The Impacts of Demand and Productivity Shocks on Product Dynamics: Evidence from Japanese Product and Firm Level Data[1]

This version: September 2022

Robert Dekle
USC

Atsushi Kawakami
Toyo University

Nobuhiro Kiyotaki
Princeton University

Tsutomu Miyagawa
Gakushuin University and RIETI

[1] We thank Erick Bartelsman, Joel David, Steven Davis, Masahisa Fujita, Kyoji Fukao, Huiyu Li, Masayuki Morikawa, Shintaro Nishioka, Kozo Kiyota and conference participants at USC, the NBER-Japan Project 2016, Stanford-Juku 2016, ABFER 2016, CAED 2017, Hitotsubashi University, Keio University, Gakushuin University, and APEA 2018 conference for helpful comments on an earlier draft. We also thank Takayuki Ishikawa for an excellent research assistance. This study is conducted as a part of the Project "Study on Productivity Growth at the Firm Level" undertaken at Research Institute of Economy, Trade and Industry (RIETI), and supported in part by a Grant-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology (No. 15H03351 and No. 18H00852) of Japan and the U.S. National Science Foundation.

ABSTRACT

We examine the effects of demand and productivity shocks on product dynamics over the business cycles, by constructing a unique firm-product data set from the Japanese Census of Manufactures from 1999 to 2010. The data are more disaggregated than comparable US data and available annually (instead of five-year intervals for US), which makes our data more suited to examining the interaction between the firm-product dynamics and business cycles. Our data show product adding and dropping by incumbent firms contributes to fluctuations of aggregate shipments much more than firm entry and exit. We find that exporters produce a larger number of products and switch their product more actively than non-exporters. Following Dekle, Jeong, and Kiyotaki (DJK 2014) model, we regress the growth rate of the number of products, the adding rate and dropping rate of products of individual firms on sector-level foreign demand, government expenditures and productivity as well as the firm-level productivity. Although the regression coefficients of the growth rate and the dropping rate of products are inconclusive, the gross adding rate of products significantly increases with favorable shocks to demand and productivity. These findings are broadly consistent with DJK (2014) model.

Keywords: Product adding and dropping, Entry and exit, TFP, Foreign demand, Government expenditures

JEL classification: E32, F12, F14, F41, L11, L2

Corresponding author

Tsutomu Miyagawa

Professor of Economics, Gakushuin University

1-5-1 Mejiro, Toshima-ku, Tokyo, Japan

E-mail address: tsutomu.miyagawa@gakushuin.ac.jp

1. Introduction

Standard models of firm dynamics which emphasize heterogeneous productivity across firms imply that the entry of new firms and the exit of low productivity firms enhance total factor productivity (TFP) in the aggregate economy. (See Hopenhayn (1992) and Melitz (2003) for example). Empirically, however, the effects of firm entry and exit on aggregate productivity improvements are not very large in the U.S. and in Japan. Hsieh and Klenow (2017) find that most productivity improvements arise from new product introductions by existing firms, not by new firm entry and exit. For Japan, Fukao and Kwon (2006) find that TFP fluctuations by incumbent firms dominate aggregate TFP movements. Aghion et. al. (1992), Bernard, Redding, and Schott (2010), and Garcia-Macia, Hsieh, and Klenow (2019) have also shown that product dynamics of incumbents is a major source of productivity movements over the medium and long runs.[2]

We construct firm-product level data from the Japanese Census of Manufactures from 1999 to 2010. The Japanese Census of Manufactures is unique in that the value of shipments can be obtained all the way down to the 6-digit level (which we define as "products"), and the product level shipment data are available at the annual frequency, making the data suitable for analysis over the business cycle. Products can be aggregated into establishments (plants), and plants can be matched to firm using firm identifiers.[3]

---

[2] See also Kawakami and Miyagawa (2013) who show for Japan that the contribution of product adding and dropping to labor productivity growth is large.

[3] In U.S. Census data, the usual product level data are only available down to the 5-digit level and are available only at five-year interval (Bernard, Redding, and Schott, 2010). Although U.S. store scanner product level data used by Broda and Weinstein (2010) and U.S. Bureau of Labor Statistics individual producer price level data used by Nakamura and Steinsson (2012) are available at a higher frequency, they need to be matched to firm level accounting data at the annual frequency before performing the empirical work that we do here.

Figure 1 decomposes the movement of total shipments of Japanese manufacturing from 1999 to 2010 into the following components: firm entries and exits, the product adding and product dropping of incumbent firms, and the increase and decrease of shipments of continuing products of incumbent firms. An exiting firm is defined as a firm that drops from one or more products to zero product. From Figure 1, we learn that the contributions of product adding or dropping is much larger than the contributions of entry and exit of firms to the total shipment change. Between 1999 and 2010, on average contributions of the adding and dropping of products were 4.7 percent and -6.0 percent, while the contributions of entry and exit were 3.3 percent and -2.9 percent. There are also large simultaneous increases and decreases of shipments of continuing products by incumbents with average contributions of 15.2 percent and -14.5 percent.

(Insert Figure 1 here)

The first recession from 2000 to 2002 was associated with the collapse of the IT stock bubble, while the second recession from 2008 to 2009 was the global financial crisis. We see that during both recessions, manufacturing shipments declined (solid line). These declines in total shipments were driven by large decreases in the excess of the shipments of continuing products of incumbents, the significant dropping over adding of products by incumbents, and exits over entries of firms. Notice that, even during downturns, many firms expanded the shipment of continuing products, added products, or newly entered. Figure 1 shows the very active gross shipment movements at the product level in both the intensive and extensive margins.

The main concern of this paper is how aggregate shocks to TFP, foreign demand and government expenditures affect product dynamics at the firm level, i.e., the adding and dropping of products by incumbent firms. Our empirical specifications are motivated by the multiproduct firm model of Dekle, Jeong and Kiyotaki (2014) (referred as DJK (2014) hereafter).[4] DJK (2014) develop a dynamic general equilibrium model of a small open economy in which the firm-product dynamics interacts with aggregate conditions. Firms are heterogeneous, facing recurrent firm-product specific shocks and aggregate shocks. Each firm potentially can produce multiple products and decides whether and how much to produce each product in domestic and export markets. From their model, we can trace how certain macroeconomic shocks can affect product creations and destructions, and thus the evolution of the number of products as well as the adding rate and the dropping rates of products of heterogeneous firms. The authors show that an increase in foreign demand and government expenditures encourages the adding of new products and raises the total number of products. The aggregate productivity improvement expands the size of market as well as raises the wage rate, which has competing effects on product innovations, while the productivity improvement at the firm-level stimulates product innovations and tends to raise the number of products of that firm.

We estimate the impact of macroeconomic shocks on product adding and dropping at the firm level by panel regression. To the best of our knowledge, this paper is one of the first to estimate a model of product adding or dropping at the firm level at the business cycle frequency, with well identified macroeconomic shocks. The estimated equations are "structural" in the sense that the specifications are based on a dynamic general equilibrium model, and that the explanatory variables are exogenous or predetermined.[5]

---

[4] Bilbie, Ghironi and Melitz's (2012) relates product level dynamics to macroeconomic shocks. They do not, however, relate macroeconomic shocks to product adding and dropping at the firm level, since the authors model only single-product firms.

[5] Garcia-Macia, et. al. (2019) use the U.S. Longitudinal database to infer how new products substitute for old products. Since they do not have product level data, they use job flows data from the Longitudinal database and develop a model to relate product turnovers to job turnovers.

While there is a large theoretical and empirical growth literature examining the long-run determinants of innovation and the introduction of new products, the literature on product innovation over the business cycle is scant. Shleifer (1986) developed a model in which the benefits of implementing new technology is big when aggregate demand is large while a larger number of implementations increases aggregate demand in equilibrium. In a series of industry level case studies, Schmookler (1966) showed that the larger the aggregate demand was, the more patentable ideas were generated. Our paper is distinct because the empirical estimation of the firm-product dynamics is based on the general equilibrium model. On the other hand, our model abstracts from the rich heterogeneity of firm-product productivity dynamics in order to make the model tractable for aggregate dynamics. We focus on examining empirically how the adding and dropping of products of heterogeneous firms react to macroeconomic shocks, without studying in detail the increases and decreases of shipments of the continuing products of incumbent firms.

Our paper is organized as follows. In the next Section, we motivate our empirical specifications by extending DJK (2014) model. In Section 3, we explain the construction of our product-firm level dataset, in addition to sector-level foreign demand, government expenditures and TFP. In Section 4, we use our data set to provide an overview of product dynamics in Japanese manufacturing firms. In Section 5, we present our estimates on the effects of shocks to sector-level foreign demand, government spending and TFP on the dynamics of products at the firm level.

2. Product Dynamics and Macroeconomic Shocks

DJK (2014) construct a dynamic general equilibrium model of a small open economy with a rich production structure. Here we summarize only key features of their model relevant for estimating the relationship between aggregate shocks and product dynamics.

2-1 The Model.

When a new firm or a new product line of an incumbent firm pays a sunk cost κ_{Et} to innovate, it draws an opportunity to produce a new differentiated product with a probability λ, or to replace an existing product with probability 1-λ. Sunk costs are positive and an increasing function of the aggregate number of product innovation N_{Et} as,

$$\kappa_{Et} = \kappa_E(N_{Et}), \text{ where } \kappa_E{}'(.) > 0.$$

Increasing marginal costs of product innovations may reflect the limited supply of engineers and facilities over the business cycles.

Once obtaining a new product or replacing an existing product, the productivity of the product is heterogeneous and is distributed according to a Pareto distribution:

$$Prob(\tilde{a} \leq a) = F(a) = 1 - a^{-\alpha}, \text{ where } \alpha > 0.$$

We assume that a fraction ϖ of innovation is done by incumbents and a fraction 1- ϖ by new entrants.

The firm with the production opportunity must pay a fixed cost κ in order to produce the product and maintain productivity for the next period. Once paid the fixed cost for product j at t, the date-t+1 productivity a_{jt+1} will be

$$a_{jt+1} = \begin{cases} a_{jt}, & with\, probability\, 1 - d_t - \zeta \\ 0, & with\, probability\, d_t \\ \tilde{a}, & with\, probability\, \zeta \end{cases}$$

The productivity of the next period will be maintained as it is with probability $1 - d_t - \zeta$, will be zero with probability d_t, and will receive a new draw from the same Pareto distribution with probability ζ. The probability of dropping product d_t is endogenous as described below.

In addition, the producer of existing products obtains another product as a spinout (irrespective to the evolution of their existing products) with probability ν per number of products. The spinout product is a new product with probability λ or replaces an existing product with probability 1-λ, and its productivity is drawn from the same Pareto distribution as the new product. Although each producer starts with a single product with new entry, each producer (called "firm") may have multiple products as a result of the history of innovation and spinouts which may outweigh the dropping of existing products.

Let N_t be the total number of products of the economy. Define the aggregate innovation rate as $e_t = \frac{N_{Et}}{N_t}$. Each existing product adds a product with innovation done by existing producers and a spinout. We assume that the adding of products is iid. across existing products. Then the expected rate of adding new products per existing products equals:

$$u_t = \omega e_t + \nu. \qquad (1)$$

The first term in the right-hand-side (RHS) is a fraction ω of innovation rate e_t per number of products done by incumbents and the second term is the spinout rate. From this, we learn that if there are favorable aggregate shocks (such as the increase in foreign demand and government expenditures) which stimulates aggregate innovation rate e_t, the gross adding rate of new products rises.

Any existing product is destroyed either exogenously with rate δ or endogenously with the replacement by the innovation and spinout of the other firms. We assume product dropping is iid. across all existing products, irrespective of the productivity of products. The expected rate of dropping per number of existing products is sum of the probabilities of the exogenous destruction and the endogenous replacement of products by innovation and spinouts as:

$$d_t = \delta + (1 - \lambda)(e_t + \nu). \qquad (2)$$

The second term in the RHS says that the destruction rate due to replacement equals the probability of replacing existing product (1-λ) times the rate of innovation and spinouts per number of existing products. We learn that the gross dropping rate is also an increasing function of the aggregate innovation rate. However, we assume $\omega > 1 - \lambda$. Thus the gross adding rate is more sensitive to the aggregate innovation rate than the gross dropping rate of products.

In the DJK model, we assume that the adding and dropping of products are independent across existing products. Thus the expected value of the change in the number of products for producer i who has N_{it} number of products equals

$$
\begin{aligned}
E_t(N_{it+1} - N_{it}) &= (u_t - d_t)N_{it} \\
&= \{[\omega e_t + \nu] - [\delta + (1-\lambda)(e_t + \nu)]\}N_{it} \\
&= [(\omega + \lambda - 1)e_t - (\delta - \lambda\nu)]N_{it}. \qquad (3)
\end{aligned}
$$

Under our assumption of $\omega > 1 - \lambda$, the expected growth rate of the number of products of existing producers is an increasing function of aggregate innovation rate e_t.

In the steady state in which the total number of products is constant, the adding rate minus dropping rate of existing products must be balanced by the rate of increase in the number of products due to innovations done by new entrants as

$$u - d = -(1-\omega)e < 0.$$

The second term is a fraction 1-ω of the aggregate innovation per number of existing products done by new entrants.[6] Hereafter we consider the dynamics of firms, products and the aggregate economy in the neighborhood of the steady state. Then the expected change in the

---

[6] In the steady state, the rate of introduction of new products due to innovation and spinouts equals the exogenous product destruction rate $\lambda(e + \nu) = \delta$. Thus the net adding rate for an existing product is $u - e = -e(1-\omega) = -\left(\frac{\delta}{\lambda} - \nu\right)(1-\omega) < 0$.

number of products is a decreasing function of the initial number of products of each firm. Equations (1), (2) and (3) are the equations we examine empirically using our firm-product level data set.

The total number of products increases with product innovations and spinouts which yield new products (with probability λ), and decreases with exogenous destruction (at a rate δ)

$$N_{t+1} = N_t + \lambda N_{Et} + \lambda \nu N_t - \delta N_t. \tag{4}$$

Product innovations and spinouts which replace existing products (with probability 1-λ) do not change the total number of products. Comparing equations (3) and (4), the gross rates of the adding and dropping of products at the individual firm level is higher than at the aggregate rates due to replacement.

The exogenous shocks to aggregate productivity, government expenditures, foreign demand and the liquidity preference for net foreign assets together with the endogenous state variables (N_t, D^*_{t-1}) recursively determine the firm-product dynamics and the aggregate variables (which include $N_{Et}, N_{t+1,}$ aggregate output, employment, consumption, export, import, net foreign asset D^*_t, and real exchange rate) in general equilibrium. Please see DJK (2014) for a complete description.

2-2. Estimation Strategy of the Model.

In the estimation, the aggregate shocks that affect the dynamics of firm-product are included at the sector level (two-digit product level) to increase the cross-section variation and the precision of the estimates. $Let\ G_{kt}, Y^*_{kt}, and\ Z_{kt}$ be sector-level government spending, foreign demand and productivity for sector k (such as electronic machineries). In DJK (2014), shocks to aggregate government spending, foreign demand, and aggregate TFP are modelled as an AR(1) process. In our estimation below, we include the sector-level shocks, $G_{kt}, Y^*_{kt}, and\ Z_{kt}$ directly. The assumption is that these variables represent exogenous “shocks” to the individual firms in the model.[7]

2-3. Including Firm Level TFP

The specification (1, 2, 3) above that we estimate is deliberately stylized. This stylized structure was necessary to allow the aggregation of heterogeneous firms with product innovations into a standard stochastic business cycle model. In reality, other variables would influence the product evolution process at the firm-level.

In growth models such as Acemoglu, Akcigit, and Kerr (2016), and product-level empirical studies such as Kawakami and Miyagawa (2013), firm-level productivity also affects product dynamics. With this empirical result in mind, we modify DJK (2014) to assume that the production innovation rate done by each firm depends on the TFP of that firm as,

$$\omega_{it} = \omega(TFP_{it}), \quad \omega' > 0.$$

By this assumption, the adding rate, the dropping rate and the growth rate of the number of products in equations (1,2,3) are affected not only by aggregate variables but also by the firm-level TFP. While this specification including firm-level TFP cannot be as easily and cleanly aggregated into a standard business cycle model, it would be interesting to see whether more productive firms add more products at the business cycle frequency.[8]

---

[7] Di Giovanni, et. al. (2014) uses sectoral-level shocks to capture the impact of aggregate shocks. We use the narrower measure of industry-level shocks to capture the impact of aggregate shocks. Foster, et. al. (2008) develops a standard multisectoral neoclassical growth model and shows that the vector of industry output growth rates follows the factor time-series model: $\varepsilon_{kt} = \beta_k S_t + v_{kt}$, where ε_{kt} is the shock to the output industry k, β_k is the matrix of coefficients that reflects how the vector of aggregate shocks S_t affect industry k’s output.

[8] Foster, Haltiwanger, and Syverson (2008) and Syverson (2011) found persistent productivity differences across a cross-section of U.S. firms. The same productivity differences are also found across Japanese firms by Fukao and Kwon (2006) and Kawakami, Miyagawa, and Takizawa (2011).

2-4. Product Dynamics of Exporters.

While the focus of this paper is on the evolution of the total number of products of individual firms, the DJK model also has predictions on how macroeconomic shocks impact the number of products that are exported. DJK (2014) show that all products with productivity greater than certain threshold of idiosyncratic productivity $\underline{a}_t$ are exported. This minimum threshold productivity level for product to be exported is a function of aggregate TFP (Z_t), the aggregate number of products (N_t), foreign demand (Y_t^*) and the real exchange rate (ϵ_t).

When aggregate TFP and the number of products are high, the real wage rate is high, which require idiosyncratic productivity to be high for the product to be exported. Thus the minimum threshold productivity for export $(\underline{a}_t)$ is an increasing function of aggregate TFP and number of products. On the other hand, when foreign demand is large and the real exchange rate is depreciated, it is more profitable to export. Then the minimum threshold productivity for export is a decreasing function of foreign demand and real exchange rates. Please see DJK (2014) for details.

The structure of our data, the Japanese Census of Manufacturers, does not permit a direct observation of exported products. We only observe whether a firm is an exporter or not and the total number of products produced by the firm. In our estimation below, we form a panel of firms that are only exporters. Firms often produce multiple products, and a firm becomes an exporter if at least one of its products has idiosyncratic productivity which is higher than the minimum threshold for exports. When the firm has a larger number of products (N_{it}) and/or has a high firm-level TFP (TFP_{it}), the firm is more likely to export because at least one of its products is likely to have an idiosyncratic productivity higher than the threshold for exporting. Thus, estimating the model on only the sample of exporters provides another way to see how firm level productivity affects the firm's response to aggregate shocks.[9]

3. The Japanese Census of Manufacturers Data and the Construction of Explanatory Variables.

We construct our firm-product data using the Census of Manufacturers conducted by the Japanese Ministry of Economy, Trade and Industry. The Census is in principle, a survey of all establishments (plants) in Japan. The data are now available annually in the format that we require for 1999-2010.[10] Because we can collect product and establishment level Census data for every year in Japan, it is more conducive to analysis at the business cycle frequency, where peaks to troughs can occur in a period as short as 2 years. We examine versions of the Census that surveys establishments with at least 4 workers, since the data covering establishments below 4 workers are not made publicly available. In 2006, 258,543 establishments have 4 or more employees, representing over 47 percent of all Japanese manufacturing establishments.

We define "Products" as goods at the 6-digit product classification level in the Japanese

---

[9] In Japan, there are only weak correlations between firm-level productivity, total shipments, profitability, export status and the export-shipment ratio across firms. This is different from the prediction of standard models such as Melitz (2003) and Eaton and Kortum (2003). Multi-product firms partly help explain this weak correlation because some firms are large because they have many products even though firm-level productivity is low, while other firms are not large but have a small number of highly productive products to export. See DJK (2014) for more.

[10] In 2012 and 2016, the Census of Manufacturers was substituted by the Eoonomic Census. Although we obtained the data of Economic Census, we were not able to construct consistent data with the 2000s, because there were many gaps between the data in the Census of Manufacturers and the Economic Census. Thus, our analysis focuses on the product dynamics in the 2000s.

Census of Manufacturers; “Industries” as goods at the 4-digit product classification level, and “Sectors” as goods at the 2-digit level of product classification.[11] In the data, each establishment reports the usual accounting data, such as the value of shipments of the different types of “products” that the establishment produces, the number of employees, raw material costs, fuel and electricity costs, and tangible fixed assets. Examples of sector, industry, and product level classifications are shown in Table 1.[12] For example, sector classification number 29 indicates the electric machinery sector. Industry classification number 2951 shows the industry which produce storage batteries. The industry consists of five 6-digit products. At the 6-digit level, we find not only usual lead storage battery but also lithium ion battery which is used for technology products such as mobile phones and personal computers. This means that if we want to examine whether a firm produces new innovative products, we have to capture movements at least at the 6-digit level.

(Insert Table 1 here)

Given that decisions on the adding and dropping of products and on shipments of each product are made at the firm level and not at the establishment level, both in reality and in the DJK model, we need to identify the “firm”. One problem with the Japanese Census data is that the data do not record a firm level identifier that would allow the grouping of establishments into firms (Bernard and Okubo, 2013). Abe et. al. (2012) develop a procedure to match

---

[11] Industry classification isn the Census of Manufacturers follows the Japan Standard Industry Classification (JSIC) in the case of the 2-digit and 4 –digit levels. The JSIC that started in 1949 is revised every five years. Every version of JSIC is adjusted to adhere to the International Standard Industry Classification (ISIC). However, in the case of the 6-digit classification, the Census of Manufacturers adopts its own classification. The classifications used in our paper follows the 2008 version of JSIC.

[12] Note that what we call “products” is a much broader category than what are typically called “products” in scanner-type data. For example, in our data, a box of cereal and a bag of rice crackers will be the same product, but in scanner type data, they will be different products. Thus, the introduction of a newer product in our data is a more significant innovation than simply introducing a newer brand of cereal in scanner data.

establishments (plants) to their parents by using information on establishment codes, address codes, and industry classifications. Using their procedure, we aggregate establishment-level data into firm-level data.

Stylized facts of the Census data concerning multiple product firms are documented in Kawakami and Miyagawa (2013). Briefly, according to Kawakami and Miyagawa, in the Japanese Census, the share of multiple product firms in the total number of firms is about 40 percent, and the average multiple-product firm in Japan produces about 3 products (i.e., three different 6-digit JSIC level products). While multiple product firms represent a minority of firms, they account for 78 percent of total shipments by Japanese firms. In multiple product firms, average shipments are 50 percent higher, employment is 28 percent higher, and shipments per worker are 30 percent higher, compared to single product firms.

In the Census, we can also identify whether a particular establishment is an exporter (with a positive export value) and the total value of their exports in that year. However, export values or quantities are only available at the establishment level and not at the product level. At the product level, only total shipment quantities and values are available and are not broken down into domestic and exporting shipments.

For our empirical analysis, we need to construct some aggregated variables using both the Census of Manufacturers and other, mostly sector level data. Sector-level government expenditures, G_{kt}, are obtained from the Input-Output Tables in the Japan Industrial Productivity Database (JIP database).[13] We use data for only the government's direct demands for sector k. We construct sector level foreign demands, Y^*_{kt}, by first obtaining exports values

[13] Hitotsubashi University and RIETI constructed the JIP database to estimate productivity at the industry level. The construction of this database is consistent with other productivity databases such as Jorgenson, Gollop, and Fraumeni (1987) and EUKLEMS database. The JIP database has several versions and we use the data in the 2018 version in our paper.

in Japanese Yen (JPY) from Japan to four of Japan's main partners, the U.S., China, the European Union, and Russia in each sector. These countries account for about 45 percent of Japan's total exports in 2010. We then obtain the value added in each of Japan's export partners in each sector from the IMF's International Financial Statistics (converted to yen at the prevailing exchange rate). For each sector, we then sum Japan's exports and value added over these four countries and area. Finally, for each sector, we take the ratio of Japan's summed exports to our summed value-added measure, and use this ratio as our sector level foreign demand variable.

Applying Good, Nadiri, and Sickels (1997) to the sector level, we measure sector level TFP, Z_{kt}, as follows[14]

$$\ln Z_{kt} = (lnQ_{kt} - \overline{lnQ_t}) - \sum_h \frac{1}{2}(s_{kt}^h + \overline{s_t^h})(lnX_{kt}^h - \overline{\ln X_t^h})$$

$$+ \sum_{\tau=1}^{t}(\overline{lnQ_\tau} - \overline{lnQ_{\tau-1}}) - \sum_{\tau=1}^{t}\sum_h \frac{1}{2}(\overline{s_\tau^h} + \overline{s_{\tau-1}^h})(\overline{lnX_\tau^h} - \overline{\ln X_{\tau-1}^h}). \quad (5)$$

In Equation (5), Q_{kt} is output in sector k. X_{kt}^h represents a factor of production h and s_{kt}^h shows share of factor of production h in sector k, where h is labor, capital, or intermediate input. $\overline{\ln A_t}$ is a log of geometric average of A_{kt} across sectors, where A_{kt} is Q_{kt}, s_{kt}^h or X_{kt}^h.

Finally, in some specifications, we add firm-level productivity as another explanatory variable. We estimate firm-level total factor productivity by using the method of De Loecker (2011) for multiproduct firms. To obtain the necessary accounting data such as the number of employees and the value added at the firm level from the Census data, we simply aggregate the

[14] We use the JIP productivity data to obtain Good, Nadiri, and Sickles TFP measure, The simple JIP productivity TFP measure is an index and does not allow for inter-sector comparisons of productivity levels. The productivity measures arising from the Good, Nadiri, and Sickels procedure corrects for this index number problem and allows for interindustry comparisons.

data for all the establishments that the firm manages. Using the estimated coefficients, we measure total factor productivity at the firm level, as described in the Appendix.

4. Stylized facts of Japanese Product Dynamics.

4-1. Stylized Facts Using All Samples

Using firm-product level data as constructed above, here we provide an overview of product-level dynamics in Japan. Following Table 1, Table 2 depicts how sectors can be divided into industries and products. For example, the food sector has 40 industries and 121 products, ships 23 trillion JPY worth of goods and has over a million workers.

(Insert Tables 2 here)

As shown in the Introduction, Figure 1 depicts the decomposition over time of the total change in shipments (solid line). Over the entire period, the biggest contributor to total shipment movements is the fluctuation in continuing products made by incumbent firms. Some continuing products expand their shipments while others contract, and their difference is pro-cyclical.

The second most important contributor to the movement in total shipments is the adding and dropping of products by incumbent firms. Compared to the contribution of products added and dropped by incumbent firms, the contribution of the entry and exit of firms to total shipment fluctuations is small. The shipment of new products by incumbent firms dominates the shipment of new products by new firm entrants. In addition, during booms, product adding exceeds product dropping, suggesting that positive macroeconomic shocks stimulate net product adding and increase the number of products.

According to Figure 2 during the period of 1999-2010, the average fraction of the contribution of new products added to total gross increase in shipments was 18.4 percent, while the contribution of new firm entry was only 4.0 percent, (while the remaining 77.6% is the contribution of increases in shipment of continuing products by incumbents). Similarly the average fraction of the contribution of old products dropped to total gross decrease in shipments was 21.0 percent, while the contribution of firm exit was only 7.3 percent, (while the remaining 71.7% is the contribution of decreases in shipment of continuing products by incumbents).

(Insert Figure 2 here)

4-2. Exporting Firms.

In Figure 3, we compare the average number of products per firm over time between exporters and non-exporters. It is well-known from earlier work that exporters tend to be larger than non-exporters (Bernard, Eaton, Jenson, and Kortum, 2003). These predictions hold for the total shipment as well as the number of products in the data. The average number of products for exporters is 2.9 to 3.5, while that of the non-exporters is around 1.7 However, the average number of products for export firms has a negative trend from 3.4 products in 2001 to 2.9 products in 2010. The gap between the number of products between exporters and non-exporters has narrowed from 1.7 in 2001 to 1.1 in 2010.

(Inset Figure 3 here)

Figure 4 compares the kernel density estimate for the distribution log of sales of exporters and non-exporters. As in the trade literature, we find that sales of exporting firms are larger on average and more dispersed than non-exporters. At the same time, we observe a significant overlap of the distributions of log sales between exporters and non-exporters.

(Insert Figure 4 here)

Figure 5 shows added products and dropped products for exporters and non-exporters. We find that exporting firms are more aggressive in product switching than non-exporting firms, because the number of added and dropped products in exporting firms are larger than those in non-exporting firms. Moreover, the product adding and dropping of exporters appears to be more sensitive to the business cycle than that of non-exporters.

(Insert Figures 5 here)

To emphasize, regardless of whether the economy is in a boom or a recession, there are simultaneously a large number of products added and dropped by incumbent firms – in addition to large simultaneous increase of shipment of some continuing products and decreases of shipment of the other continuing products in Japan. The contribution of firm entries and exits to gross shipment increases and declines are small in magnitude. The net product adding (products added minus dropped) by existing firms is cyclical, while net entry is not very cyclical. These observations argue for the importance of business cycles models with multiproduct firms as in DJK (2014). Finally, although we do not observe exports at the product level, we find that exporters tend to have a larger number of products and that add and drop of products more actively than non-exporters.[15]

5. Estimation of Product Dynamics

In our estimates below, we focus on the extensive margin of adjustment in the number of products. The estimated equations are "structural" in the sense that if the DJK model is correct, then the explanatory variables are exogenous or predetermined to the individual firm.

5-1. Empirical Specifications with only Aggregate Explanatory Variables

We start with the specification on the growth rate of the number of products in (3):

$$DH_{it} = const. + a_1 * lnY^*_{kt-1} + a_2 lnG_{kt-1} + a_3 * lnZ_{kt-1}$$

[15] Although not observed at the business cycle frequency, these features are also present in U.S. data (Bernard, Redding, and Schott, 2010).

$$+ a_4 * lnN_{it-1} + \varepsilon_{it} . \qquad (6)$$

The dependent variable (DH_{it}) is the Davis=Haltiwanger=Schuh index of the growth rate of the number of products of firm i, defined as

$$DH_{it} = \frac{N_{it}-N_{it-1}}{\left(\frac{N_{it}+N_{it-1}}{2}\right)}.$$

N_{it-1} and N_{it} are the numbers of products of firm i at time t-1 and t. We restrict the sample for the firm which exists both at time t-1 and t. On the left-hand side (LHS) of equation (6), lnY^*_{kt} is the log of foreign demand, $\ln G_{kt}$ is the log of government expenditures, and lnZ_{kt} is the log of TFP for the sector k to which firm i belongs.

Theoretically from equation (3), we have

$$\frac{N_{it}-N_{it-1}}{N_{it-1}} = (\omega_{it} + \lambda - 1)e_{kt-1} - (\delta - \lambda\nu) + \varepsilon_{it}, \text{ where}$$

$$e_{kt-1} = e(Y^*_{kt-1}, G_{kt-1}, Z_{kt-1})$$

$$\omega_{it-1} = \omega(TFP_{it-1})$$

$$\varepsilon_{it} = \frac{N_{it} - N_{it-1}}{N_{it-1}} - E_{t-1}\left(\frac{N_{it} - N_{it-1}}{N_{it-1}}\right).$$

The theory developed above predicts that a_1 and a_2 are positive, because favorable demand condition raises the product innovation rate e_t. The coefficient a_3 is expected to be ambiguous, because the increase in the sector-level TFP may expand the market as well increase wages in the sectoral labor market (which is likely to reduce the expected benefit for firms to create new products). Finally, we include the lagged number of products of firm i to take into an account the idiosyncratic factor to the number of products. We expect that the firm which has a larger number of products by luck in the previous period is likely to reduce the number of products this period because the luck is typically mean-reverting. Then we expect the coefficient a_4 to be negative.

As shown in Section 2.3, the extended model takes into an account the effect of the firm-level TFP on the rate of product innovation of that firm. We expect TFP_{it-1} to be predetermined at t, even though it evolves over time. With this in mind, we also estimate the following equation including firm-level TFP as an explanatory variable.

$$DH_{it} = const. + a_1 * lnY^*_{kt-1} + a_2 lnG_{kt-1} + a_3 * lnZ_{kt-1}$$

$$+a_4 * lnN_{it-1} + a_5 * TFP_{it-1} + \varepsilon_t \qquad (7)$$

We expect that a_5 is positive. As shown in the Appendix, the measurement of firm-level TFP is based on the estimated parameters of the production function with multiple products (De Loecker, 2011).

The summary statistics of all the variables used are presented in Table 3. The log of the average number of products equals 0.387 (the average number of products=1.749) since 0% of firms have a single product. The Davis-Haltiwanger-Schuh index of the net growth rate in the number of products has a very small mean (0.004) and a large standard deviation (0.218) because there are large simultaneous product adding and dropping across firms. We also construct two additional data and use them as alternative dependent variables for estimating comparable equations (6) and (7). One is the gross product adding rate which is measured as the ratio of the number of new products added to the average of the number of products at t and t-1. The other is the gross product dropping rate which is measured as the ratio of number of old products dropped to the average of the number of products at t and t-1. We find that the gross adding rate has a smaller mean (0.180) than the gross dropping rate (0.258). This is consistent with theory, because the gap between the dropping rate and adding rate is filled by the new products introduced by new entrants in the neighborhood of the steady state (as we showd in Section 2). In addition, as seen in Figure 3, the average number of products per firm decreases in the Japanese manufacturing sector. The number of observations of firm-level TFP is much less than those of other variables because we are not able to obtain the capital stock data of firms with less than 30 employees.

(Insert Table 3 here)

5-2. Estimation for the DH measure of the Growth Rate in the Number of Products

We estimate Equations (6) and (7) by panel fixed effects regression. Because we include the natural log of the number of products of each firm in the previous period, we restrict the sample so that that the firm exists for both periods t-1 and t. Since firms are continuously entering and exiting, the panel is unbalanced. In theory, the error terms should be serially uncorrelated. In reality, however, we find high serial correlations of the residuals, perhaps due to some omitted variables affecting the product growth rates. Thus, we estimate equations (6) and (7) by the panel fixed effects regression with only AR1 corrections. All estimations are conducted including year dummies.

Table 4 shows the estimation results when the dependent variable is the Davis =Haltiwanger= Schuh measure of the net growth rate in the number of products. We find that sector level foreign demand does not siginificatly affect the net growth rate in the number of products for both all firms and exporting firms (in the first row), controlling for the year fixed effects. Sector level government expeditures have siginificantly negative effects on the growth rate of products for all firms (in the second row and the first two columns), which is different from what we expected (even though it is not significant for exporters). This may reflect the situation that the government is subsidizing declining industries through government expenditures. Concerning sector-level TFP, we find a significantly positive effect on the net growth rate of products for both all firms and exporters, controlling for firm-level

TFP (in row 4, columns 2 and 4), even though the magnitude is small. Firm-level TFP has a significantly positive effect on the grwoth rate in the number of products for exporters (in row 5 and column 4), which is consistent with our theory, (even though it is not significat for all firms in column 2).

What is extremely significant and robust for all regressions is the negative effect of the log number of products in the previous period on the net growth rate of the number of products (in row 5). This is consistent with our theory, which includes idiosyncratic shocks. The firm which has a large number of products by good luck in the previous period is likely to reduce the number of products because good luck may not last long.

(Insert Table 4 here)

5-3. Estimation Results for Gross Product Adding Rate

One of the reasons why sectoral demand and TFP have limited effects on the net growth rate in the number of products could be that the coefficient of the sectoral innovation rate e_{kt} on the growth rate in the number of products of firms in this sector $(\omega_{it} + \lambda - 1)$ is small. From equation (1), the gross adding rate of products of each firm is

$$\frac{number\ of\ products\ added\ by\ firm\ i}{N_{it-1}} = \omega_{it} e_{kt-1} + \nu + \varepsilon_{it}.$$

When we look at the coefficient of the sectoral innovation rate on the gross adding rate of products, instead of the net growth rate of the number of products, the coefficient ω_{it} is larger because there is no offsetting replacement effect $\lambda - 1 < 0$.

Thus, we conduct regressions using equations comparable to (6) or (7), replacing the net growth rate of number of products by the gross adding rate:

$$\frac{number\ of\ products\ added\ by\ firm\ i}{\frac{N_{it-1}+N_{it}}{2}} = const. + a_1 * lnY^*_{kt-1} + a_2 lnG_{kt-1}$$

$$+a_3 * lnZ_{kt-1} + a_4 * lnN_{it-1} + a_5 * TFP_{it-1} + \varepsilon_{it} \qquad (8)$$

We compute this ratio as the average number of products between date t-1 and t instead of that of date t-1, because the former is more stable and the regression is more comparable to the regression the Davis-Haltiwanger-Schuh index in the number of products. The panel estimation results with AR1 corrections and year dummies are shown in Tables 5.

(Insert Tables 5)

In Table 5, we find that foreign demand for each sector has significantly positive effect on the gross adding rate for all firms and exporting firms in that sector, if we do not include the firm-level TFP measure (in row 1 and columns 1 and 3). Government expenditures at the sectoral level has also significantly positive effects on the adding rate of exporting firms in that sector (in row 2 and columns 3). The coefficients on sectoral level TFPs are negative and significant for all firms and exporting firms in that sector, if firm-level TFP is not included (in row 3 and columns 2 and 4). This is consistent with our theory which predicts that higher TFP and wage at this sector level may decrease the profitability and product innovation rate for the firm in that sector. In the case of exporting firms, firm-level TFP has significantly positive effects on the adding rate of products (in row 4 and column 4). However, once firm level TFP is included as an explanatory variable, the coefficients on aggregate variables are no longer significant (in column 2 and 4). Since our firm-level TFP is revenue-based TFP, the effects of aggregate variables on product adding behavior are absorbed into the effects of firm-level TFP.

As before, the lagged number of products of each firm are very significantly negative and robust on the adding rates of products (in row 5). This is consistent with our theory.

5-4. Estimation Results for Gross Product Dropping Rate

Concerning the gross dropping rate of products, our theory predicts that

$$\frac{number\ of\ products\ dropped\ by\ firm\ i}{N_{it-1}} = \delta + (1-\lambda)(e_{kt-1} + \nu) + \varepsilon_{it}.$$

Because we expect the replacement rate of existing products by product innovations, $1-\lambda$, to be not very large, (which is smaller than the fraction of innovations done by incumbent firms by assumption), we expect the effects of aggregate conditions on the dropping rate of the products to be limited. Thus, we expect the coefficients on the aggregate variables to not be very significant, when we conduct the regression of equations comparable with (6) or (7), replacing the net growth rate of number of products by the gross dropping rate:

$$\frac{number\ of\ products\ dropped\ by\ firm\ i}{\frac{N_{it-1}+N_{it}}{2}} = const. + a_1 * lnY^*_{kt-1} + a_2 lnG_{kt-1}$$

$$+a_3 * lnZ_{kt-1} + a_4 * N_{it-1} + a_5 * TFP_{it-1} + \varepsilon_{it}. \qquad (8)$$

Table 6 reports the estimation results with AR1 error corrections and year dummies.

(Insert Table 6 here)

Foreign demand at the sectoral level has inconclusive effects on the product dropping rate (in row 1). When firm-level TFP is not included, sectoral foreign demand has a significantly positive effect for exporters in column 3 (which is consistent with theory), and significantly negative effects for all firms in column 1 (which contradicts with theory). Once firm-level TFP is included, foreign demand does not have significant effects in columns 2 and 4. Government expenditures at the sectoral level does not have significant effects on the dropping rate of products in the second row, which is broadly consistent with our theory. Sector level TFP has significantly negative effect on the product dropping rate in row 3 and columns 1 and 3 (which is consistent with theory) if firm level TFP is not included. Once firm-level TFP is included, sectoral TFP does not have significant effects on the product dropping rate in columns 2 and 4.

One unexpected result is that firm-level TFP has marginally significantly *positive* effects on the gross dropping rate of products. Given that we know that firm-level TFP has a significantly positive effect on the gross adding rate of products for exporters, this may suggest that there are decreasing returns to scale at the firm level (which we abstract to facilitate the aggregation).

Curiously the lagged number of products (which used to have extremely significantly negative effects on the growth rate and the adding rate of products) now has no significant effects for exporters for all cases and all firms (when firm-level TFP is included) in row 5 and columns 2-4. This suggest that the product dropping rate is largely independent of the number of products in the previous period, although product innovations which affect the growth rate and the adding rate of products depend upon idiosyncratic shocks.

These results do not contradict DJK (2014), where product adding behavior is affected by economic factors such as foreign demand, government expenditures, sectoral TFP and firm-level TFP. However, the effects of these economic factors on the dropping rate of the number of products this period is muted by opposing factors. This reminds us of the stylized observations about gross job creation and destruction, in which the gross job creation rate is highly pro-cyclical, while the job destruction rate is only mildly counter-cyclical. (See Shimer (2005) for example).

6. Concluding remarks

Policy makers in many countries are concerned about promoting product innovation within their borders. For example, the Abe administration in Japan has undertaken expansionary fiscal and monetary policies, partly in the hope of encouraging the introduction of innovative products.[16] The expansionary monetary policy in the Euro area in the 2010s is related in part to the desire to stimulate innovation and introduction of better products (Bergin and Corsetti, 2014).

Conceptually linking business cycles with product adding and dropping behavior at the firm level is not new; the idea goes back at least to Schumpeter. To the best of our knowledge, however, this paper is one of the first to estimate a model of product adding and dropping behavior for the firm at the business cycle frequency. To estimate such a model, we need product level data that can be matched with firms at a minimum at the annual frequency.

We construct a unique firm-product database in Japan using the Census of Manufactures. The data are available at the annual frequency and products in our database are classified down to six-digits, which is more detailed than what is available in the U.S. Census of Manufactures.

In Japan, firms change their product compositions quite frequently, although the average number of products per firm is very stable. This stability, however, hides significant product adding and dropping behavior. The average number of products of exporters is larger and more cyclical than non-exporting firms. We also find that product adding and dropping are larger and more cyclical than entry and exit of firms.

In our estimates, we examine the impact of aggregate demand shocks such as foreign demand and government expenditures and supply shocks such as industry-level and firm-level productivity on alternative measures of product dynamics. When we use the growth rate

---

[16] In addition to improving overall productivity, new products increase consumer utility in a "love of variety" model.

in the number of products as a dependent variable, we do not find stable coefficients of aggregate variables on say the growth rate of the number of products. Only firm-level TFP is significantly positive effect on the growth rate of number of products for exporters. Therefore, we separate the growth rate of the number of products into the product adding rate and the product dropping rate. We then find that the coefficients of aggregate and individual variables on product adding rate are largely significant and consistent with the theoretical predictions of DJK(2014): Sectoral foreign demand and government expenditures have significantly positive effect on the product adding rate. While sectoral TFP has significantly negative effect on product adding rate for all and exporting firms, firm-level TFP has significantly positive effect of product adding rate for exporters. As the theory predicts, the effect of economic factors on the dropping rate of products is muted, making the dropping rate roughly constant.

This producer level behavior is also consistent with the recent Japanese experiences. As the Japanese population has been gradually decreasing, foreign demand has become more important in affecting Japanese innovative behavior. Although government spending affects the product dynamics of Japanese firms, the effects are small. We witness the only limited increase in Japanese growth in the 1990s, when there were large fiscal stimuluses.

Our empirical results suggest that the creative destruction of the adding of new products and the dropping of old products by incumbent firms is an important contributor to aggregate fluctuations, and much more important than the entry and exit of firms for business cycle fluctuations. This creative destruction of products is more active under favorable macroeconomic conditions of large government spending and foreign demand. To revitalize stagnant industrialized countries such as Japan's, it is important for the government to implement policies which complement the creative destructions, such as improving education, research and development, and stimulating foreign direct investment and trade, in addition to reducing the structural impediments that slow down the creative destructions.

Appendix. Estimations of Firm level TFP

We estimate a production function for multi-products firm developed by De Loecker (2011) to obtain firm-level TFP. In his paper, the output of product j at firm i, Q_{ijt}, depends on aggregate demand in industry k, Q_{kt}, and relative price, $\frac{P_{ijt}}{P_{kt}}$, as

$$Q_{ijt} = \left(\frac{P_{ijt}}{P_{kt}}\right)^{-\eta} Q_{kt} \exp(\xi_{it}). \qquad \text{(A-1)}$$

Here ξ_{it} is an unobservable demand shock to firm i and $\eta > 1$ is the elasticity of substitution.

From (A-1), the revenue function of product j by firm i is

$$R_{ijt} = P_{ijt}Q_{ijt} = Q_{ijt}{}^{\frac{\eta}{\eta-1}} Q_{kt}{}^{\frac{1}{\eta}} P_{kt} \exp(\xi_{it}). \quad \text{(A-2)}$$

Assume that production function of each product is given by

$$Q_{ijt} = L_{ijt}{}^{\alpha_l} M_{ijt}{}^{\alpha_m} K_{ijt}{}^{\alpha_k} exp(\omega_{it} + u_{it})$$

for all products produced by firm i, where j=1,2,…N_{it}. Denote the total revenue of firm i as $R_{it} = \sum_{j=1}^{N_{it}} R_{ijt}$, and the total use of labor, material and capital as $L_{it} = \sum_{j=1}^{N_i} L_{ijt}$, $M_{it} = \sum_{j=1}^{N_i} M_{ijt}$, and $K_{it} = \sum_{j=1}^{N_i} K_{ijt}$. Assuming the input is used equally across products within the firm, $X_{ijt} = \frac{X_{it}}{N_{it}}$, for $X = L, M, and\ K$. Define the log level of real revenue of firm i using the sector level price level as deflator as $\tilde{r}_{it} = lnR_{it} - lnP_{kt}$. From equation (A-2), we obtain

$$\tilde{r}_{it} = \frac{\eta-1}{\eta}(\alpha_l l_{it} + \alpha_m m_{it} + \alpha_k k_{it}) + \left[1 - \frac{\eta-1}{\eta}(\alpha_l + \alpha_m + \alpha_k)\right] n_{it}$$

$$+ \frac{1}{\eta} q_{kt} + \frac{\eta-1}{\eta}(\omega_{it} + u_{it}) + \frac{1}{\eta}\xi_{it}. \qquad \text{(A3)}$$

Here lower-case letters represent the log values of variable of upper-case letters.

We estimate Equation (A-3) by using two digit-level industry classifications as [17], [18]

$$\widetilde{r}_{it} = \beta_l l_{it} + \beta_m m_{it} + \beta_k k_{it} + \beta_n n_{it} + \beta_q q_{kt} + \omega_{it}^* + \xi_{it}^* + u_{it}^*, \qquad \text{(A4)}$$

Using estimated parameters, we measure productivity as

$$\widehat{\omega}_{it} = \left(\widetilde{r}_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_n n_{it} - \hat{\beta}_q q_{kt}\right)\frac{\eta}{\eta-1}. \quad (A5)$$

The estimation results are shown in the Appendix table 1.

---

[17] If firm I produces multi products across different industries, Equation (A-4) becomes more complicated. However, as most Japanese firms produce multi products within one industry at two-digit level, we focus on the estimation of Equation (A-4).

[18] Estimations were conducted by the Levinsohn=Petrin method.

References

Abe, Takeshi, Kazuya Hitomi, Yoko Konishi, Hideaki Tomita and Taisuke Uchino (2012) "A New Converter for Establishments from Japan's Census of Manufactures: 1993-2009," *Policy Discussion Paper*, 12-P-007, RIETI.

Acemoglu, Daren., Ufuk Akeicgit, and William. Kerr (2016), "The Innovation Network," Proceedings of the National Academy of Science 113(41): 11483-11488..

Aghion, Philippe, and Peter Howitt (1992) "A Model of Growth through Creative Destruction" *Econometrica* 60(2): 323-351.

Bergin, P. and G. Corsetti (2014), "International Competitiveness and Monetary Policy," manuscript, Cambridge University.

Bernard, Andrew, B., Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum (2003) "Plant and Productivity in International Trade" *American Economic Review* 93(4): 1268-1293

Bernard, Andrew, B. and Toshihiro Okubo (2013), "Multi-Product Plants and Product Switching in Japan" *RIETI Discussion Paper Series*, 13-E-069.

Bernard, Andrew, B., Stephen J. Redding, and Peter K. Schott (2010) "Multi-Product Firms and Product Switching," *American Economic Review*, 100(1): 70-97

Bilbie, Florin., Fabio Ghironi, and Mark Melitz (2012), "Endogenous Entry, Product Variety, and Business Cycles," *Journal of Political Economy,* 120(2): 304-345.

Broda, Christian and David Weinstein (2010). "Product Creation and Destruction: Evidence and Price Implications," *American Economic Review*, 100(3): 691-723.

Davis, Steven, John Haltiwanger, and Scott Schuh (1996), *Job Creation and Destruction,* Cambridge, M.A.: MIT Press.

Dekle, Robert, Hyeok Jeong, and Nobuhiro Kiyotaki (2014) "Dynamics of Firms and Trade in General Equilibrium" unpublished manuscript March, 2014.

Dekle, Robert, Atsushi Kawakami, Nobuhiro Kiyotaki, and Tsutomu Miyagawa (2015) "Product Dynamics and Aggregate Shocks: Evidence from Japanese Product and Firm Level Data" RIETI Discussion Paper Series 15-E-137.

De Loecker, J. (2011), "Product Differentiation, Multi-product Firms, and the Impact of Trade Liberalization on Productivity, *Econometrica* 79(5): 1407-1451.

Di Giovanni, Julian, Andrei A. Levchenko, and Isabelle Méjean (2014) "Firms, Destinations, and Aggregate Fluctuations," *Econometrica* 82(4): 1303-1340.

Eaton, Jonathan, and Samuel Kortum (2002) "Technology, Geography, and Trade" *Econometrica* 70(5): 1741-1779.

Foster, Lucia, John Haltiwanger, and Chad Syverson (2008), "Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability?" *American Economic Review* 98(1): 394-425.

Fukao, Kyoji, and Hyeog Ug Kwon (2006), "Why Did Japan's TFP Growth Slow Down in the Lost Decade? An Empirical Analysis Based on Firm-Level Data of Manufacturing Firms" *Japanese Economic Review* 57(2): 195-228.

Garcia-Macia, Daniel., C-T Hsieh, and Peter Klenow (2019), "How Destructive is Innovation?", *Econometrica* 87(5) :1507-1541.

Good, David, Isaq Nadiri, and Robin Sickles (1997) "Index number and Factor Demand Approaches to the Estimation of Productivity", M. Hashrem Perasan and Peter Schmit eds., *Handbook of Applied Econometrics: Vol. 2, Microeconometrics*, Oxford, England: Basic Blackwell.

Hsieh and Klenow (2017) "Reallocation Myth." Proceeding of the Federal Reserve of Kansas City Economic Symposium on "Fostering Dynamic Economy."

Hopenhayn, Hugo (1992) "Entry and Exit in Long Run Equilibria" *Econometrica* 60(5):

1127-1150

Jorgenson, Dale, Frank M. Gollop, and Barbara M. Fraimeni (1987) *Productivity and U.S. Economic Growth*, Harvard Economic Studies Vol. 159.

Kawakami, Atsushi, Tsutomu Miyagawa, and Miho Takziawa (2011) "Revisiting Productivity Differences and Firm Turnover –Evidence for Product-Based TFP Measure in the Japanese Manufacturing Industries" *RIETI Discussion Paper Series* 11-E-064.

Kawakami, Atsushi, and Tsutomu Miyagawa (2013) "Product Switching and Firm Performance in Japan" *Public Policy Review* 9, pp. 287-314, Policy Research Institute, Ministry of Finance.

Melitz, Marc, J., (2003) "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity" *Econometrica* 71(6): 1695-1725.

Olley, G. Steven and Pakes, Ariel (1996) "The Dynamics of Productivity in the Telecommunications Equipment Industry", *Econometrica*, 64(6): 1263-1293.

Nakamura, Emi and Jon. Steinnson (2012). "Lost in Transit: Product Replacement Bias and Pricing to Market," *American Economic Review,* 102(7): 3277-3316.

Schleifer, Andrei. (1986). "Implementation Cycles," *Journal of Political Economy,* 94(6): 1163-1190.

Schmookler, Jacob, (1966). *Innovation and Economic Growth.* Cambridge: Harvard University Press.

Shimer, Robert. (2005). "Cyclical Behavior of Equilibrium Unemployment and Vacancy." *American Economic Review* 5(1): 25-49.

Syverson, Chad (2011) "What Determines Productivity?" *Journal of Economic Literature* 49(2): 326-365.

Table 1 An example of how products are classified in the Survey of Manufacturers

Sector		Industry		Product	
2-digit classification		4-digit classification		6-digit classification	
29	Elaectirc machineries	2951	Battery	295111	Lead battery
				295112	Alkaline battery
				295113	Lithium ion battery
				295114	Associated parts with batteries

Table 2 The Survey of Manufacturers in Japan

	industry	products	products/ industry	Goods Shipments (million JPY)	Number of Employees	Shipments per Employees (million JPY)
9 FOOD	40	121	3.0	23473138	1050510	22.3
10 BEVERAGES,TOBACCO AND FEED	12	30	2.5	9420542	89354	105.4
11 TEXTILE MILL PRODUCTS	62	239	3.9	3450657	248209	13.9
12 LUMBER AND WOOD PRODUCTS, EXCEPT FOURNITURE	17	53	3.1	1881095	74158	25.4
13 FURNITURE AND FIXTURES	9	29	3.2	1365973	74349	18.4
14 PULP, PAPER AND PAPER PRODUCTS	15	65	4.3	6945736	173279	40.1
15 PRINTING AND ALLIED INDUSTRIES	7	18	2.6	5647838	256629	22.0
16 CHEMICAL AND ALLIED PRODUCTS	38	181	4.8	26051020	338910	76.9
17 PETROLEUM AND COAL PRODUCTS	5	19	3.8	14772727	22031	670.5
18 PLASTIC PRODUCTS, EXCEPT OTHERWISE CLASSIFIED	25	61	2.4	10531973	386770	27.2
19 RUBBER PRODUCTS	13	51	3.9	2960785	110064	26.9
20 LEATHER TANNING, LEATHER PRODUCTS AND FUR SKINS	10	45	4.5	305900	18992	16.1
21 CERAMIC, STONE AND CLAY PRODUCTS	43	143	3.3	6562749	220025	29.8
22 IRON AND STEEL	22	72	3.3	17887305	210548	85.0
23 NON-FERROUS METALS AND PRODUCTS	18	66	3.7	8819409	137243	64.3
24 FABRICATED METAL PRODUCTS	33	134	4.1	11354599	490041	23.2
25 GENERAL-PURPOSE MACHINERY	19	91	4.8	9867822	304240	32.4
26 PRODUCTION MACHINERY	25	152	6.1	13028847	484356	26.9
27 BUSINESS ORIENTED MACHINERY	22	82	3.7	6742342	201014	33.5
28 ELECTRONICPARTS, DEVICES AND ELECTRONIC CIRCUITS	12	39	3.3	16564505	444281	37.3
29 ELECTRICAL MACHINERY, EQUIPMENT AND SUPPLIES	23	109	4.7	14909487	463084	32.2
30 INFORMATION AND COMMUNICAION ELECTRONICS EQUIPME	12	41	3.4	12558964	209837	59.9
31 TRASPORTATION EQUIPMENT	16	80	5.0	53988315	926255	58.3
32 MISCELLANEOUS MANUFACTURING INDUSTRIES	31	130	4.2	3332345	126821	26.3

Note) We take these figures averaging the data from 1999 to 2020 of the Census of Manufacturers

Table 3 Summary of Statistics

	Obs	Mean	Std. Dev.	Min	Max
Log of number of products (lnN_i)	3,046,008	0.387	0.526	0.000	4.997
Davis=Haltiwanger= Schuh index (DH_i)	2,540,425	0.004	0.218	-1.713	1.765
Gross product adding rate	2,536,288	0.180	0.412	0.000	8.000
Gross product dropping rate	2,536,288	0.258	0.450	0.000	8.000
Log of foreign demand ($\ln Y^*_k$)	368	12.906	1.638	8.673	16.726
Log of government expenditure ($\ln G_k$)	368	10.827	1.183	7.527	13.546
Log of sector-level TFP (lnZ_k)	368	-0.046	0.819	-3.057	1.650
Log of firm-level TFP ($lnTFP_i$)	465,717	3.658	2.569	-14.872	12.255

Table 4 Estimation results (1)

Dependent variable: DH_{it} (fixed effects with AR1 and year dummy)

	All firms		Export firms	
Log of foreign demand (ln FD)	**-0.000**	**0.002 ***	**-0.001**	**-0.003**
	-1.00	**1.72**	**-0.71**	**-1.00**
Log of government expenditure (ln DG)	**-0.001 ****	**-0.002 ****	**0.000**	**0.006 ***
	-1.96	**-2.28**	**0.22**	**1.83**
Sector-level TFP (Z)	**0.000**	**0.004 *****	**0.002**	**0.012 ****
	0.43	**2.79**	**0.63**	**2.39**
Firm-level TFP		**0.001**		**0.009 *****
		0.96		**3.92**
Log of num. of products(t-1)	**-0.958 *****	**-0.768 *****	**-0.935 *****	**-0.785 *****
	-1392.83	**-338.15**	**-181.68**	**-83.01**
Constant	**0.086 *****	**-0.015 *****	**0.139 *****	**-0.131 *****
	33.47	**-6.21**	**13.74**	**-12.41**
Sample Size	**2,166,419**	**281,010**	**41,276**	**14,974**
Number of Groups	**336,053**	**94,360**	**9,702**	**4,653**
rho	**0.398**	**0.526**	**0.455**	**0.509**
R2(within)	**0.515**	**0.383**	**0.512**	**0.406**
R2(between)	**0.000**	**0.004**	**0.004**	**0.001**
R2(overall)	**0.000**	**0.000**	**0.000**	**0.000**
F statistics	**138,738.93**	**7,715.68**	**2,545.42**	**503.79**
(p value)	**0.00**	**0.00**	**0.00**	**0.00**

The lower cell in each estimation result shows t-value.

Standard errors are expressed in parentheses. *, **, and *** show significance at 10%, 5%, and 1% levels, respectively.

Table 5 Estimation results (2)

Dependent variable: Gross adding rate (fixed effects with AR1 and year dummy)

	All firms		Export firms	
Log of foreign demand (ln FD)	**0.005 *****	**-0.001**	**0.012 *****	**-0.006**
	8.08	**-0.51**	**3.59**	**-0.90**
Log of government expenditure (ln DG)	**0.001**	**0.001**	**0.010 ****	**-0.001 ***
	0.93	**0.53**	**2.50**	**-0.21**
Sector-level TFP (Z)	**-0.013 *****	**-0.006 ***	**-0.017 *****	**0.011**
	-12.17	**-1.89**	**-2.89**	**1.00**
Firm-level TFP		**-0.002**		**0.016 *****
		-1.17		**3.18**
Log of num. of products(t-1)	**-0.493 *****	**-0.566 *****	**-0.592 *****	**-0.665 *****
	-370.64	**-121.38**	**-52.89**	**-30.83**
Constant	**0.264 *****	**-0.006 *****	**0.071 ***	**-0.109 *****
	36.91	**-0.82**	**1.80**	**-3.50**
Sample Size	**2,163,197**	**280,381**	**40,177**	**14,689**
Number of Groups	**335,954**	**94,235**	**9,656**	**4,589**
rho	**0.136**	**0.384**	**0.179**	**0.369**
R2(within)	**0.078**	**0.079**	**0.098**	**0.099**
R2(between)	**0.000**	**0.001**	**0.001**	**0.001**
R2(overall)	**0.000**	**0.000**	**0.002**	**0.001**
F statistics	**11,849.05**	**1,062.46**	**255.86**	**79.13**
(p value)	**0.00**	**0.00**	**0.00**	**0.00**

The lower cell in each estimation result shows t-value.

Standard errors are expressed in parentheses. *, **, and *** show significance at 10%, 5%, and 1% levels, respectively.

Table 6 Estimation results (3)

Dependent variable: Gross dropping rate (fixed effects with AR1 and year dummy)

	All firms		Export firms	
Log of foreign demand (ln FD)	**-0.005 *****	**-0.002**	**0.012 *****	**-0.001**
	-8.00	**-1.01**	**3.21**	**-0.20**
Log of government expenditure (ln DG)	**-0.006 *****	**-0.003**	**0.001**	**-0.008**
	-8.77	**-1.56**	**0.19**	**-1.06**
Sector-level TFP (Z)	**-0.004 *****	**-0.005**	**-0.010 ****	**0.006**
	-3.60	**-1.56**	**-2.20**	**0.49**
Firm-level TFP		**0.003 ****		**0.010 ***
		1.99		**1.75**
Log of num. of products(t-1)	**-0.035 *****	**-0.004**	**0.013**	**0.009**
	-23.52	**-0.83**	**1.02**	**0.40**
Constant	**0.638 *****	**0.258 *****	**0.488 *****	**0.137 *****
	76.88	**32.51**	**11.59**	**4.01**
Sample Size	**2,162,768**	**280,277**	**39,915**	**14,626**
Number of Groups	**335,932**	**94,204**	**9,635**	**4,569**
rho	**0.121**	**0.363**	**0.154**	**0.361**
R2(within)	**0.039**	**0.069**	**0.110**	**0.150**
R2(between)	**0.111**	**0.011**	**0.003**	**0.000**
R2(overall)	**0.001**	**0.000**	**0.001**	**0.004**
F statistics	**5,316.86**	**915.26**	**312.70**	**126.73**
(p value)	**0.00**	**0.00**	**0.00**	**0.00**

The lower cell in each estimation result shows t-value.

Standard errors are expressed in parentheses. *, **, and *** show significance at 10%, 5%, and 1% levels, respectively.

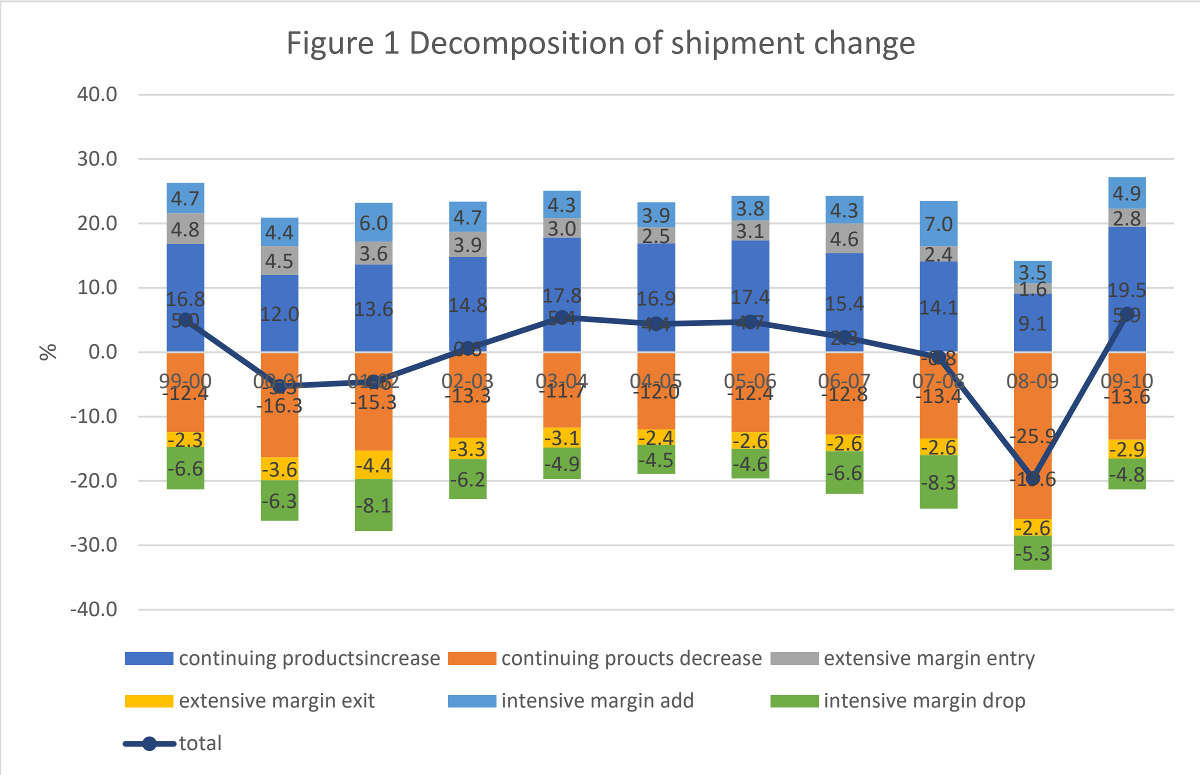


Figure 1 Decomposition of shipment change
%
continuing productsincrease
continuing proucts decrease
extensive margin entry
extensive margin exit
intensive margin add
intensive margin drop
total
99-00
00-01
01-02
02-03
03-04
04-05
05-06
06-07
07-08
08-09
09-10

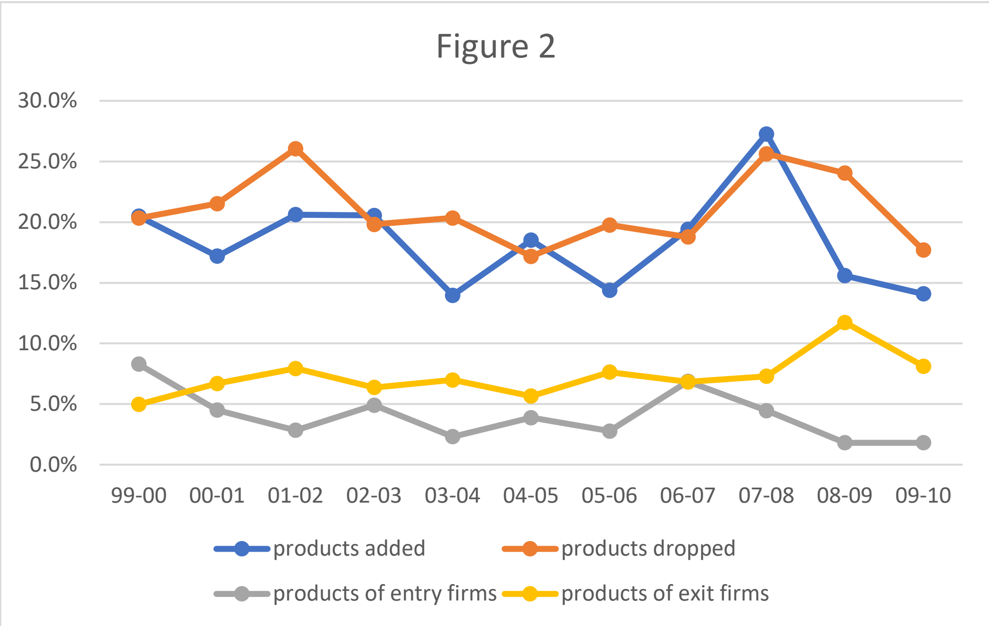


Figure 2
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
99-00
00-01
01-02
02-03
03-04
04-05
05-06
06-07
07-08
08-09
09-10
products added
products dropped
products of entry firms
products of exit firms

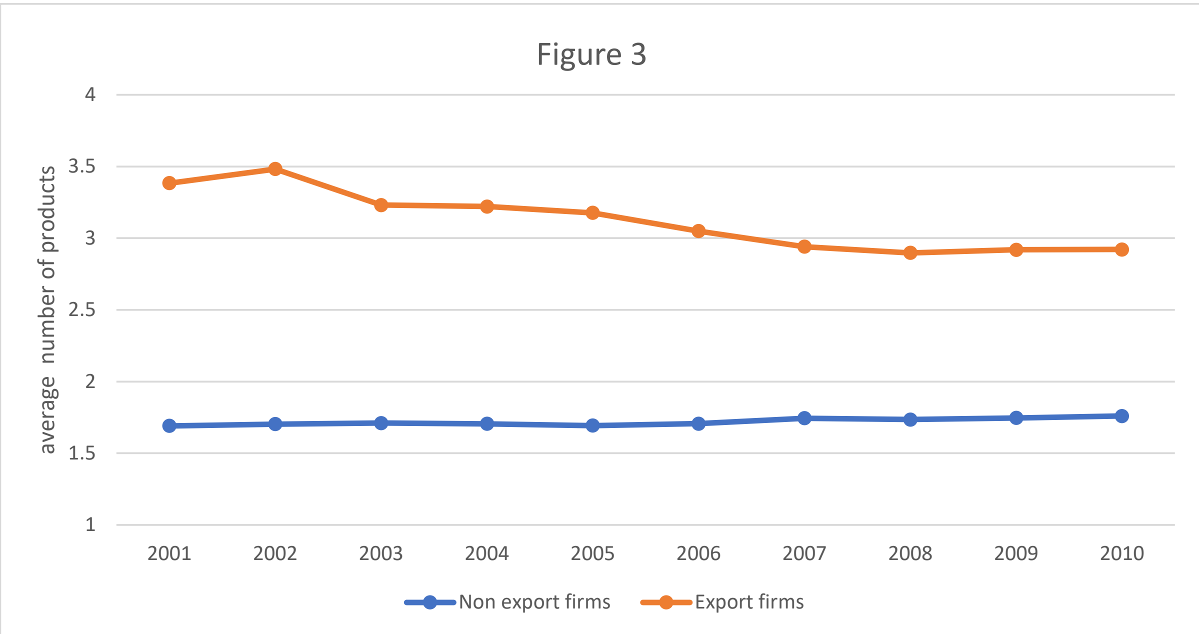


Figure 3
average number of products
4
3.5
3
2.5
2
1.5
1
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Non export firms
Export firms

Figure 4

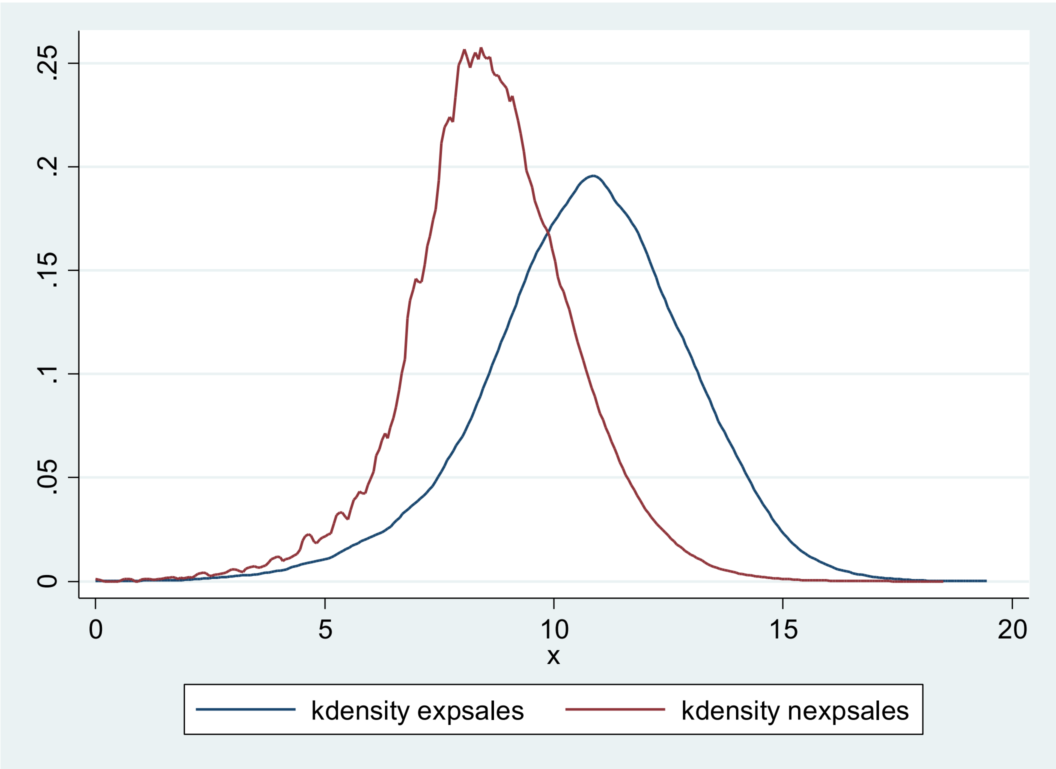
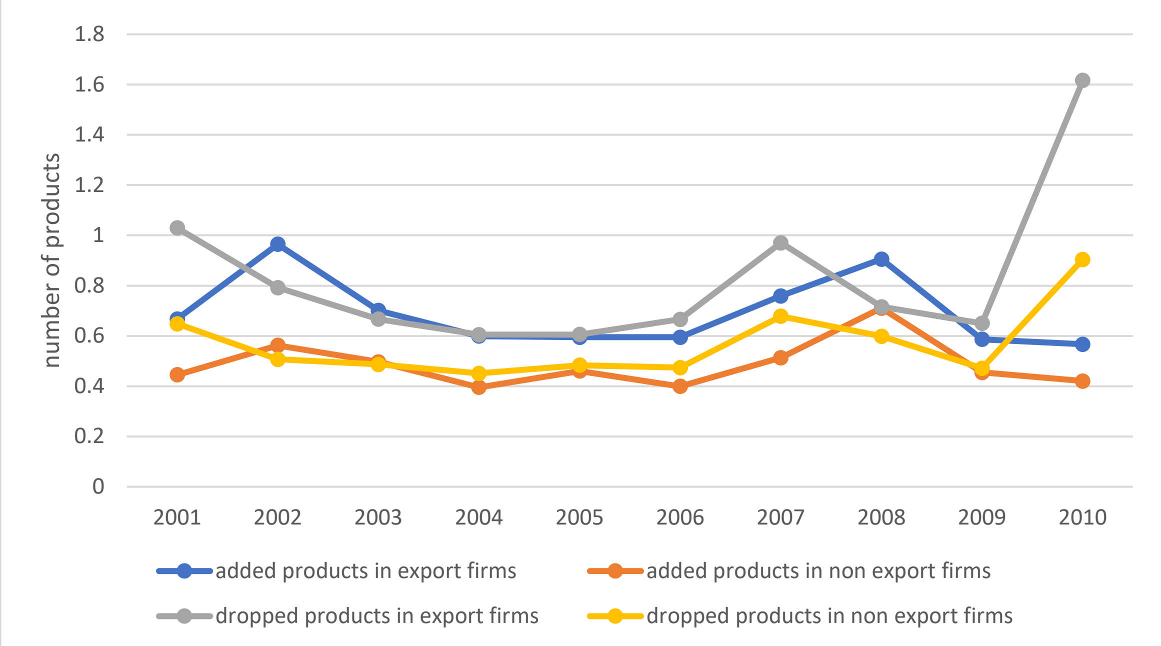


Figure 5



Appendix table 1

	FOOD	BEVERAGES,TOBACCO AND FEED	TEXTILE MILL PRODUCTS	LUMBER AND WOOD PRODUCTS, EXCEPT FOURNITURE	FURNITURE AND FIXTURES	PULP, PAPER AND PAPER PRODUCTS	PRINTING AND ALLIED INDUSTRIES	CHEMICAL AND ALLIED PRODUCTS
l	0.366 ***	0.389 ***	0.643 ***	0.444 ***	0.51 ***	0.501 ***	0.676 ***	0.3 ***
	168.68	11.19	164.68	50.26	38.39	61.76	161.07	24.73
k	0.0991 ***	0.115 ***	0.0831 ***	0.0798 ***	0.0401 **	0.0817 ***	0.0886 ***	0.152 ***
	353.96	19.48	214.58	241.84	3.08	12.79	78.5	9.99
m	0.422 ***	0.415 ***	0.266 ***	0.345 ***	0.377 ***	0.273 ***	0.244 ***	0.359 ***
	65.96	23	32.05	50.22	42.56	60.25	19.4	24.5
q	0.0146 ***	-0.0628 ***	0.0155 ***	0.203 ***	0.0514 **	0.123 ***	-0.545 ***	0.00916
	4.91	-15.26	64.54	6.59	3.29	6.79	-16.29	0.32
n	0.065 ***	0.105 ***	0.0595 ***	0.0596 ***	0.0113	0.0503 ***	0.072 *	0.00505
	22.22	4.74	15.68	19.03	0.99	3.72	2.23	0.14
Yeardummy	No	No	No	No	No	No	No	No
N	119188	12435	70787	18028	18861	25651	59609	18181
N_g	21469	2616	14519	4683	4113	4893	10241	3658
waldT	222.57	7.75	381.63	14.3	0.34	1.32	819.49	501.36
waldP	0	0.01	0	0	0.56	0.25	0	0

	PETROLEUM AND COAL PRODUCTS	PLASTIC PRODUCTS, EXCEPT OTHERWISE CLASSIFIED	RUBBER PRODUCTS	LEATHER TANNING, LEATHER PRODUCTS AND FUR SKINS	CERAMIC, STONE AND CLAY PRODUCTS	IRON AND STEEL	NON-FERROUS METALS AND PRODUCTS	FABRICATED METAL PRODUCTS
l	0.193 ***	0.492 ***	0.524 ***	0.451 ***	0.433 ***	0.451 ***	0.479 ***	0.594 ***
	6.47	67.58	30.65	17.02	140.7	51.72	21.69	667.89
k	0.128 ***	0.0797 ***	0.0749 ***	0.0213	0.0103	0.074 ***	0.191 ***	0.0897 ***
	5.97	172.47	12.46	1.56	0.35	5.31	7.75	275.97
m	0.589 ***	0.324 ***	0.31 ***	0.38 ***	0.378 ***	0.379 ***	0.325 ***	0.324 ***
	10.12	32.8	43.31	26.63	34.38	31.22	24.89	48.02
q	-0.0944 ***	-0.0155	0.123 ***	0.00583	0.201 ***	0.00387	-0.262 ***	0.0364 *
	-4.98	-0.59	6.32	0.32	10.86	0.2	-22.18	2.16
n	-0.0412	0.0436 *	0.0401 *	0.0113	-0.0254	0.0287 ***	0.0146	0.0374 ***
	-0.72	1.98	2.45	1.42	-0.77	69.09	0.54	12.23
Yeardummy	No	No	No	No	No	No	No	No
N	1781	52991	10284	6109	50869	16682	9644	99861
N_g	372	10817	2077	1260	9130	3444	2228	20046
waldT	30.64	259.64	2.82	14.75	0	39.03	171.7	17.06
waldP	0	0	0.09	0	1	0	0	0

	GENERAL-	PRODUCTION	BUSINESS	ELECTRONICPARTS	ELECTRICAL	INFORMATION AND	TRASPORTATION	MISCELLANEOUS
l	0.58 ***	0.639 ***	0.532 ***	0.62 ***	0.542 ***	0.641 ***	0.586 ***	0.556 ***
	60.33	64.84	50.54	72.24	41.12	98.59	62.63	47.82
k	0.0608 ***	0.0701 ***	0.0965 ***	0.126 ***	0.067 ***	0.115 ***	0.119 **	0.0825 ***
	168.48	458.07	184.16	387.98	431.02	211.54	3.17	182.42
m	0.329 ***	0.317 ***	0.3 ***	0.25 ***	0.285 ***	0.241 ***	0.258 ***	0.339 ***
	42.14	92.57	26.8	38.56	92.85	21.25	94.15	36.67
q	0.127 ***	0.223 ***	0.0345 ***	0.457 ***	0.188 ***	0.318 ***	0.00369	0.034 ***
	35.87	142.55	113.73	22.1	8.63	911.55	0.15	8.11
n	0.0255 ***	0.0122 ***	0.0389 ***	-0.0101	-0.0173 ***	0.0404 ***	0.0482	0.0337 ***
	7	7.6	7.65	-0.49	-12.48	7.86	1.24	7.76
Yeardummy	No	No	No	No	No	No	No	No
N	26958	61483	18573	25111	41418	11765	39663	26114
N_g	6663	13764	4643	6308	10018	3620	8761	5453
waldT	156.1	698.23	0.03	4511.83	4.22	2095.41	0.08	14.83
waldP	0	0	0.86	0	0.04	0	0.78	0

The lower cell in each estimation result shows the t-values.

Standard errors are expressed in parentheses. *, **, and *** show significance at 10%, 5%, and 1% levels, respectively.