal cost curve is a key feature of my model, which is represented

[16]The indicator function of $A \subset X$ is a function $\mathrm{I}\left\{x \in A\right\} : X \to \{0, 1\}$ defined by

$$\mathrm{I}\left\{x \in A\right\} = \begin{cases} 1 & \text{if} \quad x \in A \\ 0 & \text{if} \quad x \notin A \end{cases}.$$

by the marginal cost coefficient, denoted by α, in Equation (15). Conventional new trade and open macroeconomic models introduced by Krugman (1979, 1980), Melitz (2003), and Ghironi and Melitz (2005) fix $\alpha = 1$.

The marginal cost coefficient represents the firm's marginal cost structure. The marginal cost function is decreasing, constant, or increasing in y when $\alpha > 1$, $\alpha = 1$, or $\alpha < 1$, respectively. If the marginal cost curve is sloping ($\alpha \neq 1$), each firm's decisions in one market have effects on the profitability and decisions in other markets. When each firm's marginal cost does not vary with production level ($\alpha = 1$), the decisions in each market can be separated because the marginal cost is unchanged. $\alpha > 1$ causes positive within-firm market interdependence: large export sales lower the marginal cost, which leads to large domestic sales due to high productivity, and vice versa. Inversely, $\alpha < 1$ yields negative within-firm market interdependence: large export sales raise the marginal cost, which diminishes domestic sales due to low productivity, and vice versa.

A firm indexed by its firm-specific productivity z chooses its prices and quantities of supply to maximize its profit:

$$\max \rho_D y_D + Q\rho_X y_X - \mathrm{tc}\left(y; w, Z, z\right)$$
$$\text{subject to } y = y_D + \tau y_X,$$

where ρ_D and ρ_X are real prices relative to the price index in the destination market. Q is the real exchange rate. In each monopolistically competitive market for each industry, the firm faces the following individual demands in home and foreign markets, respectively.

$$y_D = \left(\rho_D\right)^{-\theta} D, \text{ and } y_X = \left(\rho_X\right)^{-\theta} D^*,$$

where D and D^* represent the effective home and foreign real demand for the industry in terms of destination currency. The elasticity θ is constant and larger than ones, so its markups in both markets are identical and constant: $\mu = \theta / \left(\theta - 1\right)$. To generate the existence of a unique equilibrium in a firm's maximization, I assume that the marginal cost coefficient is smaller than the markup: $\mu > \alpha$.

3.2 Exporter's and Non-exporter's Profit Maximization

I begin by solving a firm's profit maximization for given its export decision ($m_X = \mathrm{I}\left\{y_X \in \mathbb{R}_+\right\}$). For convenience, define the effective world demand by $ED\left(m_X\right) = D + m_X \left(\tau/Q\right)^{1-\theta} QD^*$. Then, a non-exporter's effective world demand is $ED_N = ED\left(m_X = 0\right)$ that is equal to the domestic demand. An exporter's effective world demand is $ED_X = ED\left(m_X = 1\right)$. ED_X increases in the real exchange rate but decreases in the iceberg trade costs. An exporter's effective world demand is larger than a non-exporter's: $ED_X > ED_N$. Thus, exporters enjoy more demand and higher revenue than non-exporters. There is a revenue side export motivation for all firms.

Taking as given the firm's export decision, its real marginal cost is given by

$$\mathrm{mc}\left(z;m_X\right)=\left[\frac{w}{\alpha\left(Zz\right)^{\frac{1}{\alpha}}}\right]\left[y(z;m_X)\right]^{\frac{1}{\alpha}-1}=\frac{1}{\mu}\left\{\mu\left[\frac{w}{\alpha\left(Zz\right)^{\frac{1}{\alpha}}}\right]\left[ED\left(m_X\right)\right]^{\frac{1}{\alpha}-1}\right\}^{\frac{\alpha\zeta}{\theta-1}}, \tag{16}$$

where $y\left(z;m_X\right)$ is the quantity produced for given export decision, and $\zeta=1/\left(\mu-\alpha\right)$ is positive by assumption ($\mu>\alpha$). Thus, a non-exporter's real marginal cost is $\mathrm{mc}_N\left(z\right)=\mathrm{mc}\left(z;m_X=0\right)$, and an exporter's real marginal cost is $\mathrm{mc}_X\left(z\right)=\mathrm{mc}\left(z;m_X=1\right)$. The optimal prices are equal to firm's markups multiplied by its marginal cost. Thus, the prices for a given export decision are given by

$$\rho_D\left(z;m_X\right)=\left\{\mu\left[\frac{w}{\alpha\left(Zz\right)^{\frac{1}{\alpha}}}\right]\left[ED\left(m_X\right)\right]^{\frac{1}{\alpha}-1}\right\}^{\frac{\alpha\zeta}{\theta-1}}, \tag{17}$$

$$\rho_X\left(z;m_X\right)=\left(\frac{\tau}{Q}\right)\rho_D\left(z;m_X\right)\qquad \text{if}\quad m_X=1. \tag{18}$$

If $\alpha=1$, exporter's and non-exporter's domestic prices are identical if they have the same productivity because there is no impact of effective world demand on prices under constant marginal cost. With $\alpha>1$, a firm can set lower prices if it exports, due to export efficiency gains derived from the decreasing marginal costs. The opposite holds for $\alpha<1$.

The domestic and export sales in terms of home currency are given by

$$\rho_D\left(z;m_X\right)y_D\left(z;m_X\right)=\left[\rho_D\left(z;m_X\right)\right]^{1-\theta}D \tag{19}$$

$$\rho_X\left(z;m_X\right)y_X\left(z;m_X\right)=\left[\rho_X\left(z;m_X\right)\right]^{1-\theta}QD^*\qquad \text{if}\quad m_X=1. \tag{20}$$

Thus, each individual exporter's domestic and export sales are complements if $\alpha>1$ but are substitutes if $\alpha<1$. For $m_X=1$,

$$\frac{\partial\rho_D y_D}{\partial QD^*}\gtreqless 0\quad\text{if and only if}\quad \alpha\gtreqless 1,$$

$$\frac{\partial\rho_X y_X}{\partial D}\gtreqless 0\quad\text{if and only if}\quad \alpha\gtreqless 1.$$

In other words, the constant marginal cost causes no within-firm interdependence. The decreasing and increasing marginal costs imply positive and negative within-firm interdependence, respectively.

3.3 Profit Curve and Export Decision

The firm's profit for a given export decision is

$$\begin{aligned}\pi(z;m_X) &= \frac{1}{\zeta}\left[\rho_D(z;m_X)\,y_D(z;m_X)+Q\rho_X(z;m_X)\,y_X(z;m_X)\right]-m_X f_X\frac{w}{Z^{\frac{1}{\alpha}}}\\ &= \frac{1}{\zeta\mu}\left[\mu\frac{w}{\alpha(Zz)^{\frac{1}{\alpha}}}\right]^{-\alpha\zeta}\left[ED(m_X)\right]^{1+(\alpha-1)\zeta}-m_X f_X\frac{w}{Z^{\frac{1}{\alpha}}},\end{aligned} \tag{21}$$

which increases in its effective world demand ($ED(m_X)$) because $\mu>\alpha$ and $\theta>1$ guarantee $1+(\alpha-1)\zeta>0$. Further, the profit is convex, linear, or concave in effective world demand if and only if $\alpha>1$, $=1$, or <1. The profit is decomposed into the domestic market profit ($\pi_D(z;m_X)$) and export market profit ($\pi_X(z;m_X)$) as follows.

$$\pi_D(z;m_X) = \frac{1}{\zeta\mu}\left[\mu\frac{w}{\alpha(Zz)^{\frac{1}{\alpha}}}\right]^{-\alpha\zeta}\left[ED(m_X)\right]^{(\alpha-1)\zeta}D \tag{22}$$

$$\pi_X(z;m_X) = m_X\left\{\left[\frac{\pi_D(z;m_X)}{D}\right]\left(\frac{\tau}{Q}\right)^{1-\theta}QD^*-f_X\frac{w}{Z^{\frac{1}{\alpha}}}\right\} \tag{23}$$

The previous assumption ($\mu>\alpha\Leftrightarrow\zeta>0$) guarantees that all firms participate in the domestic market. If a marginal cost function is flat ($\alpha=1$), the domestic profit is independent of the export decision. The profit function is linearly separable in the domestic and export market demands, so there is no firm-level market interdependence. In contrast, the decreasing marginal cost curve ($\alpha>1$) causes positive interdependence between firm's decisions in the domestic and export markets. Similarly, the increasing marginal cost curve ($\alpha<1$) implies negative interdependence between two markets at the firm level. For $m_X=1$,

$$\begin{aligned}\frac{\partial\pi_D}{\partial QD^*}&\gtreqless 0 \quad\text{if and only if}\quad \alpha\gtreqless 1,\\ \frac{\partial\pi_X}{\partial D}&\gtreqless 0 \quad\text{if and only if}\quad \alpha\gtreqless 1,\end{aligned}$$

because marginal costs depend on the total quantity produced when the cost curve is not linear.

A firm's profit with firm-specific productivity z is $\pi(z)=\max\{\pi(z;m_X=0),\pi(z;m_X=1)\}$. Since its profit strictly increases along with its firm-specific productivity, more productive firms export. An export decision can be represented by the export productivity cutoff, denoted by z_X. The cutoff level satisfies the indifferent condition as follows.

$$\pi(z_X;m_X=0)=\pi(z_X;m_X=1)$$

A firm exports when its firm-specific productivity is higher than the cutoff: $z>z_X$.

If there is no firm-level market interdependence derived by a marginal cost curve, then the condition can be expressed by $\pi_X(z_X, m_X = 1) = 0$, because the total profit function is linearly separable in the domestic market profit and export market profit. Thus, the flat marginal cost curve implies that a firm only export when its profit is positive in an export market. However, with decreasing marginal cost curve, some firms export despite negative profits in the export market. By exporting, firms increase their output and lower their marginal costs, which increases profits in the domestic market.

$$\pi_X(z_X, m_X = 1) \lesseqqgtr 0 \quad \text{if and only if} \quad \alpha \gtreqqless 1$$

For the marginally exporting firm ($z = z_X$), export profit is positive, zero, or negative if the marginal cost is increasing, constant, or decreasing, respectively.

The export decision is represented by $m_X(z) = \text{argmax}_{m_X \in \{0,1\}} \pi(z; m_X)$. The explicit solution to the export decision and cutoff is

$$m_X(z) = \begin{cases} 1 & \text{if} \quad z \geq z_X \quad \text{where } z_X = \left[\frac{\mu\zeta f_X w Z^{-\frac{1}{\alpha}}}{ED_X^{1+(\alpha-1)\zeta} - ED_N^{1+(\alpha-1)\zeta}}\right]^{\frac{1}{\zeta}} \left[\mu \frac{w}{(Zz)^{\frac{1}{\alpha}}}\right]^{\alpha} \\ 0 & \text{otherwise} \end{cases} . \tag{24}$$

The assumptions $\mu > \alpha$ and $\theta > 1$ guarantee that z_X and z_X^* are nonnegative and finite, but they can be less than z_{min}. Thus, the cutoff is $\max\{z_X,\ z_{min}\}$. I assume no corner solution for the cutoff levels: z_X and z_X^* are in (z_{min}, ∞). Then, the cutoff always increases in the iceberg cost, fixed cost, and wage but decreases in the real exchange rate and foreign demand as in Melitz (2003) and Ghironi and Melitz (2005). The interesting part is that the cutoff depends on the cost structure if $\alpha \neq 1$. The decreasing and increasing marginal cost makes negative and positive relationships between the home demand and cutoff level, respectively.

$$\frac{\partial z_X}{\partial D} \lesseqqgtr 0 \quad \text{if and only if} \quad \alpha \gtreqqless 1$$

If the marginal cost function decreases in quantity produced, a high home demand augments home firms' supply in the domestic market and lowers their marginal costs. Thus, the cutoff level lowers, and more firms export. However, the cutoff level is higher if the marginal cost is an increasing function due to complementarity of domestic and export profits and sales.

Figure 2 graphically shows impacts of allowing a sloping marginal cost curve. Under the flat marginal cost curve, exporters and non-exporters have the same slope of domestic market profit curve. Thus, an individual firm's decision to export or not is simply determined by its profit in the export market. The firm exports if the export market profit is positive. However, a sloping marginal cost curve makes the domestic profit curve different for exporters and non-exporters. If $\alpha > 1$, some firms export despite negative profit in the export market because exporting decreases their marginal costs in both markets and increases their domestic profit. Conversely, some firms in the industry with $\alpha < 1$ do not export even

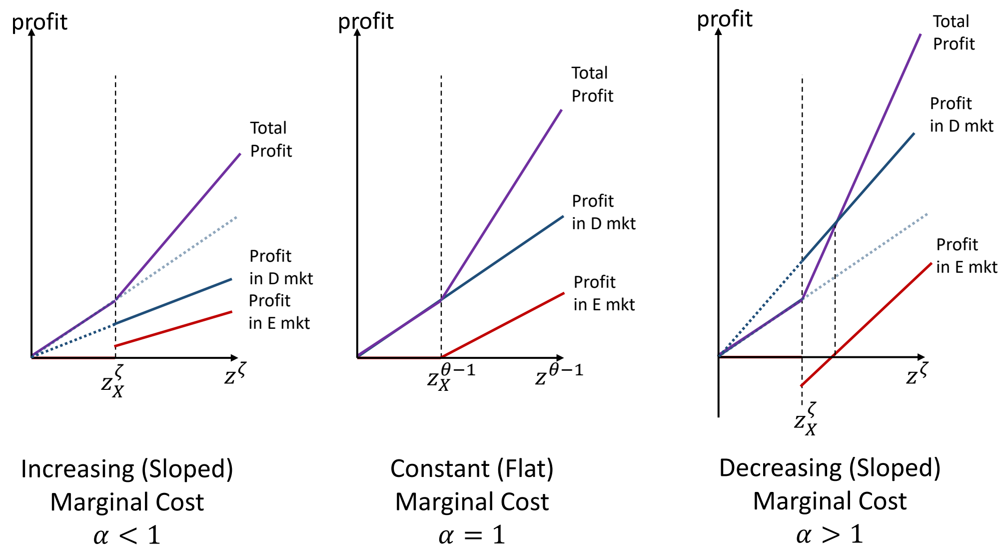

Figure 2: Profit Curves with the Flat and Sloping Marginal Cost Curve

though their export market profit is positive due to export efficiency losses. Additionally, in conventional models based on Melitz (2003), the profit is associated with the $(\theta - 1)$-th moments of firm-specific productivity, but here this result is be generalized that the profit depends on the ζ-th moment of firm-specific productivity. For the case with a constant marginal cost curve, $\alpha = 1$, the firm's optimal decision rule equals that in Ghironi and Melitz (2005).

3.4 Market Size, Export Efficiency Gains, and Cost Advantages

Export efficiency gains (or losses) can be measured by $eg\,(z) = \mathrm{mc}_N\,(z)\,/\mathrm{mc}_X\,(z)$, where $\mathrm{mc}_N\,(z)$ and $\mathrm{mc}_X\,(z)$ are marginal costs, depending on whether a firm with z does not export or exports, respectively. This ratio is independent of firm-specific productivity z: $eg\,(z) = eg$. $eg > 1$ or $eg < 1$ imply the efficiency gains or losses, respectively. The slop of marginal cost curve is associated with export gains and losses.

$$eg \gtreqless 1 \quad \text{if and only if} \quad \alpha \gtreqless 1,$$

because $eg = (ED_N/ED_X)^{(1-\alpha)\zeta/(\theta-1)}$ and $ED_N < ED_X$. With economies of scale derived from the decreasing marginal cost, exporting lowers the firm's marginal cost. Thus, exporters enjoy efficiency gains. In other words, the decreasing marginal cost curve generates a cost-side export motivation, a firm exports to reduce its costs.

To investigate the impact of market size, I consider home export efficiency gains (or losses) relative to the foreign economy.

$$\frac{eg}{eg^*} = \left\{ \frac{1 + (\tau Q)^{1-\theta} \left[D/ (QD^*) \right]}{1 + (\tau/Q)^{1-\theta} \left[(QD^*) / D \right]} \right\}^{\frac{(1-\alpha)\zeta}{\theta - 1}}, \tag{25}$$

where the term in brackets increases in the home market size relative to the foreign market size: $D/ (QD^*)$. Therefore,

$$\frac{\partial eg/eg^*}{\partial D/ (QD^*)} \lesseqgtr 0 \quad \text{if and only if} \quad \alpha \gtreqless 1.$$

If a marginal cost curve decreases in output, home export efficiency gains relative to the foreign ones decreases in the home market size relative to the foreign economy. During a home boom, a large market size makes exporting less attractive for a home firm if its marginal cost curve decreases in its production level. This mechanism causes inter-industry resource shifts to industries with small economies of scale from industries with large economies of scale in a more productive country. The opposite holds for an increasing marginal cost curve.

In contrast to the above export efficiency gains channel, a large market size makes the more productive economy concentrated in industries with large economies of scale because decreases in home production costs – by definition of economies of scale – imply cost advantages.

$$\frac{\partial \mathrm{mc}_N/\mathrm{mc}_N^*}{\partial D/ (QD^*)} \lesseqgtr 0 \quad \text{if and only if} \quad \alpha \gtreqless 1$$

$$\frac{\partial \mathrm{mc}_X/\mathrm{mc}_X^*}{\partial D/ (QD^*)} \lesseqgtr 0 \quad \text{if and only if} \quad \alpha \gtreqless 1$$

If $\alpha > 1$, home marginal costs relative to the foreign marginal costs for both exporters and non-exporters decreases in the home market size relative to the foreign ones. The opposite holds for $\alpha < 1$.

4 Dynamic Stochastic General Equilibrium Model

Based on Section 3, this section outlines the construction of a two-country two-industry dynamic stochastic general equilibrium model to investigate the effects of economies of scale derived from marginal costs on industry-level international trade and business cycles. The key feature is that the model allows for two industries, indexed by A and B, with different slopes of marginal cost curves that generate economies of scale and within-firm market interdependence.

There are two symmetric countries, home and foreign. As in Section 3, I denote foreign variables with an asterisk. In each country, there is a continuum of identical households in a unit interval $[0, 1]$. In each country and industry, there is a continuum of firms that is endogenously determined.

4.1 Preference and Demand: Representative Household and Capital Producer

In each country, there is a continuum of identical households in a unit interval $[0,\ 1]$. The preference of representative home household is represented by the time separable utility as follows. At time t_0,

$$\mathbb{E}_{t_0}\left[\sum_{t=t_0}^{\infty}\beta^{t-t_0}U\left(C_t, L_t\right)\right],$$

where $C_t \geq 0$ and $L_t \in [0,1]$ are the home overall consumption basket and the total labor supply, respectively. $\beta \in (0,1)$ is the subjective discount factor.

I assume the Cobb-Douglas preference for the industry consumption basket. Thus, the overall consumption basket is specified as

$$C_t = \left(C_t^A\right)^{\phi^A}\left(C_t^B\right)^{\phi^B}, \quad \text{where} \quad C_t^s = \left\{\int_{\omega\in\Omega^s}\left[c_t^s\left(\omega\right)\right]^{\frac{\theta-1}{\theta}}d\omega\right\}^{\frac{\theta}{\theta-1}} \quad \text{for} \quad s = A,\ B.$$

The share parameter $\phi^s \in (0,1)$ satisfies $\phi^A + \phi^B = 1$. Both industries are differentiated. The industry s' consumption basket is defined over a continuum of goods Ω^s. $\theta > 1$ is the constant elasticity of substitution across goods. To focus on impacts of economies of scale, I assume that elasticities are identical across industries. In each period t, only $\Omega_t^s \subseteq \Omega^s$ is available. The price of individual good $\omega \in \Omega_t^s$ is denoted by $p_t^s\left(\omega\right) \geq 0$. The corresponding overall and industry welfare-based price indices are denoted by P_t and P_t^s, respectively:

$$P_t = \left(\frac{P_t^A}{\phi^A}\right)^{\phi^A}\left(\frac{P_t^B}{\phi^B}\right)^{\phi^B}, \quad \text{where} \quad P_t^s = \left\{\int_{\omega\in\Omega_t^s}\left[p_t^s\left(\omega\right)\right]^{1-\theta}d\omega\right\}^{\frac{1}{1-\theta}} \quad \text{for} \quad s = A,\ B.$$

The welfare-based real exchange rate is defined by $Q_t = \varepsilon_t P_t^*/P_t$ where ε_t is the nominal exchange rate. The real industry price index relative to the price index is defined by $\rho_t^s\left(\omega\right) = p_t^s\left(\omega\right)/P_t$. Hence, the home demand function of each good ω in industry s is given by

$$c_t^s\left(\omega\right) = \left[\frac{p_t^s\left(\omega\right)}{P_t}\right]^{-\theta}\left(\frac{P_t^s}{P_t}\right)^{\theta-1}\phi^s C_t. \tag{26}$$

Table 6: Firm's Optimal Decisions in Each Industry

Export Decision	
$m_t^s(z) = 0$	if $z < z_{X,t}^s$
$m_t^s(z) = 1$	if $z \geq z_{X,t}^s$
Effective world demand	
$ED_t^s(z) = ED_{N,t}^s = (\rho_t^s)^{\theta-1} \phi^s C_t$	if $z < z_{X,t}^s$
$ED_t^s(z) = ED_{X,t}^s = (\rho_t^s)^{\theta-1} \phi^s C_t + (\rho_t^{s*})^{\theta-1} \left(\frac{\tau_t^s}{Q_t^s}\right)^{1-\theta} Q_t^s \phi^s C_t^*$	if $z \geq z_{X,t}^s$
Prices	
$\rho_{D,t}^s(z) = \left[\mu \frac{w_t}{\alpha^s (Z_t^s)^{\frac{1}{\alpha^s}}}\right]^{\frac{\alpha^s \zeta^s}{\theta-1}} \left[ED_t^s(z)\right]^{\frac{-(\alpha^s-1)\zeta^s}{\theta-1}} z^{\frac{-\zeta^s}{\theta-1}}$	for all z
$\rho_{X,t}^s(z) = \left(\frac{\tau_t^s}{Q_t^s}\right) \rho_{D,t}^s(z)$	if $z \geq z_{X,t}^s$
Sales	
$\rho_{D,t}^s(z)\, y_D(z) = \left[\frac{\rho_{D,t}^s(z)}{\rho_t^s}\right]^{1-\theta} \phi^s C_t$	for all z
$Q_t \rho_{X,t}^s(z)\, y_X(z) = 0$	if $z < z_{X,t}^s$
$Q_t \rho_{X,t}^s(z)\, y_X(z) = \left[\frac{\rho_{X,t}^s(z)}{\rho_t^{s*}}\right]^{1-\theta} Q_t \phi^s C_t^*$	if $z \geq z_{X,t}^s$
Profit in Each Market	
$\pi_{D,t}^s(z) = \left(\frac{1}{\zeta^s \mu}\right) \rho_{D,t}^s(z)\, y_D(z)$	for all z
$\pi_{X,t}^s(z) = 0$	if $z < z_{X,t}^s$
$\pi_{X,t}^s(z) = \left(\frac{1}{\zeta^s \mu}\right) Q_t \rho_{X,t}^s(z)\, y_X(z) - f_{X,t}^s \frac{w_t}{(Z_t^s)^{\frac{1}{\alpha}}}$	if $z \geq z_{X,t}^s$
Export Cutoff	
$z_{X,t}^s = \left\{ \frac{\mu \zeta^s f_{X,t}^s w_t (Z_t^s)^{-\frac{1}{\alpha}}}{\left(ED_{X,t}^s\right)^{1+(\alpha^s-1)\zeta^s} - \left(ED_N^s\right)^{1+(\alpha^s-1)\zeta^s}} \right\}^{\frac{1}{\zeta^s}} \left[\mu \frac{w_t}{\alpha^s (Z_t^s)^{\frac{1}{\alpha^s}}}\right]^{\alpha^s}$	

4.2 Heterogeneous Firms and Their Averages

In each period, a firm with firm-specific productivity z chooses its prices and quantities of supply to maximize its profit: for each $s = A$ and B,

$$\max_{\left\{\rho_{m,t}^s \geq 0,\ y_{m,t}^s \geq 0\right\}_{m=D,\ X}} \rho_{D,t}^s y_{D,t}^s + Q_t \rho_{X,t}^s y_{X,t}^s - \mathrm{tc}^s\left(y_t^s; w_t, Z_t^s, z\right)$$

$$\text{subject to} \quad q_t^s = y_{D,t}^s + \tau_t y_{X,t}^s,$$

$$y_{D,t}^s = \left(\rho_{D,t}^s\right)^{-\theta} \left(\rho_t^s\right)^{\theta-1} \phi^s C_t, \text{ and } y_{X,t}^s = \left(\rho_{X,t}^s\right)^{-\theta} \left(\rho_t^{s*}\right)^{\theta-1} \phi^s C_t^*,$$

where $\rho_{D,t}^s = p_{D,t}^s / P_t$ and $\rho_{X,t}^s = p_{X,t}^s / P_t^*$ are real prices relative to the aggregate price index in the destination market. Table 6 summarizes the firm's solution to the maximization problem for given its firm-specific productivity z.

In each period t, a mass N_t^s of firms produce in the home country for each industry s. To focus on heterogenous marginal cost structures, I assume that industries A and B have identical distribution functions for firm-specific productivity, denoted by $G(\cdot)$ with support on $[z_{min}, \infty)$. Among firms there are $N^s_{X,t} = \left[1 - G\left(z^s_{X,t}\right)\right] N^s_t$ exporters. The rest of the firms $N^s_{N,t} = G\left(z^s_{X,t}\right) N^s_t$ sell only domestically. To summarize all the information on the productivity distributions relevant for all aggregate variables as in Melitz (2003), define average productivity levels for different groups as follows. For each $s = A$ and B,

$$\text{All domestic firms:} \qquad \tilde{z}^s_D = \left[\int_{z_{min}}^{z_{max}} z^{\zeta^s} dG(z)\right]^{\frac{1}{\zeta^s}},$$

$$\text{Non-exporters:} \qquad \tilde{z}^s_{N,t} = \left[\int_{z_{min}}^{z^s_{X,t}} z^{\zeta^s} \frac{dG(z)}{G\left(z^s_{X,t}\right)}\right]^{\frac{1}{\zeta^s}},$$

$$\text{Exporters:} \qquad \tilde{z}^s_{X,t} = \left[\int_{z^s_{X,t}}^{z_{max}} z^{\zeta^s} \frac{dG(z)}{1 - G\left(z^s_{X,t}\right)}\right]^{\frac{1}{\zeta^s}}.$$

Then, these satisfy

$$\left(\tilde{z}^s_D\right)^{\zeta^s} = \left(\frac{N^s_{N,t}}{N^s_t}\right)\left(\tilde{z}^s_{N,t}\right)^{\zeta^s} + \left(\frac{N^s_{X,t}}{N^s_t}\right)\left(\tilde{z}^s_{X,t}\right)^{\zeta^s} \quad \text{for} \quad s = A,\ B. \tag{27}$$

I assume that the distribution of z has finite ζ^s-th moments for every industry: $\left(\tilde{z}^s_D\right)^{\zeta^s} = \left(\tilde{z}^{s*}_D\right)^{\zeta^s} < \infty$.

The productivity averages are constructed in such way that $\pi^s_{D,t}\left(\tilde{z}^s_{N,t}\right)$ and $\pi^s_{D,t}\left(\tilde{z}^s_{X,t}\right)$ are the average domestic market profit of non-exporters and exporters, respectively. The average export market profit of exporters is $\pi^s_{X,t}\left(\tilde{z}^s_{X,t}\right)$. The export market profit of non-exporters is zero: $\pi^s_{X,t}\left(\tilde{z}^s_{N,t}\right) = 0$ because $\tilde{z}^s_{N,t} < z^s_{X,t}$. The average profit of all home firms is given by

$$\tilde{\pi}^s_t = G\left(z^s_{X,t}\right)\pi^s_t\left(\tilde{z}^s_{N,t}\right) + \left[1 - G\left(z^s_{X,t}\right)\right]\pi^s_t\left(\tilde{z}^s_{X,t}\right). \tag{28}$$

For each industry, the average relative price of firms in their domestic market is

$$\tilde{\rho}^s_{D,t} = \left\{G\left(z^s_{X,t}\right)\left[\rho^s_{D,t}\left(\tilde{z}^s_{N,t}\right)\right]^{1-\theta} + \left[1 - G\left(z^s_{X,t}\right)\right]\left[\rho^s_{D,t}\left(\tilde{z}^s_{X,t}\right)\right]^{1-\theta}\right\}^{1/(1-\theta)}, \tag{29}$$

which does not equal $\rho^s_{D,t}\left(\tilde{z}^s_D\right)$ if $\alpha^s \neq 1$. The average relative price of firms in their export market is

$$\tilde{\rho}^s_{X,t} = \rho^s_{X,t}\left(\tilde{z}^s_{X,t}\right), \tag{30}$$

in the destination currency. By the definition of welfare based industry price index, the relative prices satisfy that

$$\rho^s_t = N^s_t\left(\tilde{\rho}^s_{D,t}\right)^{1-\theta} + N^{s*}_{X,t}\left(\tilde{\rho}^{s*}_{X,t}\right)^{1-\theta} \quad \text{for} \quad s = A,\ B. \tag{31}$$

4.3 Firm Entry and Exit

As in Ghironi and Melitz (2005), I assume a one period time-to-build lag for entrants. Entrants at t start to produce at $t+1$. Additionally, every firm faces exogenous death shocks with a constant probability $\delta \in (0,1)$ at the end of each period. Thus, the law of motion for the number of firms in the home industry s is given by $N_t^s = (1-\delta)\left(N_{t-1}^s + N_{E,t-1}^s\right)$ where $N_{E,t-1}^s$ is the mass of entrants at $t-1$.

Forward looking behaviors and rational expectations imply that domestic firm entry is decided based on the present value of the expected future stream of profits. The value of entry $\tilde{\nu}_t^s$ is

$$\tilde{\nu}_t^s = \mathbb{E}_t\left[\sum_{i=t+1}^{\infty}\left[\beta(1-\delta)\right]^{i-t}\left(\frac{\partial U_i}{\partial C_i}/\frac{\partial U_t}{\partial C_t}\right)\tilde{\pi}_i^s\right] \quad \text{for} \quad s = A,\ B. \tag{32}$$

Then, the free entry condition is represented by

$$\tilde{\nu}_t^s = f_{E,t}^s \frac{w_t}{(Z_t^s)^{\frac{1}{\alpha}}} \quad \text{for} \quad s = A,\ B, \tag{33}$$

Entry occurs until the average value of the firm on the left hand side of Equation (33) equals the entry cost on the right hand side of Equation (33). The entry cost follows:

$$f_{E,t}^s = f_E + \eta_E\left[\exp\left(N_{E,t}^s - N_{E,t-1}^s\right) - 1\right] \quad \text{for} \quad s = A,\ B, \tag{34}$$

where $\eta_E \geq 0$ is the entry adjustment costs parameter. The paramter decreases the volatility of the number of entrants and firms. Thus, positive η_E implies large resource reallocation costs across industries in the short run. Under $\eta_E = 0$, the model generates unrealistically drastic resource shifts across industries and is too volatile regarding firm entry.

4.4 Household Budget Constraint and Choices

The representative household holds two types of asset: shares in mutual funds of domestic firms and risk-free bonds with real returns. Each country has mutual funds that own all domestic firms and finance entry of new firms. As in Ghironi and Melitz (2005), the household only buys shares of domestic mutual funds. x_t^s is the share of N_t^s home firms entering period t in industry s. The mutual fund pays a total profit in each period that equals the total profit of all home firms: $N_t^s\tilde{\pi}_t^s$ in terms of the home currency. The household buys x_{t+1}^s shares in the mutual fund of $N_t^s + N_{E,t}^s$ home firms in s industry. The exogenous death shock δ at the end of period implies $N_{t+1}^s = (1-\delta)\left(N_t^s + N_{E,t}^s\right)$ home firms in industry s will produce and pay dividends in the future period $t+1$.

Each household in two countries can trade risk-free bonds domestically and internationally.[17] Home

[17] The assumption is not crucial. The financial autarky, meaning bonds are only traded domestically, shows slower adjustment in impulse responses to asymmetric shocks, but there is no qualitative difference between the two bond trading structures.

(foreign) bonds are issued by the home (foreign) household with the home (foreign) consumption real interest rate. In period t, the home household's home and foreign bond holdings are B_t and $B_{*,t}$, respectively. At the end of the period, their home and foreign bond holdings are B_{t+1} and $B_{*,t+1}$, respectively. There are adjustment costs for bond holdings, which prevents the indeterminacy problem. The home household pays quadratic adjustment costs for home and foreign bond holdings of $0.5\eta_B B_{t+1}^2$ and $0.5\eta_B Q_t B_{*,t+1}^2$, respectively.

For each industry, a labor supply in industry s is equal to the labor demand as follows.

$$L_t^s = \frac{\alpha^s \zeta^s}{w_t} N_t^s \tilde{\pi}_t^s + (1 + \alpha^s \zeta^s) N_{X,t}^s f_{X,t}^s \frac{1}{(Z_t^s)^{\frac{1}{\alpha}}} \quad \text{for} \quad A,\ B \tag{35}$$

The value of industry output is then $Y_t^s = w_t L_t^s + N_t^s \tilde{\pi}_t^s$ for $s = A$ and B, and aggregate GDP, denoted by Y_t, is

$$Y_t = \sum_{s=A,\ B} Y_t^s + N_{E,t}^s f_{E,t}^s \frac{w_t}{(Z_t^s)^{\frac{1}{\alpha}}}. \tag{36}$$

Thus, the period budget constraint (in units of home consumption) is written as

$$\begin{aligned} & B_{t+1} + Q_t B_{*,t+1} + C_t + \sum_{s=A,B} \tilde{\nu}_t^s \left(N_t^s + N_{E,t}^s\right) x_{t+1}^s \\ & = (1 + r_t) B_t + Q_t (1 + r_t^*) B_{*,t} + Y_t + \sum_{s=A,B} \tilde{\nu}_t^s N_t^s x_t^s - \frac{\eta_B}{2} \left(B_{t+1}^2 + Q_t B_{*,t+1}^2\right) + T_t^f, \end{aligned} \tag{37}$$

where $\tilde{\nu}_t^s$ is the (home currency) price of claims to future profits of home firms in industry s. r_{t+1} and r_{t+1}^* are the real interest rates of domestic and foreign bond from t to $t+1$ in terms of domestic and foreign currency, respectively. The adjustment costs transfer to the household: $T_t^f = 0.5\eta_B \left(B_{t+1}^2 + Q_t B_{*,t+1}^2\right)$.

The home household maximizes its expected intertemporal utility subject to Equation (37). The intertemporal decision rules for home and foreign bonds and share holdings are

$$1 + \eta_B B_{t+1} = \beta (1 + r_{t+1}) \mathbb{E}_t \left[\frac{\partial U_{t+1}}{\partial C_{t+1}} / \frac{\partial U_t}{\partial C_t} \right] \tag{38}$$

$$1 + \eta_B B_{*,t+1} = \beta \left(1 + r_{t+1}^*\right) \mathbb{E}_t \left[\left(\frac{\partial U_{t+1}}{\partial C_{t+1}} / \frac{\partial U_t}{\partial C_t} \right) \left(\frac{Q_{t+1}}{Q_t} \right) \right] \tag{39}$$

$$\tilde{\nu}_t^s = \beta (1 - \delta) \mathbb{E}_t \left[\left(\frac{\partial U_{t+1}}{\partial C_{t+1}} / \frac{\partial U_t}{\partial C_t} \right) \left(\tilde{\nu}_{t+1}^s + \tilde{\pi}_{t+1}^s \right) \right]. \tag{40}$$

There is no arbitrage in holding shares of mutual funds, domestic, and foreign bonds. The intratemporal labor supply decision rule is given by

$$-\frac{\partial U_t}{\partial L_t} / \frac{\partial U_t}{\partial C_t} = w_t. \tag{41}$$

4.5 Aggregation and Shock Process

The financial market clearing requires $B_{t+1} + B^*_{t+1} = 0$, $B_{*,t+1} + B^*_{*,t+1} = 0$, and $x^s_{t+1} = x^{s*}_{t+1} = 1$ for every period t. In the equilibrium. the aggregate accounting equation can be written as

$$B_{t+1} + Q_t B_{*,t+1} + C_t + \sum_{s=A,B} N^s_{E,t}\tilde{\nu}^s_t = (1 + r_t) B_t + Q_t (1 + r^*_t) B_{*,t} + Y_t. \tag{42}$$

Internationally traded bonds allow the model to accommodate trade imbalance. The labor market clearing condition is

$$L_t = \sum_{s=A,\, B} L^s_t + N^s_{E,t} f^s_{E,t} \frac{1}{(Z^s_t)^{\frac{1}{\alpha}}}. \tag{43}$$

There is no industry specific shocks: $Z_t = Z^A_t = Z^B_t$. Thus, all differences in business cycle fluctuations between industries A and B are driven endogenously. The exogenous home and foreign aggregate productivities follow a bivariate process:

$$\begin{bmatrix} \ln Z_{t+1} \\ \ln Z^*_{t+1} \end{bmatrix} = \begin{bmatrix} \rho_{ZZ} & \rho_{ZZ^*} \\ \rho_{ZZ^*} & \rho_{Z^*Z^*} \end{bmatrix} \begin{bmatrix} \ln Z_t \\ \ln Z^*_t \end{bmatrix} + \begin{bmatrix} e_{Z,t} \\ e^*_{Z,t} \end{bmatrix}, \tag{44}$$

where $e_{Z,t}$ and $e^*_{Z,t}$ are the shock innovations which are multi-normally distributed with zero mean and covariance matrix $\mathbf{\Sigma}$.

5 Quantitative Analysis

This section presents the international business cycle properties of the model. For simulation, I define data-consistent variables using CPI-based prices as in Ghironi and Melitz (2005). The data-consistent version of variables x_t and x^s_t are denoted $x_{R,t}$ and $x^s_{R,t}$, respectively. They are defined as follows:

$$x^s_{R,t} = \left(N^s_t + N^{s*}_{X,t}\right)^{\frac{1}{1-\theta}} x^s_t \quad \text{and} \quad \ln x_{R,t} = \phi^A \ln x^A_{R,t} + \phi^B \ln x^B_{R,t}.$$

5.1 Calibration

I use following preference (henceforth, GHH preference) introduced by Greenwood et al. (1988), which give a constant Frisch elasticity of labor supply:

$$U_t (C_t, L_t) = \frac{\left(C_i - \chi \frac{L_t^{1+\psi}}{1+\psi}\right)^{1-\sigma} - 1}{1-\sigma},$$

where $\sigma > 1$ governs relative risk aversion.

For calibration, I follow Ghironi and Melitz (2005). Each period represents a quarter calendar year. Set values of $\beta = 0.99$ and $\sigma = 2$, which are standard choice for business cycle models. The bond adjustment cost is $\eta_B = 0.0025$, which is sufficient to induce stationary. Empirical studies report that the aggregate macro Frisch elasticity, $1/\psi$, is between 1 and 2. I choose the middle: $\psi = 1/1.5$. χ is chosen to match the steady state labor supply, which is equal to 1/3 for the model with heterogenous α^s: $\chi \approx 1.30$.

There are two industries: A and B. The group criteria are based on U.S. data. Industries A and B correspond to industries SEOS and LEOS from Section 2, respectively. Based on my empirical results in Table 1, I allow different slopes of marginal cost curves but assume identical fixed entry and export costs. Thus, I choose $\left(\alpha^A,\ \alpha^B\right) = (0.85,\ 1.15)$ for my benchmark model. I set $\left(\phi^A,\ \phi^B\right)$ such that the economy exhibits a flat marginal cost curve at the aggregate level.[18] To investigate the effects of heterogenous sloping marginal cost curves, I also consider a comparison with the model with homogenous flat marginal costs: $\alpha^A = \alpha^B = 1$ and $\phi^A = \phi^B = 0.5$. The comparison model represents the conventional new trade open macro model introduced by Ghironi and Melitz (2005). The main differences between my conventional model and Ghironi and Melitz (2005)'s model are endogenous labor supply with GHH preference and firm entry frictions that enhance the model performance reproducing the international business cycle properties.

To focus on cost structure heterogeneity across industries, I assume that remaining parameters are identical across industries. I set $\delta = 0.025$ and $\theta = 3.8$ to match the U.S. plant and macro trade data. I set η_E to match the standard deviation of entrants (private sector new establishments) in the U.S. data. To investigate the role of entry friction, I set a range of η_E from 2 to 3. The fixed entry cost is normalized by 1 in the steady state: $f_E = 1$. A wide range of studies use an iceberg trade cost between 20% and 50%. As the benchmark, I set these costs at 30% as in Ghironi and Melitz (2005): $\tau_t = 1.3$. The fixed export cost is $f_{X,t} = 0.33 f_E \left[1 - \beta(1-\delta)\right] / \left[\beta(1-\delta)\right]$. That value of fixed export costs implies that the fraction of exporter is about 21% for the given $\tau_t = 1.3$.

The firm-specific productivity in each industry follows a Pareto distribution with shape parameter k and support on $[1, \infty)$. Industries A and B have identical distribution functions given by $G(z) = 1 - z^{-k}$ on the support. For the existence of ζ^s-th moments, k should be larger than ζ^s. In other words, $\alpha^s < \mu - 1/k$. In the previous section, I assumed that $1/\zeta^s = \mu - \alpha^s > 0$ for an inner solution to the firm's problem with positive profits. In sum, the restriction is given by

$$0 < \alpha^s < \min\left\{\mu, \mu - \frac{1}{k}\right\} = \mu - \frac{1}{k}.$$

[18] For the aggregate flat marginal cost curve, ϕ^A and ϕ^A satisfy that

$$Y_t^A + N_{E,t}^A f_{E,t}^A \frac{w_t}{\left(Z^A\right)^{\frac{1}{\alpha^A}}} = Y_t^B + N_{E,t}^B f_{E,t}^B \frac{w_t}{\left(Z^B\right)^{\frac{1}{\alpha^B}}} \quad \text{at the steady state.} \tag{45}$$

For $\alpha_A < \alpha_B$, Industry A's consumption expenditure share is lower than Industry B's: $\phi^A \approx 0.47 < 0.5$. This is because Industry A has a larger number of new entrants than Industry B in the steady state.

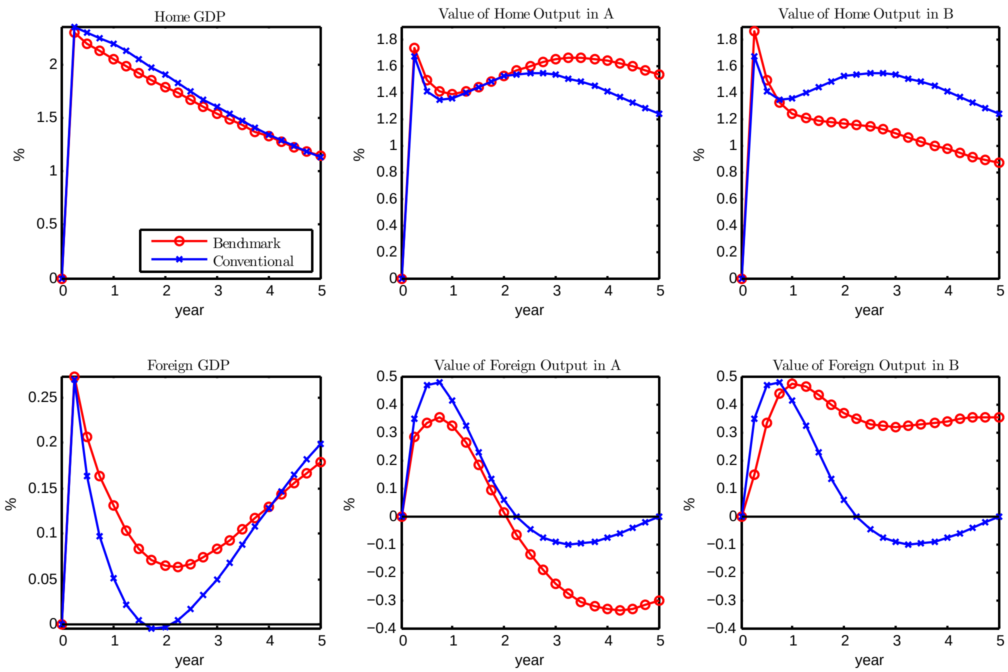

Figure 3: Impulse Responses to 1 % Transitory Productivity Shock in the Home Country

I set shape parameter of the Pareto distribution to be $k = 5.5$, which implies that the heavy tail index of firm sales is 1.14.[19] Axtell (2001) documents that the index is close to 1 in the U.S. Census data: the range from 1.06 to 1.10. In Bernard et al. (2003) and Ghironi and Melitz (2005), the index is around 1.25.

5.2 Impulse Responses

This section shows the dynamic path of model variables based on numerical simulations in response to transitory shocks to productivity. To illustrate the model implications for sloping marginal costs and industry heterogeneity, I consider a transitory shock without spillover: $\rho_{ZZ} = \rho_{Z^*Z^*} = 0.9$ and $\rho_{ZZ^*} = 0$ in Equation (44). The home and foreign shock innovations are uncorrelated. The one-time transitory shock is favorable to home: 1% increase in $e_{Z,t}$.

Figure 3 considers two cases where models with heterogeneous and homogenous marginal cost struc-

[19] I assumed that $k/\zeta^s > 1$ for both Industries A and B. Then, the aggregated level density function of firm-specific productivity can be represented by

$$1 - \text{CDF}(z) = z^{-\min\left\{\frac{k}{\zeta^A}, \frac{k}{\zeta^B}\right\}} L(z) \quad \text{for } z \geq 1, \tag{46}$$

where $L(\cdot)$ is a slowly varying function: $\lim_{x\to\infty} L(cx)/L(x) = 1$ for any constant $c > 0$. Thus, the heavy tail index is k/ζ^B because ζ^s is increasing in α^s.

tures are denoted by Benchmark (the red line with circle markers) and Conventional (the blue line with cross marker), respectively. The benchmark model follows my benchmark calibration: $\alpha^A = 0.85$ and $\alpha^A = 1.15$. Industries A and B exhibit negative and positive within-firm market interdependence, respectively. The conventional model has an identical flat marginal cost curve: $\alpha^A = \alpha^B = 1$ and represents the conventional new trade open macro model introduced by Ghironi and Melitz (2005). In both models, the entry friction is $\eta_E = 2.5$.

Since all variables are stationary, there is no long run effect. However, the impulses responses converge to the original steady states slowly because of endogenous firm entry with time to build and costs. The first column in Figure 3 shows that heterogeneous marginal costs generate more correlated business cycles. After a favorable shock to the home economy, increases in home and foreign GDP are smaller and larger in the Benchmark model than in the Conventional model, respectively. Further, the second and third columns indicate that industry outputs are more correlated across countries in Industry B than in Industry A.

In Figure 3, the second and third columns describe industry-level dynamics when a positive home productivity shock is realized. There are two main mechanisms generating the different responses between Industries A and B. First, economies of scale generate cost advantages for the home economy in Industry B for both exporters and non-exporters. Since the number of firms is slowly changing, in the short run individual home firms expands after the shock occurs. Thus, Industry B with its decreasing marginal cost curve endogenously becomes more productive relative to Industry A, and Industry B expends more than Industry A. However, that scale channel disappears over time due to the large entry of home firms. An increase in the number of home firms implies that individual firm size decreases due to high competition, which means that home firms lose their cost advantages. Thus, the channel is negatively related to the speed of firm entry dynamics. The second channel works in the opposite direction. There are export losses and gains in Industries A and B, respectively. During a home boom, export gains are more important in the foreign economy than in the home economy due to low domestic demand in the foreign economy. Thus, there are industry reallocations from Industry A to Industry B in the foreign economy: more firms and exporters in Industry B. That channel is positively associated with the speed of firm entry dynamics.

The firm entry frictions play a crucial role in determining the size of these two channels. The first is more intensive and second more extensive. As the previous paragraph discussed, the first and second channel have a negative and positive association with firm entries, respectively. Slow changes in the number of firms strengthen the first channel but weaken the second channel. Under empirically plausible parameters, the first channel is larger than the second channel in the short run, but as time passes, the second channel overwhelms the first one. In Figure 3, home Industry B expanses more than home Industry A at first. After one year, however, Industry A has a larger output than Industry B in the home economy.

The first column in Figure 3 indicates that allowing heterogeneous marginal costs generates more correlated aggregate GDP comovements across countries. The second and third columns show that the Benchmark model has larger cross-country differences in Industries A than the Conventional model, while the opposite is true for Industry B. Thus, Industry B contributes to mitigating the quantity anomaly. Conversely, Industry A worsens the quantity anomaly because within-firm market interdependence in Industries A and B are negative and positive, respectively. Positive within-firm market interdependence in Industry B is quantitatively larger than Industry A's negative interdependence because export gains and losses derived from marginal costs cause Industry B to trade more intensively than Industry A. Thus, industries with large economies of scale have larger impacts on international business cycles than industries with smaller economies of scale.

5.3 International Business Cycles

This section presents the international business cycle properties. To calculate model-generated moments, I use HP filtered variables with a smoothing parameter of 1600. Based on Ambler et al. (2004)'s empirical work, I consider two cases. Case I represents the U.S. and nine other countries – Australia, Austria, Canada, France, Germany, Italy, Japan, Switzerland, and the United Kingdom which I call the BKK sample. (Backus et al. (1992, 1995) use the sample.) Case II represents twenty industrialized countries. International business cycles are more correlated in Case I than in Case II regarding GDP, consumption, labor, and productivity. Appendix C documents the details of the data set. In the models, there are only two industries. Thus, to match the coefficients in regressions in Table 3 and 4, I calculate slopes as follows. For variable x, its slope is defined by $\left(x^A - x^B\right) / \left(\ln \alpha^A - \ln \alpha^B\right)$ that quantifies the impacts of the sloping marginal cost curve on the variable x. In Cases I and II, the models with $\eta_E = 2$ and $\eta_E = 3$ replicate the volatility of number of entrants in the U.S. data, respectively. Thus, I consider $\eta_E = \{2,\ 2.5,\ 3\}$.

The recent empirical papers have documented a very persistent shock (near unit root) with zero transmission.[20] Thus, I use following very persistent process without spill-over:

$$\begin{bmatrix} \rho_{ZZ} & \rho_{ZZ^*} \\ \rho_{ZZ^*} & \rho_{Z^*Z^*} \end{bmatrix} = \begin{bmatrix} 0.99 & 0 \\ 0 & 0.99 \end{bmatrix} \quad \text{and} \quad \mathbf{\Sigma} = 0.005^2 \begin{bmatrix} 1 & \sigma_{ZZ^*} \\ \sigma_{ZZ^*} & 1 \end{bmatrix}.$$

I choose the standard deviation of the shock innovation as 0.005 to match GDP volatility in the U.S. data. Since there is no productivity spill-over, cross-country comovements are mainly derived by endogenous mechanisms. The main advantage of shocks without spill-over is a low cross-country correlation of consumptions. With spill-over, foreign households expect increases in foreign productivity after home positive productivity shocks. Thus, the shock process with $\rho_{ZZ^*} = 0$ generates lower consumption correlation between home and foreign countries than a shock with positive transmissions: $\rho_{ZZ^*} > 0$. I set $\sigma_{ZZ^*} = \{0.2, 0.1\}$ for Cases I and II, respectively. Ambler et al. (2004) document the unweighted

[20] See Baxter (1995) and Baxter and Farr (2005) for the details.

average of the BKK sample countries' correlation of the "Solow residual" measure of productivity (using only labor) with the U.S. as 0.25. Baxter and Farr (2005) document that the median of sample countries' correlations is 0.18 where they use both labor and capital.[21] I choose 0.2 in Case I. The unweighted average of pairwise cross-country correlations of productivity among twenty industrialized countries is 0.16 (using only labor) and 0.09 (using both labor and capital when available). I set 0.1 in Case II.

5.3.1 Within-Country Business Cycles

The results of my simulations are summarized in Table 7. Panel A and B report my model's aggregate- and industry- level international business cycle properties, respectively. In each case, I report the low, medium, and high entry frictions for both Conventional models with identical flat marginal cost curves and Benchmark models with heterogeneous slopping marginal cost curves. The results of Cases I and II are indistinguishable except for cyclicality of exports, which implies that cross-country shock correlations have limited effects on aggregate variables' dynamics and second moments.

The first and second parts of Panel A in Table 7 describe the volatilities of the aggregate macro and trade flows, where allowing industry cost heterogeneity plays a minor role. The model overpredicts the standard deviation (relative to aggregate GDP) of consumption and labor and underpredicts that of exports and imports. Although the model successfully generates less volatile consumption than GDP, the standard deviation (relative to aggregate GDP) of consumption is larger than in the data. That is because a near-unit root shock without spillover and GHH preference lowers consumption smoothing. Thus, consumption becomes very persistent and volatile.[22] In the model, exports and imports have very similar standard deviations, and they are smaller than in the U.S. data. As in Ghironi and Melitz (2005), an individual firm's export decision depends on fixed export costs. For tractability, I omit sunk export cost. While Alessandria and Choi (2007) find that the export cost structure in models plays a limited role in business cycle patterns of net exports, introducing sunk export costs would generate more persistent export and import flows. Thus, adding sunk export costs would be helpful to correct the low volatilities of trade flows. More importantly, the model fails to reproduce the larger volatility of imports than that of exports. In the model, extensive margins are more important in exports than in imports, but intensive margins are more important in imports than in exports. Since the number of firms changes slowly, the export process is more persistent than the import process. Thus, exports have a relatively large standard deviation in the model.

The last part of Panel A reports cyclical properties within a country. All models successfully reproduce the observed patterns that imports are more procyclical than exports in which cost heterogeneity and entry frictions play a vital role. First, allowing industry cost heterogeneity enhances the model's

[21] Their sample countries are 10 OECD countries.

[22] See Ghironi and Melitz (2005) for differences between a near-unit root shock without spillover and a persistent shock with spillover introduced by Backus et al. (1992). See Raffo (2008) for details of GHH preference in international business cycle models.

Table 7: International Business Cycle (within-country): Data and Simulated Moments

		Case I: $\sigma_{ZZ^*} = 0.25$						Case II: $\sigma_{ZZ^*} = 0.1$					
	US Data	Conventional			Benchmark			Conventional			Benchmark		
η_E		2	2.5	3	2	2.5	3	2	2.5	3	2	2.5	3
Panel A: Aggregate-level International Business Cycle													
Volatility: standard deviation %													
GDP	1.58	1.55	1.54	1.54	1.54	1.53	1.53	1.55	1.54	1.53	1.53	1.53	1.52
Volatility: standard deviation relative to GDP													
Consumption	0.66	0.96	0.96	0.96	0.97	0.97	0.97	0.96	0.96	0.96	0.97	0.97	0.97
Labor	0.61	0.76	0.76	0.75	0.72	0.71	0.71	0.76	0.76	0.76	0.72	0.72	0.71
Export	2.66	1.94	1.91	1.88	1.95	1.91	1.88	1.97	1.94	1.91	1.98	1.93	1.89
Import	3.08	1.75	1.73	1.70	1.79	1.76	1.73	1.77	1.75	1.72	1.81	1.77	1.74
# of Entrants	3.37	4.29	4.16	4.05	3.44	3.30	3.18	4.51	4.39	4.27	3.62	3.48	3.35
Cyclicality: correlation to GDP													
Consumption	0.84	0.99	0.99	0.99	1.00	1.00	1.00	0.99	0.99	0.99	1.00	1.00	1.00
Labor	0.82	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Export	0.31	0.16	0.18	0.20	0.25	0.28	0.30	0.07	0.09	0.12	0.17	0.19	0.22
Import	0.74	0.89	0.90	0.90	0.92	0.93	0.93	0.88	0.89	0.89	0.92	0.92	0.92
# of Entrants	0.56	0.73	0.73	0.73	0.76	0.76	0.76	0.74	0.74	0.74	0.77	0.77	0.77
Panel B: Industry-level International Business Cycle													
Volatility: Slope of standard deviation %													
Output	4.59				0.17	0.23	0.27				0.15	0.21	0.27
Volatility: Slope of standard deviation relative to industry output													
Export	-2.04				-7.02	-7.01	-6.96				-7.24	-7.24	-7.20
Import	-2.73				-6.65	-6.63	-6.58				-6.88	-6.87	-6.82
Cyclicality: Slope of correlation to GDP													
Output	0.40				0.27	0.25	0.23				0.31	0.29	0.27
Export	0.29				0.04	0.12	0.17				0.03	0.11	0.18
Import	0.19				0.30	0.23	0.17				0.33	0.25	0.19

Notes: The aggregate US data statistics are quarterly and seasonally adjusted. The number of entrants data are from private sector establishment births in Bureau of Labor Statistics database. The sample period is from 1993:q2 to 2016:q4. The relative standard deviation of number of entrants is relative to standard deviation GDP from 1993:q2 to 2016:q4. The other aggregate-level US quarterly data is from OECD database except for the number of entrants. The sample period is from 1960:q1 to 2000:q4, that is the same as in Ambler et al. (2004). The industry-level data are from Section 2. The slopes are the coefficients of economies of scale derived from marginal costs in regressions (see Column 3 in Tables 3 and 4). For simulated moments, I replicate 1000 for simulated moments. The length of each simulation is 10000, and I drop the first 2000. For the industry-level, the slopes of variable x for models are $\left(x^A - x^B\right) / \left(\ln \alpha^A - \ln \alpha^B\right)$ in simulations. All variables are HP filtered.

ability to reproduce quantitatively better cyclical patterns of export. In both Cases I and II, the models with homogeneous industries tend to generate weakly procyclical exports, which is one of the problems in Conventional models. Heterogeneous sloping marginal cost curves in Benchmark models make exports more procyclical – more consistent with the data – than in models with a homogeneous linear cost function through a within-firm market interdependence channel. Second, models with larger entry frictions reproduce more procylical exports and imports than models with smaller entry frictions. During a boom, great firm entry implies large terms of labor appreciation (high costs in the more productive economy). Thus, firms loose their competitiveness in both domestic and export markets due to high production costs. Firm entry frictions mitigate these extensive margin channels. This mechanism explains why entry frictions increase the procyclicality of trade flows in new trade open macro models regardless of cost structure.

In the data, consumption and labor are strongly procyclical. In Panel A, all models generate more strongly correlated consumption and labor to GDP than the data. Indeed, correlations with GDP are near perfect in the model. As discussed above, a near unit root shock lowers consumption smoothing. Thus, consumption moves in the same direction as income (GDP). For tractability, a representative household supplies labor. This and the GHH preference imply that labor supply depends only on wages. Hence, labor is very strongly correlated to GDP.

Panel B in Table 7 illustrates how properties of heterogeneous international business cycles across industries change when I vary the firm entry friction. My models with plausible entry frictions capture the qualitative patterns in the four digit SIC U.S. manufacturing industries. Section 2 documents that volatility of exports and imports decreases, but that of output increases in economies of scale derived from marginal costs. Further, industry output, exports, and imports are more procyclical in industries with large α than in industries with small α. The results of Case I and II are quantitatively very similar and qualitatively equivalent, which implies that cross-country shock correlations have no major effect on industry-level business cycle properties. Despite success at reproducing the qualitative patterns of the industry-level business cycle, the models are less successful from the quantitative perspectives. The bootstrapping confidence intervals reported in Table 3 and 4 indicate that the models with $\eta_E = 2.5$ and 3 succeed in generating the slopes of cyclicality measures of output, exports, and imports. However, all models fail to generate the slopes of volatility measures within the 95% confidence intervals. These quantitative failures could be caused by the simplicity of the model. The model contains only two industries, and uses only aggregate productivity shock.

During a home boom, cost advantages due to economies of scale increase Industry B's output more than Industry A's output. Thus, industries with large α have more volatile and procyclical output than do industries with small α. In industries with decreasing marginal costs (Industry B), world demands are relatively more important than in industries with increasing marginal costs (Industry A) because domestic and export market demands are complements and substitute in industry B and A, respectively. Thus, international goods trade dampens demand channels of domestic shocks in Industry B, but amplifies in Industry A. Hence, exports and imports are fluctuated less in Industry B than in Industry A. That channel serves to lower the slope of the output volatility measure in the models.

Section 5.2 explains why Industry A has less procyclical production than Industry B. The models reproduce the empirical observation that the slope of the export cyclicality measure increases in entry frictions. As I discussed in Section 5.2, there are two channels: cost advantages and export gains. During

Table 8: International Comovements: Data and Simulated Moments

	Case I: $\sigma_{ZZ^*} = 0.2$							Case II: $\sigma_{ZZ^*} = 0.1$						
	Data I	Conventional			Benchmark			Data II	Conventional			Benchmark		
η_E		2	2.5	3	2	2.5	3		2	2.5	3	2	2.5	3
Cross-Country Correlation														
GDP	0.29	0.24	0.25	0.26	0.31	0.32	0.32	0.22	0.14	0.15	0.17	0.22	0.23	0.23
Consumption	0.22	0.19	0.20	0.20	0.23	0.24	0.25	0.14	0.09	0.10	0.11	0.14	0.15	0.15
1st - 2nd row	0.07	0.05	0.05	0.06	0.08	0.08	0.08	0.08	0.05	0.05	0.06	0.08	0.08	0.08
Labor	0.27	0.11	0.13	0.15	0.19	0.21	0.23	0.25	0.01	0.03	0.05	0.09	0.11	0.13

Notes: Data I and II are from Table 5 and 1 in Ambler et al. (2004), respectively. The sample period is from 1960 to 2000. I replicate 1000 for simulated moments. The length of each simulation is 10000, and I drop the first 2000. All variables are HP filtered.

a home boom, the cost advantage channel increases exports in Industry B relative to Industry A, and is large when firms enter slowly. The export gain channel generates incentives for the home country to be concentrated in Industry A rather than Industry B, which depends on reallocations of firms across industries. Hence, increasing entry frictions causes the first channel to dominate the second channel. These channels affect imports in the opposite way. The slopes of the cyclicality of exports and imports increases and decreases in entry frictions, respectively.

5.3.2 Cross-Country Business Cycles

Table 8 reports the results for cross-country correlations of GDP, consumption and labor. In both Case I and II, the models with heterogeneous sloping marginal cost curves better reproduce observed international comovements than the models with homogeneous flat marginal cost curves. As discussed in Section 5.2, industry heterogeneity of marginal costs yields more correlated GDP and labor across countries through within-firm market interdependence channels. Also, consumption cross-country correlations increase because GHH preference implies that consumptions comove with labor. Furthermore, the heterogeneous industry models generate a larger difference between GDP and consumption comovements than do the homogeneous industry models. Thus, I conclude that cost-side industry heterogeneity mitigates the quantity anomaly.

GHH preference and near-unit root shocks help to increase output correlations and decrease consumption correlations across countries. However, the homogeneous industry models with a flat marginal cost curve still have a smaller difference between GDP and consumption comovements than the data as shown in Table 8. As noted earlier, conventional models need additional positive interdependence channels to solve the quantity anomaly. Positive home productivity shocks directly promote new firm entry (or more investments in capital) in the home economy due to high profits. The large entry with costs (or more investments in capital) induces cross-country resource shifts from the foreign economy to the home economy. The strong incentive for resource allocation to the more productive economy is why both standard international real business cycle model and new trade open macro models have low GDP comovements problems.

Table 8 indicates that entry frictions are associated with the resource shifts channel. The resource shifts from the less productive economy to the more productive economy are based on more firm entry (larger investment) in the more productive economy. Thus, slow changes in firm entry weaken the resource shifts channel. Hence, large entry frictions augment GDP and labor cross-country correlation. Thus, introducing firm entry frictions help mitigate low GDP and labor comovements.

6 Concluding Remarks

This paper investigates how international business cycle fluctuations vary with industries different marginal cost structures empirically and theoretically. First, I document the relationship between cost structures and the main business cycle properties of output, export, and import across narrowly defined industries in the U.S. manufacturing sector. Second, I provide a framework to study sloping marginal cost curves and industry heterogeneity and their implications for industry- and aggregate-level dynamics. The model generates industry- and aggregate-level business cycles that are consistent with evidence from the U.S.

The four-digit U.S. manufacturing data shows the association between the slope of the marginal cost curve and industry-level macro and trade dynamics. The value of output is more volatile, but exports and imports are less volatile in industries with large economies of scale derived from marginal costs than in industries with small economies of scale from marginal costs. Procyclicality of industry output, exports, and imports increases when the industry faces large economies of scale derived from marginal costs.

I develop a two-country two-industry dynamic stochastic general equilibrium model with monopolistic competition and heterogeneous firms in which industries have different marginal cost curves. Under a plausible range of firm entry friction, the model reproduces the observed industry- and aggregate-level business cycle fluctuations. Allowing for different slopes of marginal cost curves across industries enhances the internal propagation mechanisms of the model. The marginal cost heterogeneity propagates the effects of aggregate shocks, which delivers more correlated business cycles across countries. Thus, the quantity anomaly is mitigated. These results are obtained because the sloping marginal costs generate within-firm interdependence between domestic and export markets.

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Appendix

A Derivation: Industry Production Function and Economies of Scale

As in Kim (2004), I introduce a parameter $\varepsilon \in [0,1]$ as follows.

$$\frac{w}{Z^{\frac{1}{\alpha}}} f_C = \frac{1}{\kappa}\left[\frac{1}{\zeta\mu} Z\left(K^{\vartheta_k} L^{\vartheta_l} M^{\vartheta_m}\right)^{\alpha}\right]^{\varepsilon} \quad \text{and} \quad N^{\alpha} = \frac{1}{\kappa}\left[\frac{1}{\zeta\mu} Z\left(K^{\vartheta_k} L^{\vartheta_l} M^{\vartheta_m}\right)^{\alpha}\right]^{1-\varepsilon},$$

where κ is an arbitrary scaling constant.

$$N^{\alpha} = \kappa\left(\frac{w}{Z^{\frac{1}{\alpha}}} f_C\right)^{\frac{1-\varepsilon}{\varepsilon}} \tag{1}$$

Thus, ε is associated with the elasticity of firm entry. The industry production function is

$$Y = N\rho y = \tilde{Z}\left(K^{\vartheta_k} L^{\vartheta_l} M^{\vartheta_m}\right)^{\varepsilon\alpha+(1-\varepsilon)\mu}, \tag{2}$$

where $\tilde{Z} = Z^{\varepsilon+(1-\varepsilon)\mu/\alpha}\left(\alpha/\mu\right)\left[\kappa\left(\zeta\mu\right)^{\varepsilon-1}\right]^{1/(\alpha\zeta)}$. Since eos $= \mu$ and $\tilde{f}_C = \tilde{F}_C$, I obtain that

$$Y = N\rho y = \tilde{Z}\left(K^{\vartheta_k} L^{\vartheta_l} M^{\vartheta_m}\right)^{\alpha\left[1+(1-\varepsilon)\vartheta_l \tilde{F}_C\right]}. \tag{3}$$

Hence, the aggregated industry-level inverse elasticity of total costs is given by Equation (7).

B Bootstrapping Algorithm

- First level: Panel data
  - Step 1: Equations (8), (9), and (10)
  - Step 2: Equation (11)
- Second level: Cross-section data
  - Step 1: Equation (12)
  - Step 2: Equation (13)

To handle generated regressor problem with multi-level and multi-step, I construct bootstrapping algorithm. It is similar to the bootstrapping algorithm for multi-level models introduced by Leeden et al. (1995).[23]

The re-sampling procedure is as follows.

[23] See Leeden et al. (2008) for details of multi-level models with bootstrap.

1.1. Draw a bootstrap sample $j = 1, 2, \cdots, J$ (with replacement),

$$\{\{\Delta Y_t^s(j), \Delta L_t^s(j), \Delta K_t^s(j), \Delta M_t^s(j), \vartheta_{l,t}^s(j), \vartheta_{m,t}^s(j), \tilde{F}_{C,t}^s(j)\}_{t=1}^T\}_{s=1}^S.$$

1.2. Estimate Equations (8), (9), (10), and (11).

: Get $\{\gamma^s(j), \tilde{F}_C^s(j)\}_{s=1}^S$ for each $j = 1, 2, \cdots, J$.

2.1. Calculate the implied sloping marginal cost curve coefficients by using Equation (12).

: Get $\{\gamma^s(j), \tilde{F}_C^s(j), \alpha^s(j)\}_{s=1}^S$ for each $j = 1, 2, \cdots, J$.

2.2. For each $j = 1, 2, \cdots, J$ and given $\{\gamma^s(j), \tilde{F}_C^s(j), \alpha^s(j)\}_{s=1}^S$, draw a bootstrap sample $b_j = 1_j, 2_j, \cdots, B_j$ (with replacement),

: Get $\{\mathbf{x}^s(b_j), \gamma^s(b_j), \tilde{F}_C^s(b_j), \alpha^s(b_j)\}_{s=1}^S$ where $\mathbf{x}^s(b_j)$ is a set of volatility or cyclicality of industry s output, exports, and imports.

2.3. Estimate Equation (13).

: Get the distribution of $\{b_0, b_1, b_2\}$ for each model.

3. Then, I can calculate the parameters' standard deviation and confidence interval based on $J \times B$ bootstrap samples.

C Data and Measurement

C.1 Industry-level Macro and Trade Data: U.S. Manufacturers

A data frequency is annual.

C.1.1 Cost Structure Estimation

I collect industry-level macro data in NBER-CES Manufacturing Industry Database from 1958 to 2011.(See Bartelsman and Gray (1996) for the details.) I use the 1987 SIC version.

Output I use the value of shipments deflated by the shipments deflator from the BEA.

Capital Input I use the real capital stock.

Labor Input The labor input is not actually correlated. The benchmark follows Baily et al. (1992). The alternative uses the production workers' hours.

Material Input I use the cost of materials deflated by the material cost deflator calculated using data from the benchmark use-make (input-output) tables and the GDP-by-Industry data of the BEA.

C.1.2 International Business Cycle Estimation

All variables are logarithmic and HP-filtered with parameter 6.25.

The output is corrected from NBER-CES Manufacturing Industry Database from 1974 to 2011. I construct the four digit 1987 SIC level U.S. export and import flows from following bilateral trade data between the U.S. and its trading partners. I correct the bilateral trade data in Schott (2008)'s SIC87- and NAICS-level U.S. imports and exports data from 1972 to 2005. I drop 1972 and 1973 because there is no c.i.f. import data. Schott (2008) provides HS-level U.S. imports and exports data from 2006 to 2011. I convert the data to 1987 SIC by using Pierce and Schott (2009).

Output I use the value of shipments deflated by the shipments deflator from the BEA.

Exports I use the exports deflated by the shipments deflator from the BEA.

Imports I use the c.i.f imports deflated by the shipments deflator from the BEA.

C.2 Aggregate U.S. Variables

The data frequency is quarterly. I use seasonally adjusted variables. All variables are logarithmic and HP filtered with a smoothing parameter of 1600.

The aggregated GDP, consumption, exports, and imports are in terms of 1996 dollars. The aggregated GDP, consumption, exports, imports, and labor (civilian employment) are from the OECD QNA and MEI databases. The sample period is from 1960:q1 to 2000:q4 to match Ambler et al. (2004).

The number of entrants data is from private sector establishment births in BLS database. The sample period is from 1993:q2 to 2016:q4. When calculating its standard deviation relative to GDP and correlation to GDP, I use the real aggregate GDP from 1993:q2 to 2016:q4.

Number of Entrants I use private sector establishment births.

C.3 Cross-country Correlations

International comovements data in Table 8 are from Table 5 and 1 in Ambler et al. (2004). First, Data I is from the results for the unweighted average of nine countries in Table 5 in Ambler et al. (2004) where the nine countries are: Australia, Austria, Canada, France, Germany, Italy, Japan, Switzerland, and the United Kingdom. The sample is from 1960:q1 to 2000:q4. Second, Data II is from the first column of Table 1 in Ambler et al. (2004) that is the average cross-correlation for 20 countries during the sample period from 1960:q1 to 2000:q4. The twenty countries in the sample are Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, the United Kingdom and the United States.

D Table

Table 1: Industry Cost Structure: OLS Benchmark with Two by Two Classification

		SEOS				LEOS				Total			
		EOS	α	$\tilde{f}_C$	Obs.	EOS	α	$\tilde{f}_C$	Obs.	EOS	α	$\tilde{f}_C$	Obs.
		Panel A: Unweighted Averages of EOS, Sloping MC, and Fixed Cost											
ND	mean	0.910	0.847	0.584	90	1.303	1.171	0.553	64	1.073	0.982	0.571	154
	stdv.	0.266	0.245	0.307		0.155	0.145	0.291		0.298	0.263	0.300	
D	mean	1.082	0.931	0.747	75	1.326	1.138	0.703	134	1.238	1.064	0.719	209
	stdv.	0.157	0.145	0.521		0.118	0.127	0.375		0.177	0.166	0.432	
Total	mean	0.988	0.885	0.658	165	1.319	1.149	0.654	198	1.168	1.029	0.656	363
	stdv.	0.239	0.209	0.425		0.131	0.134	0.356		0.250	0.217	0.388	
		Panel B: Weighted Averages of EOS, Sloping MC, and Fixed Cost											
ND	mean	0.804	0.749	0.684	90	1.315	1.174	0.582	64	0.925	0.850	0.660	154
	stdv.	0.281	0.258	0.409		0.131	0.114	0.278		0.334	0.294	0.383	
D	mean	1.253	0.940	1.782	75	1.351	1.111	0.919	134	1.317	1.053	1.214	209
	stdv.	0.272	0.159	1.029		0.107	0.115	0.575		0.186	0.154	0.863	
Total	mean	1.009	0.836	1.185	165	1.345	1.121	0.864	197	1.181	0.982	1.021	363
	stdv.	0.355	0.238	0.933		0.112	0.117	0.551		0.310	0.234	0.778	

Notes: Weighted is based on the over-time average of industry's fraction of unfiltered real output in each year from 1974 to 2011: $\text{weight}_Y^s = (1/38)[\sum_{t=1974}^{2011}(Y_t^s / \sum_{s'} Y_t^{s'})]$.

Table 2: Summary Statistics: (Unweighted) Volatility and Cyclicality

		SEOS				LEOS				Total			
		output	export	import	Obs.	output	export	import	Obs.	output	export	import	Obs.
						Panel A: Volatility (Unweighted)							
ND	mean	5.662	3.015	3.144	90	7.313	2.477	2.649	64	6.348	2.791	2.938	154
	stdv.	2.704	1.966	2.334		3.497	1.202	3.128		3.155	1.707	2.694	
D	mean	6.424	2.829	3.012	75	7.004	2.339	2.551	134	6.796	2.515	2.716	209
	stdv.	2.258	2.474	2.587		2.258	2.474	2.587		2.338	1.976	2.037	
Total	mean	6.008	2.930	3.084	165	7.104	2.384	2.583	198	6.606	2.632	2.811	363
	stdv.	2.532	2.206	2.446		2.776	1.494	2.224		2.720	1.869	2.338	
						Panel B: Cyclicality (Unweighted)							
ND	mean	0.123	0.064	0.250	90	0.238	0.086	0.281	64	0.171	0.073	0.263	154
	stdv.	0.270	0.185	0.260		0.253	0.195	0.240		0.268	0.189	0.252	
D	mean	0.294	0.125	0.312	75	0.451	0.153	0.380	134	0.395	0.143	0.355	209
	stdv.	0.247	0.182	0.240		0.242	0.199	0.234		0.254	0.193	0.238	
Total	mean	0.201	0.092	0.278	165	0.382	0.131	0.348	197	0.300	0.113	0.316	363
	stdv.	0.273	0.186	0.253		0.264	0.199	0.240		0.283	0.194	0.248	

Notes: Volatilities of output are measured by standard deviations in terms of percentage. Volatilities of imports and exports are measured by standard deviations relative to output. Cyclicalities are correlations to aggregate GDP.