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ABSTRACT

The collapse of trade during the great recession of 2008–2009 has raised the question of whether the rise of global value chains (GVCs) has increased or accelerated the international transmission of business cycle shocks. In this paper, we empirically investigate two channels through which a country's integration into GVCs may increase the income elasticity of its exports. First, GVCs may simply be concentrated in sectors that are more sensitive to external income fluctuations (composition effect). Alternatively, there may be characteristics that are inherent to GVCs that trigger a faster and more amplified propagation of business cycle shocks (supply chain effect). Using trade data from the People's Republic of China, we find supporting evidence for the composition effect. However, we find no evidence that trade within GVCs have an intrinsically higher income elasticity than regular trade.

I. INTRODUCTION

A distinct feature of the world economy in recent decades has been the international fragmentation of production. Production now often involves many suppliers that are located in several countries, giving rise to global value chains (GVCs). In particular, East Asia has become a key player in the GVCs of products that are consumed in Western markets. Many income-sensitive, high-technology products that can be found on the shelves of Best Buy in the United States (US) or *Fédération Nationale d'Achats des Cadres* (FNAC) in France incorporate components produced in Japan, the Asian Tigers (Hong Kong, China; the Republic of Korea; Singapore; and Taipei,China), the five largest Association of Southeast Asian Nations countries (Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam), and the People's Republic of China (PRC). In many cases, parts and components come from a number of countries and cross borders more than once before they are assembled into final products and shipped to the United States (US) and the European Union (EU).

This trend may well have important implications for the transmission of the business cycle across countries, creating newer and faster channels for the international propagation of adverse external shocks. A growing number of studies have investigated the role of GVCs in the international transmission of business cycle shocks. Burstein, Kurz, and Lesar (2008), Ng (2010), and di Giovanni and Levchenko (2010) find that country pairs with stronger GVC linkages experience higher business cycle correlations, and especially in North–South relations. Freund (2009) and Cheung and Guichard (2009), then again, identify GVCs as an important driver of the steady increase in the long-run elasticity of trade to income over the past few decades to the rise of GVCs. These findings have important implications for a country or region's vulnerability to external shocks. Bems, Johnson, and Yi (2010, 2011) ascribe the large trade collapse during the great recession of 2008–2009 to the growing role of GVCs in international trade. Athukorala and Kohpaiboon (2011), Park, Lee, and Park (2011), and Pula and Peltonen (2011) find that East Asia, which is increasingly integrated in GVCs, has become more vulnerable to business cycle movements in the US and the EU.

It remains unclear, however, through which channels GVCs affect the international transmission of business cycle shocks. Is it merely that international production fragmentation is concentrated in sectors that are more sensitive to external income fluctuations (composition effect)? Or, are there characteristics inherent to GVCs that trigger a faster and more amplified propagation of business cycle shocks (supply chain effect)?

Addressing these questions requires data on trade flows within GVCs, which are difficult to come by (Ma and Van Assche 2010). In this paper, we exploit a unique data set from the *General Administration of Customs of the People's Republic of China* covering the PRC's international trade by customs regime. As we will explain in detail, the disaggregation by customs regimes provides a rare opportunity to compare the drivers of intra-GVC trade versus other trade. Specifically, processing trade unambiguously takes place within GVCs, while non-processing trade acts like regular trade. This breakdown across the PRC's customs regimes allows us to investigate whether the role of GVCs on the transmission of international business cycle shocks is primarily due to a composition effect or a supply chain effect.

We start off by exploring whether international production fragmentation primarily takes place in sectors with a higher income elasticity of exports, thereby creating a composition effect. We find strong evidence of this. First, we find that processing trade is particularly prevalent in durable goods sectors such as electrical machinery and transportation equipment. Second, we find that the PRC's durable goods exports to Organisation for Economic Co-operation and

Development (OECD) countries have an income elasticity that is about four times larger than nondurable goods exports.

Next, we investigate whether there are features inherent to GVC trade that make it more sensitive to external demand fluctuations than regular trade. We consider two channels through which GVCs may be different. First, we assess whether, after controlling for the composition effect, the PRC's processing exports to OECD countries have a significantly higher income elasticity than non-processing exports. We find no systematic evidence of this. Second, we investigate whether final demand shocks amplify as they reverberate upstream through GVCs, creating a bullwhip effect (Escaith and Gonguet 2009; Escaith, Lindenberg, and Miroudot 2010). We only find limited evidence of this in durable goods sectors, and no evidence of this in nondurable goods sectors.

These results have important implications for policy makers. The findings suggest that it is not integration into GVCs per se that increases the sensitivity of a country's exports to foreign business cycles. Rather, it is the fact that GVCs are most prevalent in durable goods sectors, and these sectors have a higher foreign demand elasticity.

We have organized the paper in seven sections. In Section II, we document the growing role of GVCs and East Asia's role. In Section III, we examine the various channels through which GVCs can affect the income elasticity of a country's exports and present the hypotheses we will test in our empirical analysis. In Section IV, we discuss the unique characteristics of the trade data from the PRC's Customs Statistics. In Section V, we then present our empirical strategy and discuss estimation challenges. In Section VI, we present the results of our empirical analysis. Finally, Section VII provides concluding remarks.

II. EAST ASIA'S ROLE IN GVCs

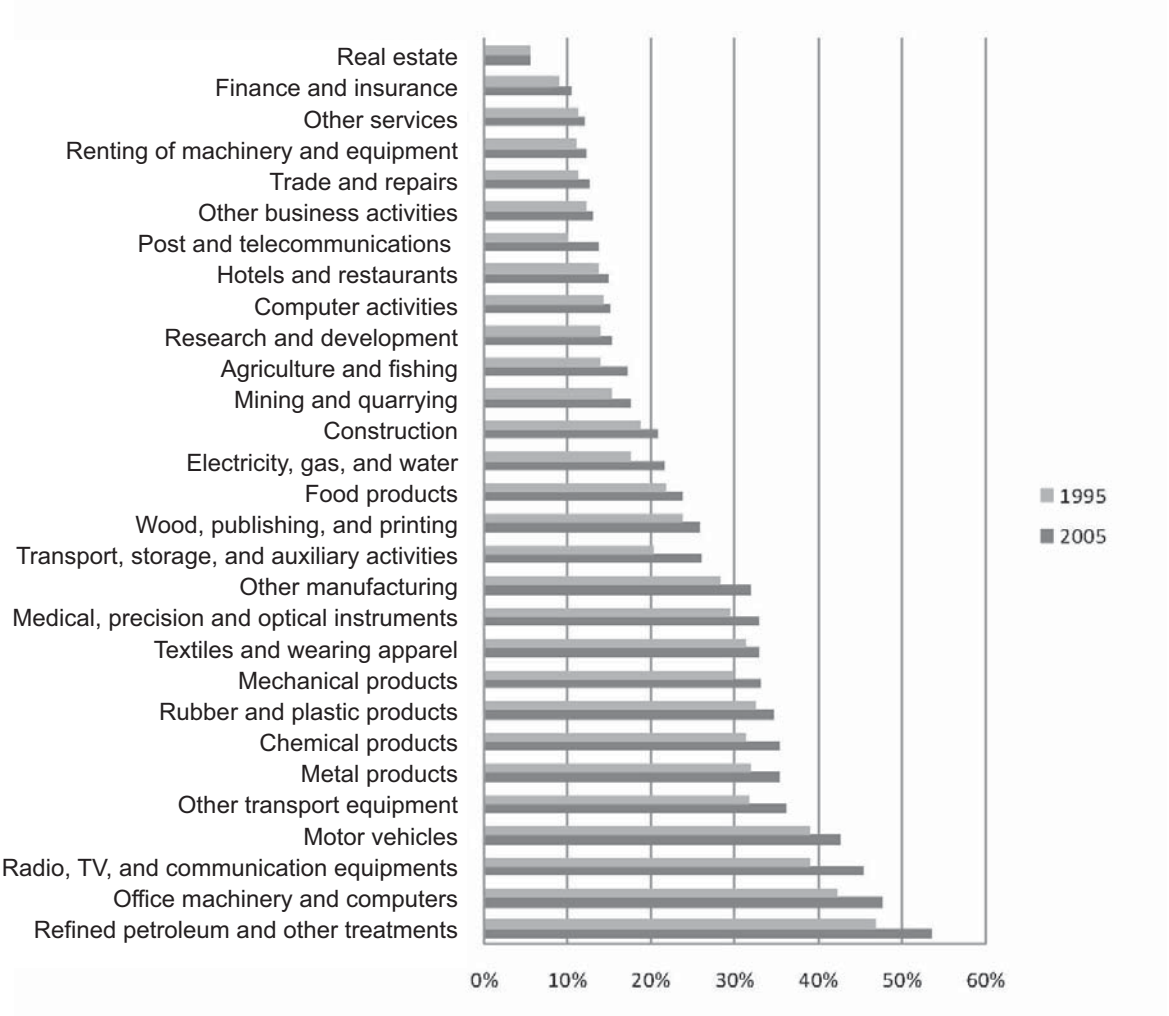
The organization of international production has fundamentally changed in the past few decades. Thanks to reductions in communication costs, transportation costs, and other trade barriers, many firms have sliced up their supply chains and have dispersed their production activities across multiple countries. At the same time, they have outsourced large portions of their supply chain activities to external firms. As a result, the production process of consumer goods now involves many firms that are located in various countries across the globe, giving rise to GVCs.

An implication of the rise of GVCs is that international trade is increasingly dominated by trade in tasks (within GVCs) instead of trade in goods (Grossman and Rossi-Hansberg 2008). Currently, trade in intermediate inputs accounts for roughly two-thirds of international trade (Johnson and Noguera 2012). In addition, countries rely more and more on imported inputs to produce their exports. For instance, Hummels, Ishii, and Yi (2001) use input–output tables for 14 countries and estimate that the import content on average accounted for nearly 21% of the exports value in 1990. Using more recent data, Miroudot and Ragoussis (2009) estimate that the average import content of exports has risen from 26% in 1995 to 31% in 2005.

GVCs have expanded asymmetrically across industries, predominantly emerging in durable goods sectors such as electronic machinery and transportation equipment (Bems, Johnson, and Yi 2011, Miroudot and Ragoussis 2009). As is shown in Figure 1, the import content embodied in exports is on average larger for durable goods than for nondurable goods and services. For key durable goods sectors such as radio, TV and communications

equipments; office machinery and computers; and motor vehicles, import content represented more than 40% of exports value in 2005. For services, import content amounts to less than 15%.

Figure 1: Average Import Content Share of OECD Countries' Exports, Various Industries, 1995 and 2005



OECD = Organisation for Economic Co-operation and Development.

Source: Miroudot and Ragoussis (2009).

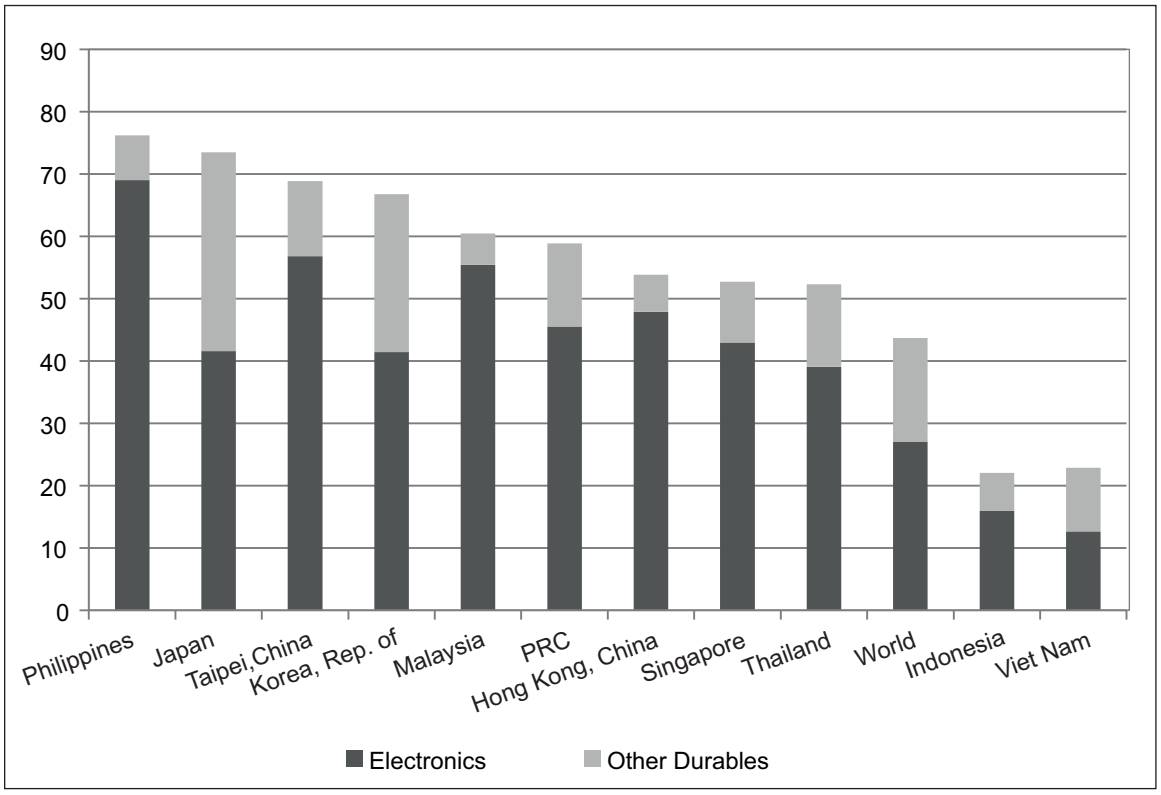
GVCs have also expanded asymmetrically across regions. East Asian economies have taken on a key role in the GVCs of durable goods, effectively turning the region into the "factory of the world."[1] Trade patterns reflect East Asia's growing dominance in durable goods sectors. From 2000 to 2007, East Asia's share in world durable goods exports has grown from 35.2% to 39.0%.[2] The growth in the region's share of the world's durable goods exports is not only due to its overall trade expansion, but also due to its specialization in durable goods trade. As shown in

[1] See Ma and Van Assche (2012) for a discussion of East Asia's role within the GVCs of durable goods.

[2] As we explain in our data appendix, we consider durable goods industries to comprise machinery, electrical, transportation, and miscellaneous manufacturing.

Figure 2, the exports of East Asian economies are more heavily concentrated in durable goods than those of the rest of the world. With the exception of Indonesia and Viet Nam, the share of durable goods exports in total exports exceeded 50% for all East Asian countries in 2007. This is largely due to East Asia's key role in the GVCs of electronics. Electronics constituted more than three quarters of durable goods exports in 2007 for the region, except for Indonesia, Viet Nam, and the two automobile giants, the Republic of Korea and Japan.[3]

Figure 2: Share of Durable Goods and Electronic Products in Total Exports, Various East Asian Economies, 2007 (%)



PRC= People's Republic of China. Electronics = Harmonized System (HS) codes 84 and 85. Other Durables = HS codes 86-97.

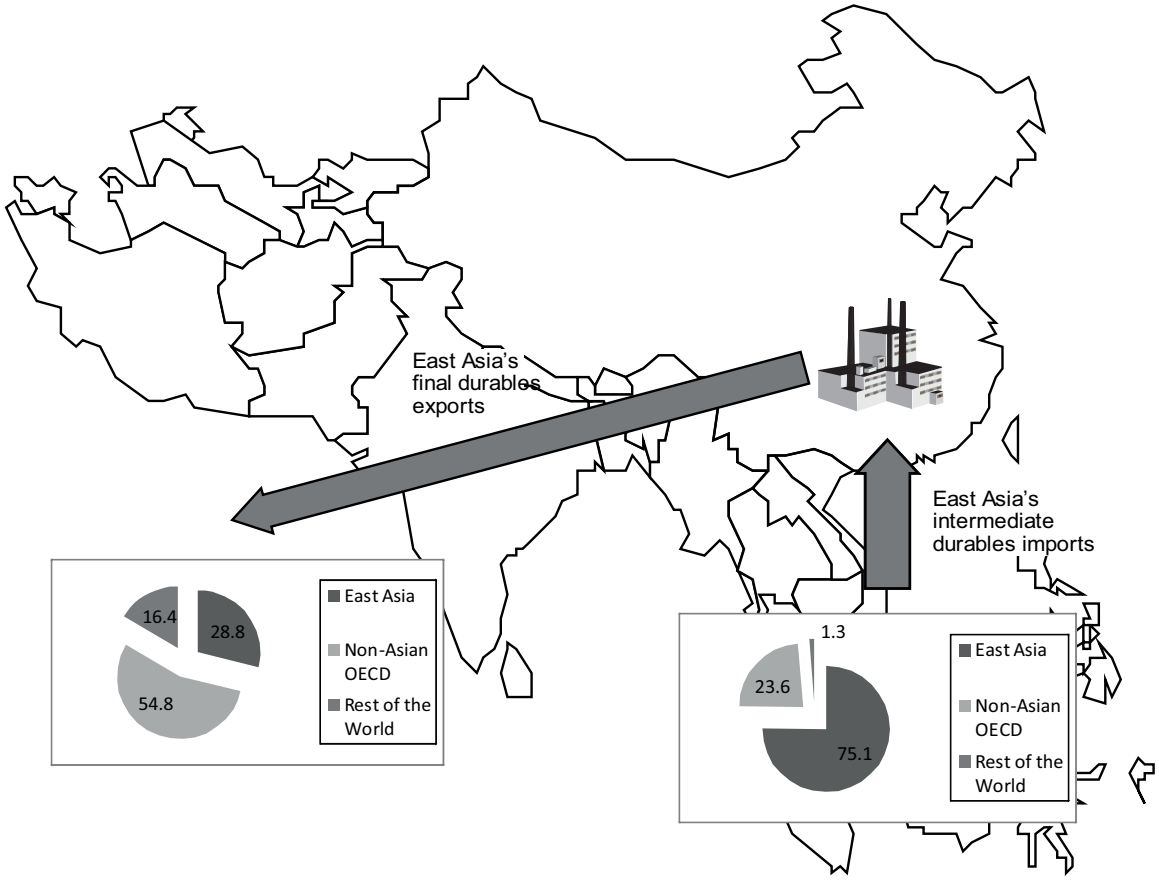
Source: Authors' calculations, using CEPII BACI data.

While durable goods trade has clustered in East Asia, the final consumption of durable goods has remained concentrated in North America and Europe. We can see this by dissecting East Asia's durable goods trade into intermediate and final goods trade.[4] Figure 3 demonstrates that East Asian countries heavily trade intermediate goods among each other to produce durable final goods. Indeed, 75% of East Asia's intermediate durables were imported intra-regionally in 2007. In contrast, only 29% of East Asia's exports of final durable goods were destined intra-regionally, with 55% going to non-Asian OECD countries (essentially the US and the EU) in 2007.

[3] Gangnes and Van Assche (2010, 2012) provide a detailed discussion of East Asia's role in electronics value chains.

[4] We make use of the BEC classification to distinguish between intermediate and final goods trade.

Figure 3: Source and Destination of East Asia's Durable Goods Trade, 2007 (%)



OECD = Organisation for Economic Co-operation and Development.

Source: CEPII BACI trade data.

These trends have led to a growing concern among East Asian policy makers that the region is becoming more vulnerable to business cycle movements in the US and the EU. Economic downturns in these regions, so it is argued, can reverberate globally through supply chains. If intra-GVC trade is especially sensitive to external business cycle shocks, then this can lead to significant export reductions and economic contractions in East Asia.

III. GVCs AS TRANSMISSION CHANNELS

The key question at the heart of this paper is whether and through which channels GVCs affect the international transmission of business cycle shocks. Is it merely that international production fragmentation is concentrated in sectors that are more sensitive to external demand fluctuations (composition effect)? Or are there characteristics inherent to GVCs that trigger a faster and more amplified propagation of business cycle shocks (supply chain effect)? We consider these questions in turn, and use the discussion to frame a number of testable hypotheses.

A. Composition Effect

A first channel through which the rise of GVCs may increase the sensitivity of a country's exports with respect to foreign demand fluctuations is through a composition effect. As we have shown in Figure 2, international production fragmentation has primarily occurred in durable goods sectors. If durable goods exports have a higher sensitivity to foreign demand, measured by income elasticity, then the rise of GVCs will raise the weight of high-income elasticity goods in a country's export bundle, therefore leading to an increase in the income elasticity of their overall exports.

There have only been a limited number of studies that have assessed whether durable goods exports are more income-elastic than nondurable goods exports. Using US trade data, Chinn (2010) finds that US durable goods exports have a higher income elasticity than nondurables.[5] Similarly, using the PRC's data, Aziz and Li (2008) find that export demand elasticities are highest for capital goods, such as machinery and electric and electronics machinery, and lowest for primary products.

A number of studies have relied on this finding to explain the rising income elasticity of trade and the trade collapse during the great recession of 2008–2009. Bems, Johnson, Yi (2011) use a global input–output table to show that the asymmetric expansion of GVCs in durable goods sectors has raised the weight of durable goods in world trade compared to its weight in world gross domestic product (GDP). In 2008, durable goods had grown to almost 40% of trade, but amounted to only 10% of final demand. Building on this stylized fact, Engel and Wang (2011) set up a two-country, two-sector model in which durable goods are tradable while nondurables are nontradable. They show that since durables expenditures are several times more volatile than GDP and international trade is highly concentrated in these durable goods, trade should also experience larger swings than GDP. This has also been used to explain the severity of the trade collapse during the great recession of 2008–2009. Bems, Johnson, Yi (2011) and Eaton et al. (2011) estimate that the composition effect accounted for 70% and 80% of the global decline in the trade-to-GDP ratio during the crisis, respectively.

In this paper, we will use a different data set and a different methodology to analyze the following hypothesis:

Hypothesis 1: *Other things being equal, the income elasticity of export demand is larger for durable goods than for nondurable goods.*

B. Supply Chain Effect

An alternative channel through which GVCs may affect the sensitivity of exports to foreign demand fluctuations is through characteristics that are inherent to their vertically specialized supply chain structure. In that case, we can speak of a supply chain effect.

There is growing evidence that GVC trade is intrinsically different than regular trade, even though it is not clear how this affects the income elasticity of GVC exports. Hummels et al. (2001), Yi (2003), and Gangnes, Ma, and Van Assche (2011) argue that trade within GVCs should be more sensitive to system-wide trade friction shocks than regular trade because of the need for GVC inputs to cross borders multiple times. Aziz and Li (2008) and Freund, Hong, and

[5] Surprisingly, Chinn (2010) finds that US durable goods imports have a lower income elasticity than nondurables.

Wei (2012) find that trade within GVCs is less sensitive to exchange rate movements than regular trade, which they attribute to the lower domestic content of GVC exports.

There are a number of reasons why GVC exports may have a different income elasticity than regular exports. It may be that, within industries, GVCs produce more fashion-sensitive products, which are subject to greater demand volatility. Alternatively, GVCs may be more prone to adopt just-in-time production techniques, which allow them to more rapidly adjust to foreign business cycle shocks. If intra-GVC exports have a higher income elasticity than regular exports, the following hypothesis should hold:

Hypothesis 2: *Within industries, the income elasticity of export demand is larger for intra-GVC trade than for regular trade.*

As an alternative supply chain effect, we consider the possibility that GVCs may amplify business cycle shocks as they propagate up the value chain due to inventory adjustment (Alessandria, Kaboski, and Midrigan 2010, 2011; and Altomonte et al. 2012). Scholars in the field of operations management refer to this as a bullwhip effect.

The existence of a bullwhip effect in GVCs crucially depends on the role of inventories for a firm. To see this, consider the scenario where a firm uses imported inputs M_t to produce exports X_t.[6] The imported inputs are non-perishable so that they can be put in the inventory stock. As a result, the following accounting identity holds:

$$M_t = X_t + I_t - I_{t-1} \quad (1)$$

where $I_t - I_{t-1}$ is the change in the inventory stock of imported inputs. If $I_t - I_{t-1} > 0$, a portion of the imported inputs is put in inventory, leading to an increase in the inventory stock of imported inputs. If $I_t - I_{t-1} < 0$, a portion of the imported inputs is taken out of inventory, leading to a decrease in the inventory stock.

In the long-run equilibrium, $I_t - I_{t-1} = 0$ so that $\bar{M} = \bar{X}$. By inserting the long-run equilibrium into the identity above and rearranging, we then obtain:

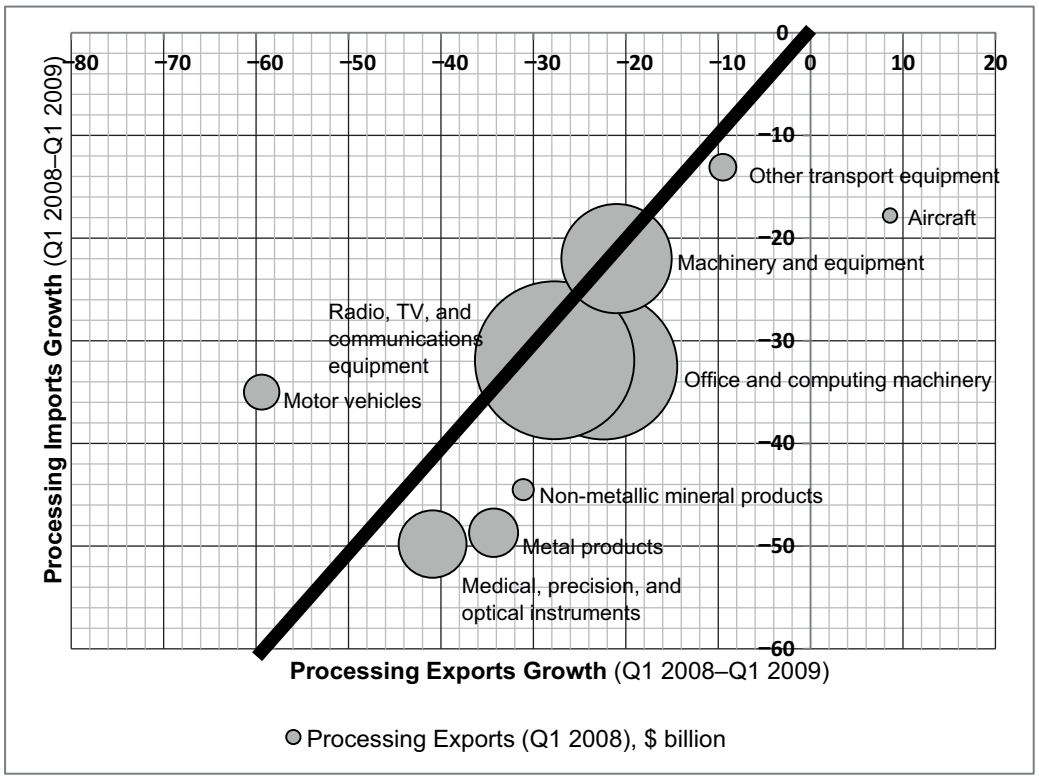
$$\frac{M_t - \bar{M}}{\bar{M}} = \frac{X_t - \bar{X}}{\bar{X}}\left(1 + \frac{I_t - I_{t-1}}{X_t - \bar{X}}\right) = \frac{X_t - \bar{X}}{\bar{X}}(1 + \varphi_t) \quad (2)$$

The equation shows that a deviation from long-run exports growth leads to an amplified deviation in the long-run growth of imported inputs or bullwhip effect if $\varphi_t > 0$. In that case, firms react to above trend exports growth ($X_t - \bar{X} > 0$) by expanding their inventory of imported inputs even further ($I_t - I_{t-1} > 0$). Conversely, firms react to below trend exports ($X_t - \bar{X} < 0$) by depleting their inventory of imported inputs ($I_t - I_{t-1} < 0$). There is no bullwhip effect if $\varphi_t < 0$. In that case, firms react to above trend exports growth ($X_t - \bar{X} > 0$) by depleting their inventory of imported inputs ($I_t - I_{t-1} < 0$). Conversely, they react to below trend exports ($X_t - \bar{X} < 0$) by increasing their inventory of imported inputs ($I_t - I_{t-1} > 0$). The implication is that the demand for imported inputs is inelastic to or smoother than changes in exports demand, leading to production smoothing.

[6] This theoretical exposition builds on Alessandria, Kobaski, and Midrigan (2011). Allowing firms to use both domestic and foreign inputs does not alter the mechanisms of the bullwhip effect.

A number of scholars find evidence of bullwhip effects in international trade during the great recession of 2008–2009. Alessandria, Kobaski, and Midrigan (2011) find that, in the US auto industry, two-thirds of the decline in imports was due to firms running down their inventory stocks, therefore leading to $\varphi_t > 0$. Similarly, Altomonte et al. (2012) used French firm-level data to show that imports of intermediate goods during the crisis overreacted to the final demand shock as firms ran down their inventory stocks. Ma and Van Assche (2011), then again, find that the PRC's processing imports across industries contracted more severely than processing exports in the first quarter of 2009 compared to a year earlier. As is shown in Figure 4, with the exception of motor vehicles, all durable goods sectors lie to the right of the 45-degree line, suggesting that processing imports dropped by a larger percentage than processing exports.

Figure 4: Bullwhip Effect in the People's Republic of China's Processing Trade Regime during the Great Recession of 2008–2009



Source: Ma and Van Assche (2010).

During noncrisis years, however, the evidence of the bullwhip effect is not as clear-cut. Cachon, Randall, and Schmidt (2007) use monthly sales and inventory data from the US Census Bureau and only find evidence of a bullwhip effect in some manufacturing and wholesale industry. Using monthly firm-level data, Bray and Mendelson (2011) find that two-thirds of the publicly-traded companies bullwhip, whilst one-third conducts production smoothing.

In this paper, we analyze if there is a bullwhip effect in GVCs by postulating the following hypothesis:

Hypothesis 3: *Other things being equal, the elasticity of imported inputs with respect to export demand within GVCs exceeds 1.*

Scholars in operations management attribute the existence and size of the bullwhip effect to the degree of demand uncertainty that firms face in an industry (Chen and Lee 2009; Lee, Padmanabhan, and Whang 1997). If a firm faces low demand uncertainty, then an unexpected shock to demand will generally have a limited impact on a firm's forecast of future demand. As a result, the firm will react to the shock in demand by adjusting its inventories instead of its production, therefore leading to $\varphi_t < 0$. Conversely, if a firm faces a highly unpredictable future demand, then it may use observed current demand to update its demand forecasts for the future. For example, if a firm experiences an unexpected surge in demand, it may interpret this as a signal of higher future demand. In that case, the firm may react to the demand shocks by placing a disproportionately larger order for intermediate inputs, leading to $\varphi_t > 0$.

The role of demand uncertainty may explain why bullwhip effects are only found in some industries with high demand uncertainty. Furthermore, it may explain why many studies found evidence of a bullwhip effect during the great recession of 2008–2009, a period where most industries faced heightened demand uncertainty. We use these insights to frame our final hypothesis:

Hypothesis 4: *Other things being equal, the elasticity of imported inputs with respect to export demand is larger for industries with a high uncertainty of demand.*

IV. TRADE DATA FROM THE PRC's CUSTOMS STATISTICS

To test our hypotheses, we use a unique trade dataset from the PRC's Customs Statistics for the years 1995–2009. Similar to regular trade data, this dataset records for each flow of goods across the PRC's border, the product classification, the value and quantity shipped, the year of shipment, and the source/destination country. Unique to this dataset, however, it also provides information on the customs regime under which an international flow takes place. This is useful for our purposes since one customs regime—the processing trade regime—is intensively used by GVCs, while other customs regimes reflect mostly regular trade.

In the mid-1980s, the PRC government instituted the processing trade regime to entice foreign firms to transfer their production activities to the PRC, while protecting the domestic market from foreign competition. Under this regime, firms located in the PRC are granted duty exemptions on imported raw materials and other inputs as long as they are used solely for export purposes. Since firms only have the incentive to use this customs regime if they import components for export purposes, processing exports unambiguously reflect intra-GVC trade. Furthermore, since the processing imports are required to be used for export purposes, we can explore whether downstream shocks are amplified as they move up the GVC, i.e., from processing exports to processing imports.

Three stylized facts highlight the relative size and distinctive nature of the PRC's processing trade versus non-processing trade. First, the share of processing exports in the PRC's total exports has risen from 49.5% in 1995 to 55.2% in 2004, and has then decreased to 48.9% in 2009. In other words, throughout the sample period, roughly half of the PRC's exports were intra-GVC trade and the other half regular trade.

Second, as can be expected within GVCs, processing exports rely more heavily on imported inputs than non-processing exports. In a recent paper, Koopman, Wang, and Wei (2008) combine the PRC's Customs Statistics trade data with an input–output table for the PRC to estimate the domestic content share of the PRC's processing and non-processing exports. They find that in 2006 the domestic content share of processing exports was only 18.1%, implying that the value of imported inputs accounted for 81.9% of the processing export value. Conversely, the domestic content share of non-processing exports stood much higher at 88.7%, meaning that imported inputs only represented 11.3% of the non-processing export value.[7]

Third, processing exports are predominantly conducted by foreign invested enterprises (FIEs),[8] whereas non-processing exports are largely conducted by local firms. The share of processing exports conducted by FIEs has varied from a high of 89.7% in 1995 to a low of 84.1% in 2009. Conversely, FIEs' share of non-processing exports has consistently remained below 30%.

Similar to the rest of East Asia (see section II), the PRC's integration into GVCs has been primarily in the fastest growing durable goods sectors. We can see this from the following stylized facts. First, processing trade has been particularly important in the fastest growing export industries during the period 1995–2009. As is shown in column 3 of Table 1, the highest annualized export growth rates were in the sectors machinery, electrical (32%); transportation (25%); plastics and rubbers (24%); and miscellaneous manufacturing (23%). Column 5 of Table 1 highlights that these are precisely the four industries in which the processing exports share is highest. In particular, 77.3% of exports in machinery, electrical occurred under the processing trade regime in 2009. For transportation, plastics and rubbers, and miscellaneous manufacturing, processing exports amounted to 60.9%, 59.9%, and 44% of industry exports, respectively.

The three sectors machinery, electrical; miscellaneous manufacturing; and transportation also happen to be the sectors that most intensively export durable goods. Figure 5 depicts the share of durable goods in the PRC's sector exports. In 2009, 68.3% of exports in machinery, electrical were durable goods. For miscellaneous manufacturing and transportation, the shares were 56.1% and 30.3%, respectively. In this paper, we consider durable goods to comprise these three sectors, while nondurables capture all other sectors.[9]

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[7] Using similar trade data, Aziz and Li (2008) argue that the domestic content of the PRC's trade processing has increased in recent years. This finding, however, has been contested by Koopman et al. (2008).

[8] Foreign-invested enterprises include wholly foreign-owned enterprises, Sino-foreign contractual joint ventures with more than 25% foreign ownership, and Sino-foreign equity joint ventures with more than 25% foreign ownership. Note that in the PRC's Customs Statistics, companies from Hong Kong, China; Macau, China; and Taipei,China are considered foreign firms.

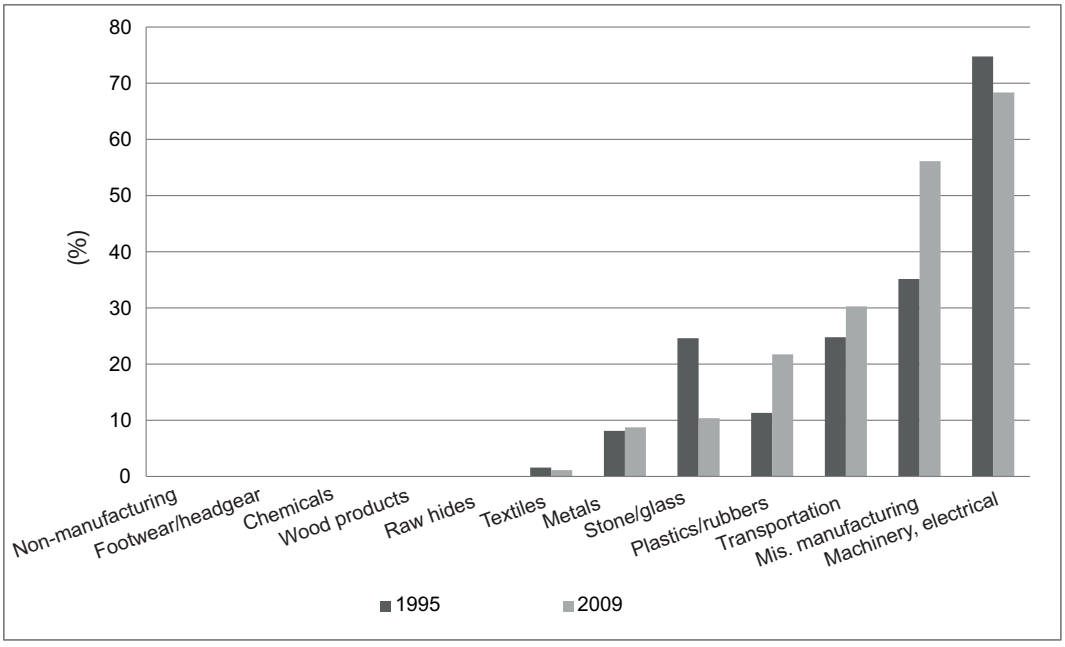
[9] Our main results are unaffected by the inclusion of *plastics and rubbers* as a durable goods sector.

Table 1: PRC's Exports, by Sector, Various Years

	Share of Total Exports (%)		Annualized Growth Rate (%)	Processing Exports Share (%)	
	1995	2009	1995–2009	1995	2009
Machinery, electrical	10.09	43.03	32.17	70.2	77.3
Transportation	2.14	4.18	25.04	77.8	60.9
Plastics and rubbers	1.75	3.16	24.29	58.9	59.9
Miscellaneous manufacturing	6.49	10.76	23.54	50.2	44.0
Footwear and headgear	3.20	3.12	18.93	56.2	39.1
Stone and glass	2.30	2.00	18.01	13.1	20.0
Wood and wood products	2.55	1.90	16.70	11.8	31.6
Non-manufacturing	20.42	4.62	16.22	11.4	22.8
Other	0.39	0.27	16.22	2.67	1.76
Metals	10.34	6.39	15.13	44.5	19.6
Chemical and allied industries	8.07	4.40	14.09	12.1	17.6
Textiles	28.67	14.57	13.53	41.8	20.8
Raw hides, skins, leathers, and furs	3.59	1.59	12.39	62.2	25.5
Total	**100.00**	**100.00**	**19.15**	**49.5**	**48.9**

Source: Authors' calculations using the PRC's Customs Statistics data.

Figure 5: Share of Durable Goods in the PRC's Exports to OECD Countries, by Sector, Various Years (%)



OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Source: Authors' calculations using the PRC's Customs Statistic.

V. EMPIRICAL STRATEGY

A. Export Demand Model

To analyze the sensitivity of the PRC's exports to foreign demand fluctuations, we estimate variants of the workhorse export demand model (Goldstein and Kahn 1985). To take into account the effect of rapid industrialization and productivity improvements in the PRC unleashed by structural reforms, however, we modify the standard export demand equation by adding a supply side variable (Chinn 2010, Gagnon 2003):

$$lnx_{kt} = \alpha + fe_k + \beta lnrgdp_{kt} + \gamma lnrer_t + \delta \ln sup_t + \varepsilon_{kt} \quad (3)$$

where the dependent variable lnx_{kt} is the natural logarithm of the PRC's real exports to OECD countries in industry *k* at time *t*, fe_k are industry fixed effects, $lnrgdp_{kt}$ is the natural log of real trade-weighted foreign GDP of the PRC's trade partners at time *t*, $lnrer_t$ is the natural log of real exchange rate of the yuan versus foreign currencies, $\ln sup_t$ is a supply side variable and ε_{kt} is an error term. We expect β to be positive, indicating that the PRC's exports increase with foreign demand. We expect γ to be negative, meaning that a real appreciation of the PRC's currency raises the price of its exports, therefore reducing its exports. Finally, δ is expected to be positive since an increase in supply capacity will increase the PRC's exports, all else being equal.

To avoid potential spurious results due to nonstationary regressors, we estimate the equation in differenced logarithm form (approximate growth rates):[10]

$$\Delta lnx_{kt} = \alpha + fe_k + \beta \Delta lnrgdp_{kt} + \gamma \Delta lnrer_t + \delta \Delta \ln sup_t + \varepsilon_{kt} \quad (4)$$

To test if durable goods exports are more sensitive to foreign GDP fluctuations than nondurable goods, we create a dummy variable *dur* that equals 1 for durable goods industries and 0 otherwise. We then estimate the following equation:

$$\Delta lnx_{kt} = \alpha + fe_k + \beta_1 \Delta lnrgdp_{kt} + \beta_2 \Delta lnrgdp_{kt} * dur_k + \gamma_1 \Delta lnrer_t + \gamma_2 \Delta lnrer_t * dur + \delta_1 \Delta \ln sup_t + \delta_1 \Delta \ln sup_t * dur_k + \varepsilon_{kt} \quad (5)$$

If Hypothesis 1 holds, we should find that the interaction term β_2 is positive and significant, which suggests that durable goods exports are more sensitive to foreign GDP fluctuations than nondurable goods exports.

To test if processing exports are more sensitive to foreign GDP fluctuations than non-processing exports—after controlling for the composition effect—we disaggregate the PRC's sectoral exports into processing versus non-processing exports. We then create a dummy variable *proc* that equals 1 for processing exports and 0 otherwise. To test Hypothesis 2, we estimate the following specification:

[10] An alternative approach is to estimate the log-linear model directly in a cointegration (equivalently error-correction) framework, as is done, for example in Aziz and Li (2008) and Cheung, Chinn, and Qian (2012), This has the advantage of including information contained in the levels of the variables that is lost under differencing, as well as easier comparability with results of many previous studies. In a panel setting, estimation of cointegrating relationships is complicated by heteroskedasticity and potential cross-sectional dependence (Bai, Kao, and Ng 2009; Kapetnios 2011). In our particular case, the very short available time series makes evaluation and treatment of these issues difficult. For the current analysis, we have opted to work with stationary differenced variables, although we plan to explore panel cointegration methods in subsequent research.

$$\Delta lnx_{rkt} = \alpha + fe_{rk} + \beta_1 \Delta lnrgdp_{kt} + \beta_2 \Delta lnrgdp_{kt} * proc_r + \gamma_1 \Delta lnrer_t + \gamma_2 \Delta lnrer_t * proc_r + \delta_1 \Delta \ln sup_t + \delta_2 \Delta \ln sup_t * proc_r + \varepsilon_{rkt} \quad (6)$$

where subscript *r* stands for regime, and fe_{rk} are industry-regime dummies. If Hypothesis 2 holds, the coefficient on β_2 should be positive: the elasticity of processing exports with respect to income is larger than for non-processing exports within the same industry.

To investigate if shocks are amplified as they move upstream along a GVC, we analyze if the elasticity of processing imports pm_{kt} with respect to processing exports px_{kt} exceeds unity. For this purpose, we use the following specification:

$$\Delta lnpm_{kt} = \alpha + fe_k + \beta \Delta lnpx_{kt} + \varepsilon_{kt} \quad (7)$$

Hypothesis 3 will hold if β is significantly larger than unity.

Finally, to analyze if sectors with a higher uncertainty of demand have a larger bullwhip effect, we need to create a variable *vol* that increases with the degree of demand uncertainty (i.e., volatility). This will allow us to test hypothesis 4 using the following specification:

$$\Delta lnpm_{kt} = \alpha + fe_k + \beta_1 \Delta lnpx_{kt} + \beta_2 \Delta lnpx_{kt} * vol_k + \varepsilon_{kt} \quad (8)$$

If Hypothesis 4 holds, β_2 should be positive and significant.

Classifying industries according to their uncertainty of demand is not a straightforward exercise since it requires insights into the firms' expectations of demand. In our analysis, we therefore consider two different measures to proxy for the uncertainty of demand. First, we consider the coefficient of variation of a sector's processing exports growth during the sample period. We acknowledge, however, that this is potentially a poor measure of demand uncertainty since it ignores the effect of supply side factors on export growth fluctuations. Furthermore, the annual nature of our data does not allow us to capture short-term demand changes (monthly or quarterly), which are most likely to affect firms' inventory management decisions. Indeed, Hummels and Schaur (2010) estimate demand uncertainty by calculating the coefficient of variation for an industry within each year, an exercise that we cannot replicate. Second, we rely on Hummels's (2001) and Hummels and Schaur's (2010) findings that trading firms generally use fast and expensive air shipping to deal with demand uncertainty. Hummels (2001) estimates that the industries listed in Table 2 are the time-sensitive industries in which firms are most willing to pay the highest air premium for fast delivery (see Hornok [2011] who has made a similar argument). These industries are roughly the durable goods industries, and we therefore will investigate if the bullwhip effect is larger for durable goods industries than nondurables.

Table 2: Time-Sensitive Industries, by NACE Industry

NACE	Time sensitive
29	Machinery and equipment
30	Office machinery and computers
31	Electrical machinery and apparatus
32	Radio, TV, and communication equipment
33	Medical, precision, and optical instruments
34	Motor vehicles, trailers, and semi-trailers
35	Other transport equipment

NACE = The statistical classification of economic activities in the European Community (in French: Nomenclature statistique des activités économiques dans la Communauté européenne).

Source: Hornok (2011), based on Hummels (2001).

B. Estimation Challenges in Previous PRC Trade Research

There have been a limited number of studies in recent years that model the PRC's trade flows using variants of the workhorse export demand model. Often the motivation for this research has been the debate over the PRC's growing trade surplus and its possible link to an undervalued currency. Generally speaking, these studies have found it difficult to estimate models with reasonable parameters or with much precision.[11] In part, these disappointing results reflect the limited available sample period, and the difficulty capturing the dramatic supply-side changes that have come with rising productive capacity and productivity. They may also reflect the difficulty applying aggregate models driven by final demand to the PRC's trade that is increasingly focused in processing goods manufacture.

Cheung, Chinn, and Qian (2012) represents a recent attempt to explore a range of potential explanations for the poor fit of the traditional trade model to the PRC's trade flows. They find that the standard log-linear model provides a reasonable description of the PRC's export behavior, once allowance is made for a deterministic trend. Aggregate exports of the PRC respond to foreign income, measured by weighted average real GDP, with an elasticity of about 1.4, and there is considerable sensitivity to relative prices, with an elasticity to real exchange rate changes of about 1.6 over the 1994–2010 period. Imports of the PRC are another story. The standard trade model results in a very large income elasticity of about 3.2 and a large and significant perverse relative price effect, even when the sample is constrained to the post-World Trade Organization (WTO) accession period. They find more reasonable income and price effects when the PRC exports are used as the "income" determinant of the PRC imports. In all cases, the results are sensitive to the inclusion of time trends.

Cheung, Chinn, and Qian (2012) proceed to explore alternative specifications that disaggregate trade flows along a number of lines, including customs regime (processing versus ordinary trade), manufactured goods versus primary products, and state-owned enterprises versus foreign-invested enterprises and other private firms. The hypothesis is that the changing composition and nature of the PRC's trade might cause aggregate estimates to be unstable.[12] They find that export price elasticities vary considerably with the type of firm. On the import side, results are very sensitive to the level of disaggregation and the use of alternative income

[11] See Cheung, Chinn, and Qian (2012). Garcia-Herrero and Koivu (2007) review papers from 1999 onward.

[12] They also consider other control variables, including changing gender ratio, the nominal exchange rate regime, and commodity prices, as well as a potential role for fixed asset investment as a determinant of manufactured goods.

proxies. Moreover, there are a number of specifications that yield perverse income or price effects.

Aziz and Li (2008) address the same issue, whether changing composition of trade may explain the instability in aggregate elasticity estimates. Using rolling regressions, they show that elasticity estimates have changed considerably over time, with export sensitivity rising in recent years. Import elasticities show less change, consistent with the less dramatic changes in composition of these trade flows. They provide evidence of widely differing (and evolving) elasticities across industries, and of a role for customs regime and product sophistication in explaining changing trade sensitivity.

Other recent studies illustrate the sensitivity of the PRC's trade equation estimates to model specification, level of aggregation, and econometric approach. Among studies that break out processing and non-processing trade, Thorbecke and Smith (2010) use dynamic ordinary least squares in cross-country panels of the PRC's exports, including capital stock to proxy for supply growth and a WTO accession dummy. They find reasonable estimates for income and weighted average exchange rate elasticities, with a considerably higher income sensitivity for processing exports than for non-processing exports. In a Johansen multivariate cointegration framework, Garcia-Herrero and Koivu (2007) find large and significant real exchange rate elasticities on PRC exports (–1.3 for processing and –1.8 for ordinary trade), but the perverse import relative price effect that has been found in some other studies. The authors attribute the latter to the importance of export good competitiveness in driving the demand for imported inputs. Income elasticities are small, although they increase following WTO accession. Marquez and Schindler (2007) use an unusual trade share specification to sidestep the problem of inadequate price measures for deflating trade flows of the PRC. They find that an appreciation of the yuan reduces the PRC's share of world exports. On the import side, an appreciation increases the demand for ordinary imports, but reduces the demand for processing imports.

Using an error-correction specification on a panel of PRC exports to the US, EU, and Japan, Shu and Yip (2006) find large and significant long-run effects of real exchange rate change on export flows of the PRC. Estimated income effects are very large, likely reflecting an inadequate proxying of trend export growth. They find that processing trade is somewhat less sensitive to relative price changes than ordinary trade, income elasticities do not differ much. Ahmed (2009), who uses a growth rate specification similar to ours, finds large and significant effects of currency appreciation on the PRC's exports, although estimated income effects are improbably large.

Many researchers have specified the PRC's import demand equations using real GDP of the PRC as the appropriate "income" measure, effectively treating these imports as final goods. Cheung, Chinn, and Qian (2012) include the PRC's capital investment variable in import equations, and find that this term has a larger effect than GDP for some types of goods. Freund, Hong, and Wei (2012) use partner country exports to the rest of the world as a driver for imports of the PRC. This differs from our approach of modeling the PRC's demand for processing imports as a function of the country's processing exports.

The conclusion we draw from this review of previous research is that reliable estimation of the PRC's trade elasticities is particularly challenging. Elasticity estimates vary widely and are very sensitive to specification, sample period, and treatment of events such as the 2001 WTO accession. The literature does not provide any clear results for the potential differences between the behavior of processing and non-processing trade.

C. Data and Specification

In this subsection, we provide a description of the data used in the present analysis and details of our equation specification. We use annual data for the PRC's exports and imports that are available at the detailed commodity level, broken down by customs regime (processing versus non-processing trade).[13] The trade data have been aggregated into the 12 major industries described in Appendix 1. We also describe our data sources in the appendix.

Following Aziz and Li (2008), we exclude data prior to 1994 since the unification of the PRC's exchange rate system in 1994 has likely introduced a structural break. Our dataset therefore runs over the period 1995–2009.

A challenge for modeling the PRC's trade is the lack of adequate price deflators for a sufficient sample period (PRC trade price series begin in 2005). A number of proxy series have been used, including the unit value indices for trade via Hong Kong, China; world trade price series from international organizations; or US import price deflators (see the discussion in Cheung, Chinn, and Qian 2012). We adopt the latter approach. Following Chinn (2006), we deflate exports of the PRC using the US Bureau of Labor Statistics price deflator for imports from nonindustrial countries. Chinn (2006) finds that this series closely matches the US Bureau of Labor Statistics price deflator for imports from the PRC, which became available in 2003.

For the foreign income measure $rgdp_{kt}$, we use the export-weighted real GDP of the OECD countries, where weights equal the shares of the PRC's exports destined to each OECD country over the period 1995–2009. Note that $rgdp_{kt}$ differs across industries since the composition of the PRC's export destinations also varies across sectors.

Ideally, we would also have a real exchange rate variable rer_t that varies across industries. Due to the poor coverage of export prices for the PRC, however, we rely on the International Monetary Fund's consumer price index deflated trade-weighted index of the yuan against a broad basket of currencies.

Previous studies have used a wide variety of supply side factors to capture the PRC's rise in productive capacity. In our primary regressions, we use as supply side variable total factor productivity (TFP) growth of the PRC, obtained from the Conference Board's Total Economy Database. However, since previous studies have shown that the trade elasticities can be highly sensitive to the supply side factor used, in the appendix we also report regressions using two alternative supply side variables: the PRC's relative productivity, measured by the PRC's real GDP per capita relative to the US output-per-man-hour in the nonfarm business sector (PROD), and the PRC's fixed asset investment to GDP ratio (FAI). Our main results are unaffected by the choice of supply side factor.

All our regressions are estimated with a single lag of each independent variable to allow for the possibility of gradual adjustment of the PRC's exports to income and exchange rate movements. This also helps to eliminate first-order serial correlation from regression residuals.[14]

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[13] The dataset can be sliced in various ways. We have explored a separate approach that analyzes the determinants of trade within a panel of PRC exports to various OECD countries. The results were generally unsatisfactory, often resulting in insignificant or perversely signed coefficients. Exploration of this panel in a nonstationary level analysis suggests that these poor results may be due to substantial heterogeneity across destination country markets.

[14] Preliminary specification tests indicate both heteroskedasticity and first-order serial correlation are present in the industry panel. An appropriate robust estimator due to Woolridge (2002) is used to address these concerns. Results are generally robust to estimation under alternative assumptions about the nature of the panel regression error term.

VI. RESULTS

Our regression results are presented in Tables 3–6. In all equations, we compute standard errors that are robust to heteroscedasticity and auto-correlation within panels, i.e., panel clustered standard errors (Woolridge 2002). In each case, we report results for four specifications: with and without lagged effects, and with and without the TFP supply proxy. As noted, our preferred specification includes the supply side variable $\Delta lntfp_t$ and 1-year lags, and our discussion will primarily focus on the results under this specification.

Table 3 reports coefficient estimates for equation (4). The income elasticity is positive and significant and varies between 1.0 when no supply side factor is introduced (columns 1 and 3) and 1.4 with the inclusion of $\Delta lntfp_t$ (columns 1 and 4). The price elasticity is negative, and the significant effect usually occurs with a 1-year lag. The price elasticity is large in absolute value, although within the range of previous studies, with a cumulative effect ranging from about 1.4 to 1.7. Total factor productivity exerts a significant positive effect on exports. The magnitude of this effect is not large, however, presumably because industry-specific fixed effects are capturing much of the trend growth in exports. The traditional export equation appears to do a reasonable job of describing the PRC's exports in this industry panel.

Table 3: Panel Regressions: Standard Export Equation with Supply Proxy Regression Results, 1995–2009

Dependent Variable	Exports Growth			
	(1)	(2)	(3)	(4)
$\Delta \ln RGDP$	1.07	1.19*	1.04*	1.39**
	[0.60]	[0.66]	[0.52]	[0.53]
$\Delta \ln RGDP$ (1-lag)			0.36	0.28
			[0.27]	[0.40]
$\Delta \ln RER$	–0.73*	–0.52*	–0.50	0.10
	[0.28]	[0.29]	[0.34]	[0.33]
$\Delta \ln RER$ (1-lag)			–1.18***	–1.53***
			[0.33]	[0.37]
$\Delta \ln TFP$		0.00		0.01***
		[0.00]		[0.00]
$\Delta \ln TFP$ (1-lag)				–0.01***
				[0.00]
Industry Dummies	Yes	Yes	Yes	Yes
Observations	168	168	156	156
R-squared	0.23	0.24	0.39	0.44

RER = Yuan's real exchange rate against a broad basket of currencies, RGDP = Export-weighted real GDP of the OECD countries, TFP = PRC's total factor productivity.

Notes: Standard errors in brackets are robust to heteroscedasticity and auto-correlation within panels.
* means significant at 10%, ** means significant at 5%, *** means significant at 1%.
Coefficients on constant and fixed effects not reported.

Source: Authors' estimates.

In Table 4, we report estimates of equation (5). In line with Hypothesis 1, we find that the coefficient on the term interacting foreign GDP and the durable goods dummy is consistently positive and significant, suggesting that the PRC's durable goods exports are more sensitive to income fluctuations in OECD countries than are nondurable goods exports. In our preferred specification in column 4, the size of the coefficient is 2.7, indicating that the income elasticity of durable goods exports is almost 4 times as large as the income elasticity of durable goods exports (1.1). There is no evidence that durable goods exports have a different price elasticity than nondurable goods exports, or that they have a different relationship with TFP growth.

Table 4: Panel Regressions: Durable versus Nondurable Exports Regression Results, 1995–2009

Dependent Variable	**Exports Growth**			
	(1)	**(2)**	**(3)**	**(4)**
$\Delta \ln RGDP$	0.65	0.80	0.70	1.09**
	[0.51]	[0.59]	[0.46]	[0.48]
$\Delta \ln RGDP$ * durable	3.13***	3.10***	2.59***	2.66***
	[0.64]	[0.72]	[0.76]	[0.60]
$\Delta \ln RGDP$ (1-lag)			0.29	0.26
			[0.26]	[0.23]
$\Delta \ln RGDP$ * durable (1-lag)			0.63*	0.80*
			[0.32]	[0.44]
$\Delta \ln RER$	–0.71*	–0.41	–0.30	0.35
	[0.36]	[0.33]	[0.34]	[0.35]
$\Delta \ln RER$ * durable	0.17	–0.02	–0.55	–0.67
	[0.51]	[0.53]	[0.90]	[0.75]
$\Delta \ln RER$ (1-lag)			–1.35***	–1.71***
			[0.41]	[0.44]
$\Delta \ln RER * durable$ (1-lag)			0.79	1.13
			[0.54]	[0.72]
$\Delta \ln TFP$		0.01		0.02***
		[0.00]		[0.00]
$\Delta \ln TFP$ * durable		–0.00		-0.01
		[0.00]		[0.01]
$\Delta \ln TFP$ (1-lag)				–0.02***
				[0.00]
$\Delta \ln TFP$ * durable (1-lag)				0.01*
				[0.00]
Industry Dummies	Yes	Yes	Yes	Yes
Observations	168	168	156	156
R-squared	0.26	0.27	0.43	0.48

RER = yuan's real exchange rate against a broad basket of currencies, RGDP = export-weighted real GDP of the OECD countries, TFP = PRC's total factor productivity.

Notes: Standard errors in brackets are robust to heteroscedasticity and auto-correlation within panels.
* means significant at 10%, ** means significant at 5%, *** means significant at 1%.
Coefficients on constant and fixed effects not reported.

Source: Authors' estimates.

In Table 5, we estimate equation (6). Counter to Hypothesis 2, we find no evidence that processing exports have a different income elasticity than non-processing exports within the same sector. Indeed the coefficients on $\Delta lnrgdp_{kt} * proc_r$ and its 1-year lag are insignificant across all four specifications. There is some evidence that processing exports may have a different price responsiveness than non-processing exports. In the model with lagged regressors, the real exchange rate movement has a larger immediate impact on processing exports, although this difference is attenuated or reversed after two periods. This result is interesting, considering that other researchers (Aziz and Li 2008; Freund, Hong, and Wei 2012) have found processing trade to have a lower price sensitivity than non-processing exports, and have attributed this to lower local content.

In Table 6, we estimate equations (7) and (8). Counter to Hypothesis 3, we find no evidence that the elasticity of processing imports with respect to processing exports exceeds unity. Indeed the coefficient on $\Delta lnpm_{kt}$ is roughly 0.9, suggesting that demand shocks are dampened as they are transmitted from processing exports to processing imports. While this result seems in contrast to previous studies that have found evidence of a bullwhip effect during the great recession of 2008–2009 (Alessandria, Kaboski, and Midrigan 2011; Altomonte et al. 2012; Ma and Van Assche 2011), it needs to be noted that this discrepancy can be consistent with theory. Severe economic downturns such as the great recession of 2008–2009 are likely to create greater-than-usual demand uncertainty. From our theoretical exposition above, this implies that bullwhip effects can emerge during severe economic downturns in industries that do not normally have bullwhip effects.

We find mixed evidence that the elasticity of processing imports with respect to processing exports is larger for industries with a larger demand uncertainty. Columns 2 and 5 of Table 6 suggest that there is no evidence that sectors with a higher export volatility have a larger elasticity. As we have explained above, this may be because our measure of export volatility poorly captures the degree of demand uncertainty that firms face. We do find weak evidence that the elasticity is larger (roughly 1.0) for durable goods sectors than for nondurable goods sectors, which is in line with Hypothesis 4.

In sum, we find little evidence that there are factors inherent to the structure and operation of GVCs that may have led to an increase in the income elasticity of exports. Instead, the results are consistent with the notion that the driving force has been the increasing role of durable goods in trade of the PRC. The GVC impact on trade then comes from the role of this production structure in facilitating growth of trade in durable goods in recent years.

Table 5: Panel Regressions: Processing versus Non-processing Exports Regression Results, 1995–2009

Dependent Variable	Exports Growth			
	(1)	(2)	(3)	(4)
$\Delta \ln RGDP$	1.06	1.26*	1.24*	1.55**
	[0.62]	[0.69]	[0.61]	[0.56]
$\Delta \ln RGDP$ * processing	0.13	–0.18	–0.23	–0.23
	[0.94]	[0.97]	[0.80]	[0.80]
$\Delta \ln RGDP$ (1-lag)			0.34	0.05
			[0.28]	[0.14]
$\Delta \ln RGDP$ * processing (1-lag)			0.27	0.56
			[0.46]	[0.44]
$\Delta \ln RER$	–0.94***	–0.59*	–0.11	0.53
	[0.23]	[0.33]	[0.35]	[0.38]
$\Delta \ln RER$ * processing	0.28	–0.26	–1.10*	–1.24**
	[0.44]	[0.50]	[0.54]	[0.53]
$\Delta \ln RER$ (1-lag)			–1.48***	–2.16***
			[0.35]	[0.33]
$\Delta \ln RER$ * processing (1-lag)			0.93**	1.41***
			[0.43]	[0.47]
$\Delta \ln TFP$		0.01*		0.01***
		[0.00]		[0.00]
$\Delta \ln TFP$ * processing		–0.01**		-0.00
		[0.01]		[0.00]
$\Delta \ln TFP$ (1-lag)				–0.02***
				[0.00]
$\Delta \ln TFP$ * processing (1-lag)				0.01***
				[0.00]
Industry-regime Dummies	Yes	Yes	Yes	Yes
Observations	336	336	312	312
R-squared	0.22	0.22	0.37	0.48

RER = yuan's real exchange rate against a broad basket of currencies, RGDP = export-weighted real GDP of the OECD countries, TFP = total factor productivity.

Notes: Standard errors in brackets are robust to heteroscedasticity and auto-correlation within panels.
* means significant at 10%, ** means significant at 5%, *** means significant at 1%.
Coefficients on constant and fixed effects not reported.

Source: Authors' estimates.

Table 6: Panel Regressions: Bullwhip Effect
Regression Results, 1988–2009

Dependent Variable	Processing Imports Growth					
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln Processing\ Exports$	0.87***	0.84***	0.82***	0.90***	0.91***	0.83***
	[0.10]	[0.19]	[0.12]	[0.10]	[0.19]	[0.12]
$\Delta \ln Processing\ Exports$ * volatility		0.02			–0.01	
		[0.10]			[0.10]	
$\Delta \ln Processing\ Exports$ * durable			0.21			0.25*
			[0.15]			[0.14]
$\Delta \ln Processing\ Exports$ (1-lag)				0.05	0.07	0.04
				[0.06]	[0.14]	[0.06]
$\Delta \ln Processing\ Exports$ * volatility (1-lag)					–0.02	
					[0.05]	
$\Delta \ln Processing\ Exports$ * durable (1-lag)						0.00
						[0.18]
Industry Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	252	252	252	240	240	240
R-squared	0.61	0.61	0.62	0.65	0.65	0.66

Notes: Standard errors in brackets are robust to heteroscedasticity and auto-correlation within panels.
* means significant at 10%, ** means significant at 5%, *** means significant at 1%.
Coefficients on constant and fixed effects not reported.

Source: Authors' estimates.

VII. CONCLUSIONS

This paper asks whether there is something about GVCs that makes trade in such goods more sensitive to foreign demand disturbances than "regular" trade. In other words, do GVCs amplify the international transmission of business cycle shocks? The answer from our analysis is no, or at least not for reasons that are inherent to GVCs. Using data from the PRC's processing trade regime, we find no significant difference in the income elasticity of the PRC's processing and non-processing exports, once one controls for the industry composition of trade. Furthermore, we find little evidence of bullwhip effects propagating within GVCs.

That is not to say that GVCs are unimportant in business cycle transmission. But their primary role comes through their impact on the composition of traded goods. GVCs are most prevalent in durable goods industries, which we find to be particularly sensitive to business cycle fluctuations—for the PRC, four times as sensitive as nondurable goods. As GVCs have grown, durable goods have become a larger part of trade, particularly for East Asian developing economies at the core of these production networks. As a result, the overall exports of a country like the PRC or Malaysia now likely respond more dramatically to a boom or bust in the US or Europe than in the past.

Our analysis suggests that East Asian decoupling from the US and the EU is not likely to occur in the near future. If anything, the growth of GVCs has increased interdependence both

within the region and between Asia, North America, and Europe. Technology has made it easier than in the past to exploit comparative advantage, by locating component production where it can occur at lowest relative cost. Future changes in manufacturing methods, transportation costs, and other factors can be expected to alter production arrangements, and growth within Asia will help to diversify markets for the region's final goods. But it seems unlikely that the extent of interdependence will diminish significantly.

Analysis of GVC trade is complicated by the difficulty of identifying such trade from among all trade flows between the countries. In this paper, we have addressed this problem by focusing on the PRC's unique processing trade regime. Because, under the regime, all processing inputs must ultimately end up as processing exports, this trade is by definition GVC trade. However, working with the PRC's processing trade data presents some challenges. Perhaps most important, the PRC has short available data history, in our case extending back only to 1995. This time period has been marked by extraordinary structural transformations that make estimating stable trade relationships difficult. Because of the PRC's restrictive exchange rate policy, there is also limited real exchange rate movement, making it difficult to estimate relative price effects. For these reasons, previous literature has often found it difficult to obtain reasonable elasticity estimates and has found estimates to be sensitive to model specification. In our view, the results of the current paper should therefore be treated with caution. Further research is certainly called for to assess the robustness of our results.

Appendix 1: Data Sources

Table A1.1: Industries Classification

HS Codes	Industry Description	Durable versus Nondurable
01–27	Nonmanufacturing	Nondurable
28–38	Chemical and allied industries	Nondurable
39–40	Plastics and rubbers	Nondurable
41–43	Raw hides, skins, leathers and furs	Nondurable
44–49	Wood & wood products	Nondurable
50–63	Textiles	Nondurable
64–67	Footwear & headgear	Nondurable
68–71	Stone and glass	Nondurable
72–83	Metals	Nondurable
84–85	Machinery, electrical	Durable
86–89	Transportation	Durable
90–97	Miscellaneous manufacturing	Durable

HS = Harmonized Commodity Description and Coding System.

Source: Authors' compilation.

Table A1.2: Data Sources

Variable	Definition/Source
PRC's exports	Data from [People's Republic of] *China Custom Statistics* in $, linked to re-exports data from Census and Statistical Office of Hong Kong, China.
Export prices	US Bureau of Labor Statistics price deflator for imports from non-industrial countries
Export-weighted real GDP	Export-weighted real GDP of the OECD countries, where weights equal the share of PRC exports destined to an OECD country over the period 1989–2009. The real GDP data were collected from the IMF's *International Financial Statistics.*
Real effective exchange rate	IMF's CPI deflated trade-weighted index of the yuan against a broad basket of currencies
TFP growth	Obtained from Conference Board's *Total Economy Database*
Relative productivity	PRC real GDP per capita relative to the US output per man-hour in the nonfarm business sector. Real GDP per capita was obtained from the IMF's *International Financial Statistics*. US output per man-hour in the nonfarm business sector was collected from the US Bureau of Labor Statistics.
Fixed asset investment to GDP ratio	Stock of the PRC's fixed asset investment data and GDP data come from the [People's Republic of] *China Statistical Yearbook*
Durable goods sectors	Sectors *Machinery (electrical), Transportation equipment,* and *Miscellaneous Manufacturing*

CPI = consumer price index, GDP = gross domestic product, IMF = International Monetary Fund, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China, TFP = total factor productivity, US = United States.

Source: Authors' compilation.

Appendix 2: Alternative Supply-Side Factors

Table A2.1: Panel Regression Results, 1995–2009

Dependent Variable	Exports Growth	
	(3)	(2)
$\Delta \ln RGDP$	1.75***	0.72
	[0.51]	[0.44]
$\Delta \ln RGDP$ (1-lag)	0.97***	0.47**
	[0.26]	[0.18]
$\Delta \ln RER$	0.89**	–1.34**
	[0.33]	[0.43]
$\Delta \ln RER$ (1-lag)	–0.54*	–1.33***
	[0.28]	[0.27]
$\Delta \ln PROD$	3.23***	
	[0.59]	
$\Delta \ln PROD$ (1-lag)	–5.34***	
	[0.57]	
$\Delta \ln FAI$		–0.33*
		[0.17]
$\Delta \ln FAI$ (1-lag)		–1.43***
		[0.40]
Industry Dummies	Yes	Yes
Observations	156	156
R-squared	0.50	0.51

FAI = PRC's fixed asset investment as a share of GDP, PROD = PRC's productivity relative to the US, RER = yuan's real exchange rate against a broad basket of currencies, RGDP = export-weighted real GDP of the OECD countries.

Notes: Standard errors in brackets are robust to heteroscedasticity and auto-correlation within panels.
* means significant at 10%, ** means significant at 5%, *** means significant at 1%.
Coefficients on constant and fixed effects not reported.

Source: Authors' estimates.

Table A2.2: Panel Regression Results, 1995–2009

Dependent Variable	Exports Growth	
	(1)	(2)
$\Delta \ln RGDP$	1.41**	0.38
	[0.49]	[0.35]
$\Delta \ln RGDP$ * durable	2.26**	2.95**
	[0.90]	[0.94]
$\Delta \ln RGDP$ (1-lag)	0.89***	0.40
	[0.27]	[0.19]
$\Delta \ln RGDP$ * durable (1-lag)	0.38	0.83*
	[0.38]	[0.40]
$\Delta \ln RER$	0.95**	–0.96**
	[0.37]	[0.42]
$\Delta \ln RER$ * durable	–0.20	-1.09
	[0.90]	[1.13]
$\Delta \ln RER$ (1-lag)	–0.68*	–1.39***
	[0.34]	[0.35]
$\Delta \ln RER * durable$ (1-lag)	0.54	0.29
	[0.47]	[0.47]
$\Delta \ln PROD$	3.35***	
	[0.80]	
$\Delta \ln PROD$ * durable	–0.91	
	[0.93]	
$\Delta \ln PROD$ (1-lag)	–5.02***	
	[0.68]	
$\Delta \ln PROD$ * durable (1-lag)	–0.64	
	[1.40]	
$\Delta \ln FAI$		–0.50*
		[0.17]
$\Delta \ln FAI$ * durable		1.09***
		[0.24]
$\Delta \ln FAI$ (1-lag)		–0.95**
		[0.37]
$\Delta \ln FAI$ * durable (1-lag)		–1.95***
		[0.58]
Industry Dummies	Yes	Yes
Observations	156	156
R-squared	0.53	0.57

FAI = PRC's fixed asset investment as a share of GDP, PROD = PRC's productivity relative to the US, RER = yuan's real exchange rate against a broad basket of currencies, RGDP = export-weighted real GDP of the OECD countries.

Notes: Standard errors in brackets are robust to heteroscedasticity and auto-correlation within panels.
* means significant at 10%, ** means significant at 5%, *** means significant at 1%.
Coefficients on constant and fixed effects not reported.

Source: Authors' estimates.

Table A2.3: Panel Regression Results, 1995–2009

Dependent Variable	Exports Growth	
	(1)	(2)
$\Delta \ln RGDP$	1.84***	0.64
	[0.57]	[0.47]
$\Delta \ln RGDP$ * processing	0.05	0.31
	[0.77]	[0.71]
$\Delta \ln RGDP$ (1-lag)	0.87***	0.31*
	[0.26]	[0.17]
$\Delta \ln RGDP$ * processing (1-lag)	0.43	0.57
	[0.46]	[0.39]
$\Delta \ln RER$	1.03**	–0.81*
	[0.42]	[0.41]
$\Delta \ln RER$ * processing	–0.35	–1.51**
	[0.61]	[0.63]
$\Delta \ln RER$ (1-lag)	–0.89***	–1.45***
	[0.30]	[0.31]
$\Delta \ln RER$ * processing (1-lag)	0.92**	0.51
	[0.43]	[0.38]
$\Delta \ln PROD$	2.98***	
	[0.58]	
$\Delta \ln PROD$ * processing	0.15	
	[0.97]	
$\Delta \ln PROD$ (1-lag)	–4.62***	
	[0.61]	
$\Delta \ln PROD$ * processing (1-lag)	–1.76	
	[1.16]	
$\Delta \ln FAI$		–0.79***
		[0.12]
$\Delta \ln FAI$ * processing		0.93***
		[0.24]
$\Delta \ln FAI$ (1-lag)		-0.68*
		[0.37]
$\Delta \ln FAI$ * processing (1-lag)		–1.76***
		[0.56]
Industry-regime Dummies	Yes	Yes
Observations	312	312
R-squared	0.47	0.51

FAI = PRC's fixed asset investment as a share of GDP, PROD = PRC's productivity relative to the US, RER = yuan's real exchange rate against a broad basket of currencies, RGDP = export-weighted real GDP of the OECD countries.

Notes: Standard errors in brackets are robust to heteroscedasticity and auto-correlation within panels.
* means significant at 10%, ** means significant at 5%, *** means significant at 1%.
Coefficients on constant and fixed effects not reported.

Source: Authors' estimates.

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Global Value Chains and the Transmission of Business Cycle Shocks

In this paper, we investigate empirically two channels through which a country's integration into global value chains (GVCs) may increase the income elasticity of its exports. First, GVCs may simply be concentrated in sectors that are more sensitive to external income fluctuations (a composition effect). Alternatively, some characteristics inherent to GVCs may trigger a faster and more amplified propagation of business cycle shocks (a supply chain effect). Using trade data of the People's Republic of China, we find supporting evidence for the composition effect. However, we find no evidence that trade within GVCs has an intrinsically higher income elasticity than regular trade.

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