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Dollar Invoicing, Global Value Chains, and the Business Cycle Dynamics of International Trade

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Dollar Invoicing, Global Value Chains, and the Business Cycle Dynamics of International Trade

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ABSTRACT: Recent literature has highlighted that international trade is mostly priced in a few key vehicle currencies and is increasingly dominated by intermediate goods and global value chains (GVCs). Taking these features into account, this paper reexamines the relationship between monetary policy, exchange rates and international trade flows. Using a dynamic stochastic general equilibrium (DSGE) framework, it finds key differences between the response of final goods and GVC trade to both domestic and foreign shocks depending on the origin and ultimate destination of value added and the intermediate shipments involved. For example, the model shows that in response to a dollar appreciation triggered by a US interest rate increase, direct bilateral trade between non-US countries contracts more than global value chain oriented trade which feeds US final demand, and exports to the US decline much more when measured in gross as opposed to value added terms. We use granular data on GVCs at the sector level to document empirical evidence in favor of these key predictions of the model.

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1 Introduction

This paper examines the implications of two empirically documented features of the evolving international trade system that could potentially alter the response of exports to monetary policy and exchange rate fluctuations. The first feature is the dominant currency pricing (DCP) of international trade (see Boz et al, 2019 and Gopinath, 2020 et al). Globally, a large share of exports are priced in key "vehicle" currencies such as the US dollar or Euro.[1] Second, international trade is increasingly dominated by global value chains (GVC) in which intermediate materials cross borders multiple times before the value added reaches the final consumption destination.[2]

Under DCP, the passthrough of exchange rates to export prices for non-dominant countries is significantly reduced, and the export competitiveness effects from exchange rate adjustment are muted. Instead, adjustment occurs primarily through imports, where passthrough is close to complete.[3] However, we find that global value chains introduce another export based channel of exchange rate adjustment, particularly in the case of DCP. An appreciation of the dominant currency disrupts materials trade and leads to a shift towards domestic content of exports. We find, theoretically and empirically, that there can be limited adjustment of *gross* exports following such an appreciation, accompanied by a sharp increase in the domestic *value added* embedded in exports.

We model a three country New Keynesian DSGE trading system where two "regional" economies trade with each other, as well as trade outside the region with a large economy issuing the dominant global economy. We model a simple global value chain operating in this world. Each regional economy operates an export platform producing goods to satisfy final demand from the broader global economy. Each export platform uses both domestic value added and imported regional and global inputs. Modeling a platform export sector allows us to clearly delineate an economy's gross exports from the domestic value added embedded in exports. Following the DCP paradigm, the global currency is used for all regional and global trade, and regional currencies are used only for their own domestic economy. When the dominant currency appreciates relative to a regional currency, both global *and* regional materials become uncompetitive, even if cross exchange rates between the two regional economies remain stable. This induces a strong shift toward the domestic

[1] DCP contrasts with producer currency pricing (PCP) models with trade priced in the exporter's currency (Obstfeld and Rogoff ,1995), or local currency pricing (LCP), with trade priced in importer's currency (Betts and Devereux. 1996). The prevalence of DCP has been documented in several studies, for instance Goldberg and Tille (2008), Gopinath (2016), Kamps (2006) and Ito and Chinn (2013).

[2] See for instance Johnson and Noguera (2012), Hummels, Ishii and Yi (2001) and Koopman, Wang and Wei (2014).

[3] See Cook and Devereux (2006a, 2006b), Goldberg and Tille (2009), and Gopinath et al (2020).

value added content of exports to the global economy, even as economies' gross exports decline due to the disruption of intra-regional trade.

We examine the equilibrium effects of domestic and external monetary policy shocks that appreciate the dominant global currency relative to domestic exchange rates. Each shock leads to a decline in intraregional trade and gross exports of the regional economies. We emphasize two predictions of the model to an external policy led appreciation of the dominant currency that we subsequently test in the data. First, the theory predicts that value added exports [4] to the regional economy contract by more than value added exports to the dominant economy. Second, the domestic value added content of exports to the dominant economy increase relative to gross exports of the regional economy, due to the disruption of materials trade.

Testing these predictions of the model is difficult using standard international trade databases that do not capture global value chain activity.[5] The rising prominence of the global value chains also implies that empirical measurement must distinguish between the gross exports leaving an economy's borders and the domestic value added content of those exports. It must also distinguish the immediate destination of the exports as well as the final destination after further border crossings. To accomplish this we use a granular decomposition of international trade flows combining input-output tables at the sector level developed by Wang, Wei and Zhu (2013, 2017 a and b) to identify the origin and the destination of the value added content of trade. We use it to test the degree to which exchange rate changes shift the domestic content of exports. We find that value added exports through the global value chain to the US react much less in response to US interest shocks than does trade to other countries, which is in line with DCP. This is due to the fact that changes in the global value of the US dollar directly affect the domestic currency price of dollar invoiced imports for customers not in the US. However, customers in the US are insulated from the global value of the dollar, as their imports are priced in dollars. We therefore also find, consistent with our model, that the level of domestic content of exports relative to total gross exports to the US increases following a US interest shock.[6]

[4] Value added exports from country A to B denote the value added generated in country A that is eventually absorbed as final demand in country B. This may include direct exports of final goods, direct exports of intermediate goods that are used to produce and consume final goods within B, or indirect exports via third countries in GVCs. See for instance Johnson and Noguera (2012) and Wang, Wei and Zhu (2013).

[5] Custom regulations in certain sectors of countries like China that require processing imports to be recorded separately are an exception to this trend.

[6] While the main focus of our analysis is to study the relationship between exchange rates and international trade, we use a specific shock to the interest rate (either domestic or foreign) to condition the movements in the exchange rate. Since the exchange rate is an endogenous variable, the literature has recently emphasized the importance of such conditioning on the nature of the shock-see for instance Forbes et al (2018) and García-Schmidt and Garcia-Cicco (2018).

The remainder of this paper is organized as follows. This section concludes with an overview of the related literature. We lay out the benchmark model in section 2. Section 3 discusses the calibration and illustrates the main dynamics of the model. Section 4 discusses the data and presents empirical results motivated by the model. Section 5 concludes with a summary of the main messages and policy implications that arise from the analysis.

Literature review

While we take the currency of trade invoicing as given, a number of papers have identified factors determining this currency choice. These factors include nominal and real volatility (Devereux et al. 2004 and Engel, 2006), price elasticities (Friberg, 1998), currency hedging (Golberg and Tille, 2008), imported inputs (Novy, 2006), financial market development and openness (Ito and Chinn, 2013; Ito and Kawai, 2016), market size (Bacchetta and van Wincoop, 2004), and transaction costs (Portes and Rey, 1998). In addition, the emergence of dominant currencies has also been attributed to strategic complementarities interacting with country size, (Mukhin, 2019), the number of independent currencies, (Devereux and Shi, 2013) and currency of financial contracts (Gopinath and Stein, 2018).

Goldberg and Tille (2008) and Kamps (2006) were among the first to collect data on invoicing currencies for a broad set of countries, finding a heavy role for the US and Europe. This data is extended in Ito and Chinn (2013) and Gopinath (2016). Devereux, Hinton, and Dong (2016) and Goldberg and Tille (2016) identify the currency invoicing choice of Canadian importers. Zhang (2019) and Goldberg and Tille (2009) and Gopinath et al (2020) study how spillovers of US monetary policies are affected by currency of invoicing, and show how higher shares of foreign currency invoicing makes domestic monetary policy less potent. Gopinath et al, (2020), Egorov and Mukhin (2019) and Goldberg and Tille (2009) study optimal policy under dollar invoicing. These papers however do not focus on the distinction between gross and value added trade flows, which is our key contribution.

The phenomena of global value chains has been one of the defining and most celebrated facets of globalization over the last few decades (Baldwin and Lopez Gonzales (2015)). Hummels, Ishii and Yi (2001) and Hummels Rappoport and Yi (1998) were among the first to quantify the prevalence of vertical specialization in international trade, documenting a 20% growth in vertical specialization between 1970 and 1990. Recent advances in both data and methodology over the last 10 years has led to a resurgence in the literature studying GVCs. Johnson and Noguera (2012) propose a framework to decompose gross trade flows into value added components. Koopman Wang and Wel (2014) provide a framework to decompose gross exports into a more granular eight-term decomposition, including measures such as

reexports to third countries and reexports back to the original export country, as well as double counted value added terms. Wang, Wei and Zhu (2013, 2017a, 2017b) have extended the framework of Koopman, Wang and Wei (2014) to allow for a similar decomposition of trade flows at the bilateral and sector levels. Such data has led to a reexamination of several classical questions in international economics. For example, Patel, Wang and Wei (2019) study how real effective exchange rates should be interpreted in a world with global value chains. While we focus on business cycle implications of global value chains, there is also an extensive literature arguing in favor of structural benefits of global value chain participation in terms of increase in overall output and productivity.[7]

2 Model

We model a trading system consisting of two regional economies, A and B, each with its own currency, along with a global economy ("Rest of the world",W) that issues dollars as a currency.[8] We index all of the economies with $j = A, B, W$ and use $d = A, B$ on occasion for regional economies. All cross-country financial transactions are priced in dollars. In the benchmark model, all goods that cross international borders are priced in dollars, even for trade between the regional economies. Local currencies are only used within each economy for domestic transactions. Each of these countries import goods for final use. In addition, A and B operate platform export sectors which combine an array of value added from regional and global producers for ultimate final export to the global economy. The exchange rate of currency j with global dollars is S_t^j.

2.1 Household

The preferences of the household in all economies j are given by:

$$\sum_{t=0}^{\infty} \beta^t u(C_t^j, L_t^j) = \sum_{t=0}^{\infty} \beta^t \left\{ \frac{\zeta}{\zeta - 1} C_t^{j\,\frac{\zeta-1}{\zeta}} - \Gamma_j \frac{\theta}{1+\theta} \cdot L_t^{j\,\frac{\theta+1}{\theta}} \right\} \tag{2.1}$$

[7]See for instance Kordalska et al (2016), Baldwin and Yan (2014) and Taglioni and Winkler (2016)

[8]Our paper is motivated by trade in the East Asia/Pacific region, where regional and global vale chains are fairly prominent and heavily involved in servicing final demand for the US, which is akin to the global economy in the model. That said, for both the model and the empirical analysis, the interpretation of "regional" for the two small economies is not meant to be literal. Indeed, the two regional economies may lie in different regions of the world.

where L_t^j is aggregate labor supply and C_t^j is the consumption basket of economy j which is a CES aggregate of regional goods, CR_t^j, and global goods, CW_t^j:

$$C_t^j = \left(a_j^{\frac{1}{\xi}} \left\{ CR_t^j \right\}^{\frac{\xi-1}{\xi}} + (1-a_j)^{\frac{1}{\xi}} \left\{ CW_t^j \right\}^{\frac{\xi-1}{\xi}} \right)^{\frac{\xi}{\xi-1}} \tag{2.2}$$

Regional goods are a combination of goods from each regional trading partner.

$$CR_t^j = \left(b_j^{\frac{1}{\psi}} \left\{ CA_t^j \right\}^{\frac{\psi-1}{\psi}} + (1-b_j)^{\frac{1}{\psi}} \left\{ CB_t^j \right\}^{\frac{\psi-1}{\psi}} \right)^{\frac{\psi}{\psi-1}} \tag{2.3}$$

where CA_t^j is goods produced in A and consumed in j while CB_t^j is goods produced in B and consumed in j. Relative demand for global goods are based on their relative price:

$$CR_t^j = a_j \left(\frac{PR_t^j}{CPI_t^j} \right)^{-\xi} C_t^j \qquad CW_t^j = (1-a_j) \left(\frac{PW_t^j}{CPI_t^j} \right)^{-\xi} C_t^j \tag{2.4}$$

where CPI_t^j is the country j consumer price index, PW_t^j is the price of global goods charged in country j measured in country j currency, and PR_t^j is the cost-minimizing marginal cost of consuming regional goods.

PA_t^j is the price of country A goods in country$j$ measured in country$j$ currency, while PB_t^j is the price for country B goods in the same location and currency. The demand for regional goods can then be written as:

$$\frac{CA_t^j}{CR_t^j} = b_j \left(\frac{PA_t^j}{PR_t^j} \right)^{-\psi} \qquad \frac{CB_t^j}{CR_t^j} = (1-b_j) \left(\frac{PB_t^j}{PR_t^j} \right)^{-\psi} \tag{2.5}$$

9

Households save by holding bonds(B_t^j) denominated in international dollars. The budget constraint for households in country j is given by:[10]

$$B_t^j = (1+r_t^j)B_t^j + \frac{W_t^j L_t^j - CPI_t^j C_t^j + \Pi_t^j}{S_t^j} \tag{2.6}$$

[9]Implicitly, the consumer price indices are $CPI_t^j = \left(a_j \cdot \left\{ PR_t^j \right\}^{1-\xi} + (1-a_j) \cdot \left\{ PW_t^j \right\}^{1-\xi} \right)^{\frac{1}{1-\xi}}$ and prices of regional goods are $PR_t^j = \left(b_j \cdot \left\{ PA_t^j \right\}^{1-\psi} + (1-b_j) \cdot \left\{ PB_t^j \right\}^{1-\psi} \right)^{\frac{1}{1-\psi}}$.

[10]We study the dynamics of the model around a steady state with zero net international investment positions. Wealth effects from holdings of international bonds only have second order effects in this case.

The nominal exchange rate of country j is S_t^j, defined in terms of units of j currency per dollar, so than an increase means a domestic depreciation and $S_t^W = 1$ by definition. W_t^j denotes nominal wage. Interest rate $(1+r_t^j)$ is the effective interest rate on international bonds relevant to the household in j. The term Π_t^j represents all lump-sum profit pay-outs and taxes.

The first order conditions of the household's problem are given by

$$\begin{aligned} \Omega_t^j W_t^j &= -MU_t^L \ = \Gamma_j L_t^{j\frac{1}{\theta}} && (2.7) \\ \Omega_t^j CPI_t^j &= MU_t^C = C_t^{j\frac{-1}{\varsigma}} && (2.8) \\ 1 &= E_t[\beta\frac{\Omega_{t+1}^j}{\Omega_t^j}(1+i_t^W)\frac{S_{t+1}^j}{S_t^j}] = E_t[\beta\frac{\Omega_{t+1}^j}{\Omega_t^j}(1+r_t^j)] \end{aligned}$$

where Ω_t^j is the shadow value of domestic currency and i_t^j is the domestic currency nominal interest rate.

2.2 Firms

2.2.1 Domestic Value Added

Domestic value added in each country is produced with labor according to a linear production function

$$Y_t^j = L_t^j \tag{2.9}$$

where Y_t^j is output. The domestic currency marginal cost of production goods (denotedMCY_t^j) is given by:

$$MCY_t^j = W_t^j \tag{2.10}$$

2.2.2 Export Platforms

Each of the regional economies also hosts a platform that generates value for export to the global economy, V_t^d, which is a CES aggregate of regional value added , VR_t^j, and global value added, VW_t^jused by country$j's$ platform

$$V_t^d = \left(e_d^{\frac{1}{\gamma}} \left\{ VR_t^d \right\}^{\frac{\gamma-1}{\gamma}} + (1-e_d)^{\frac{1}{\gamma}} \left\{ VW_t^d \right\}^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}} \tag{2.11}$$

Optimal demand is given by:

$$\frac{VW_t^d}{V_t^d} = (1-e_d)\left(\frac{PW_t^d}{MCV_t^d}\right)^{-\gamma} \qquad \frac{VR_t^d}{V_t^d} = e_d\left(\frac{MCRV_t^d}{MCV_t^d}\right)^{-\gamma} \tag{2.12}$$

where MCV_t^d and $MCRV_t^d$ are, respectively, the cost minimizing marginal cost of the export platform and of regional materials. Regional material inputs are a CES aggregate of materials from economies A and B.

$$VR_t^d = \left(f_d^{\frac{1}{\nu}}\left\{VA_t^d\right\}^{\frac{\nu-1}{\nu}} + (1-f_d)^{\frac{1}{\nu}}\left\{VB_t^d\right\}^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}} \tag{2.13}$$

The demand for materials from each of the regional economies is this given by:

$$\frac{VA_t^d}{V_t^d} = f_d\left(\frac{PA_t^d}{MCRV_t^d}\right)^{-\nu} \qquad \frac{VB_t^d}{V_t^d} = (1-f_d)\left(\frac{PB_t^d}{MCRV_t^d}\right)^{-\nu} \tag{2.14}$$

where VA_t^d and VB_t^d are materials used in d sourced from A and B respectively.[11]

The weights $\{a_j, b_j, e_d, f_d\}$ determine the degrees of home and regional bias and are set on a country-specific basis. A key part of the model will be the pattern of invoicing for export goods and domestic goods. In all cases, domestic value added sold in the domestic market will feature prices set in the domestic currency. In the benchmark dominant currency pricing (DCP) model, all exports are priced in the currency of the global economy, regardless of the origin and the destination country. In the local currency pricing (LCP) model, exports are priced in the currency of the destination market. We use $P_t^j \in \{PA_t^j, PB_t^j, PW_t^j\}$as placeholders for the implied domestic currency price under each scenario in order to be as concise as possible.

2.3 Distribution Firms and Sticky Prices

For each producer and destination, there exists a distribution industry that aggregates individual varieties and produces an aggregate bundle. For example, there is an industry that distributes domestic value added for domestic processing. Each distribution sector is made up of a unit range of monopolistically competitive firms whose output is aggregated

[11] Implicitly, $MCV_t^d = \left(e_d\left\{MCRV_t^d\right\}^{1-\nu} + (1-e_d)\left\{PW_t^d\right\}^{1-\nu}\right)^{\frac{1}{1-\nu}}$ and $MCRV_t^d = \left(f_d\left\{PA_t^d\right\}^{1-\nu} + (1-f_d)\left\{PB_t^d\right\}^{1-\nu}\right)^{\frac{1}{1-\nu}}$.

as follows: $H_t^j = \left[\int h_{l,t}^{\frac{\phi-1}{\phi}} dl\right]^{\frac{1}{1-\phi}}$, where

$$CA_t^A + VA_t^A = H_t^A \qquad CB_t^A + VB_t^B = H_t^B \qquad CW_t^W = H_t^W \tag{2.15}$$

Define the price of each domestic good as ppi_t^l, where the price index is defined as $PPI_t^j H_t^j \equiv \int \{ppi_{l,t} h_{l,t}\} dl$.

Another sector produces for regional export purposes, $EX_t^j = \left[\int ex_{l,t}^{\frac{\phi-1}{\phi}} dl\right]^{\frac{1}{1-\phi}}$, such that:

$$CB_t^A + VB_t^A = EX_t^A \qquad CA_t^B + VA_t^B = EX_t^B \tag{2.16}$$

For the case of the global economy, $j = W$,

$$CA_t^W + VA_t^W + CB_t^W + VB_t^W = EX_t^W \tag{2.17}$$

Define the price of each regional export as $ipi_{l,t}$ where the price index is defined $IPI_t^j EX_t^j \equiv \int \{ipi_{l,t} ex_{l,t}\} dl$. Note that this price is denominated in global dollars in the DCP model and in j currency under LCP.

Finally, regional economies $d \in \{A, B\}$ have exports to the global economy are also constructed by distribution.

$$M_t^d = \left[\int m_{l,t}^{\frac{\phi-1}{\phi}} dl\right]^{\frac{1}{1-\phi}} \qquad CA_t^W = M_t^A \quad CB_t^W = M_t^B \tag{2.18}$$

Exports to the global economy, $xpi_{l,t}^d$, are also priced in global dollars and the price index is defined $XPI_t^d M_t^d \equiv \int \left\{xpi_{l,t} m_{l,t}\right\} dl$.

All firms in the distribution sector face cost minimizing demand for $d_{l,t}^j \in \{h_{l,t}^j, ex_{l,t}^j, m_{l,t}^j\}$ relative to total demand $D_t^j \in \{H_t^j, EX_t^j, M_t^j\}$, such that

$$d_{l,t}^j = \left(p_{l,t}^j / P_t^j\right)^{-\phi} D_t^j \tag{2.19}$$

where $p_{l,t}^j \in \{ppi_{l,t}^j, ipi_{l,t}^j, xpi_{l,t}^j\}$ and $P_t^j \in \{PPI_t^j, IPI_t^j, XPI_t^j\}$ is the price index defined by $P_t^j D_t^j \equiv \int \left\{p_{l,t}^j d_{l,t}^j\right\} dl$.

2.3.1 Sticky price firms

Distribution firms are given a chance to change prices with an exogenous probability each period, $1 - \kappa$. When allowed, they set an optimal price as a markup over a weighted

average of future marginal costs. For instance, consider the distribution firms targeting the domestic sector. The optimal price that they set in period t if given by

$$\overline{ppi}_t^j = \tau \frac{\phi}{\phi - 1} \frac{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^j H_{t+n}^j PPI_{t+n}^{j\phi}\right] MCY_{t+n}^j}{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^j H_{t+n}^j PPI_{t+n}^{j\phi}\right]} \tag{2.20}$$

where τ is a subsidy on production provided to offset monopoly power. Aggregate producer prices are give by:

$$PPI_t^{j(1-\phi)} = (1-\kappa)\overline{ppi}_t^{j(1-\phi)} + \kappa PPI_{t-1}^{j(1-\phi)} \tag{2.21}$$

For all $j \in \{A, B, W\}$.[12]

The global export distribution sector for $d = A, B$ also prices in international dollars. The optimal price is given by

$$\overline{xpi}_t^d = \tau \frac{\phi}{\phi - 1} \frac{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^d M_{t+n}^d XPI_{t+n}^{d\phi}\right] MCV_{t+n}^d}{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^d M_{t+n}^d XPI_{t+n}^{d\phi} S_{t+n}^d\right]} \tag{2.22}$$

This yields the following aggregate price index,

$$XPI_t^{d(1-\phi)} = (1-\kappa)\overline{xpi}_t^{d(1-\phi)} + \kappa XPI_{t-1}^{d(1-\phi)} \tag{2.23}$$

so that $PA_t^W = XPI_t^A$ and $PB_t^W = XPI_t^B$ for either DCP or LCP.

The nature of invoicing also affects the pricing of exports to the regional economies. The prices of goods exported to regional economies $d \in \{A, B\}$by producer $j \in \{A, B, W\}$.is represented as $IPI_t^{j:d}$. The optimal reset price is

$$\overline{ipi}_t^{j:d} = \tau \frac{\phi}{\phi - 1} \frac{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^j EX_{t+n}^j IPI_{t+n}^{j\phi}\right] MCY_{t+n}^j}{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^j EX_{t+n}^j IPI_{t+n}^{j\phi} E_{t+n}^{j:d}\right]} \tag{2.24}$$

where $E_t^j$is the exchange rate of producer economy$j$ with the invoicing currency. The dynamics of regional import prices are therefore given by:

$$IPI_t^{j:d(1-\phi)} = (1-\kappa)\overline{ipi}_t^{j:d(1-\phi)} + \kappa IPI_{t-1}^{j:d(1-\phi)} \tag{2.25}$$

Under dominant currency pricing, the invoicing currency is global dollars, such that $E_t^j = S_t^j$. Under local currency pricing, the destination country's currency is used as the

[12] The domestic prices targeting the domestic sector are therefore given by $PA_t^A = PPI_t^A, PB_t^B = PPI_t^B$, and $PW_t^W = PPI_t^W\}$

invoicing currency, so we can write the relevant exchange rate as the cross rate, $E_t^{j:d} = \frac{S_t^j}{S_t^d}$; this will convert the price into the target market economy's currency. In the case of LCP, $PA_t^B = IPI_t^{B:A}$ and $PB_t^A = IPI_t^{A:B}$while for $j = B, W$; $PW_t^d = IPI_t^{W:d}$ for $d = A, B$. Thus, in the LCP case, exports to the regional economies are priced directly in regional currency. In the case of DCP, $PA_t^j = S_t^A IPI_t^{j:A}$ for $j = B, W$ and $PB_t^j = S_t^B IPI_t^{j:B}$. Thus, the exchange rate with the global economy affects both the relative price of exports to the regional economy whether the source economy is the regional or global economy.

2.4 Market Equilibrium

Goods market equilibrium implies that for all economies, the sum of exports to regional economies and goods absorbed by home consumers or platforms equal the total value added.

$$Y_t^j = \int \{h_{l,t} + ex_{l,t}\}\, dl \quad = \quad H_t^j DH_t^j + EX_t^j DX_t^j \tag{2.26}$$

$$DH_t^j \equiv \left[\int \left(\frac{ppi_{l,t}}{PPI_t^j} \right)^{-\phi} dl \right] \qquad DX_t^j \equiv \left[\int \left(\frac{ipi_{l,t}}{IPI_t^j} \right)^{-\phi} dl \right] \tag{2.27}$$

and for the regional economies, output of the platforms equals exports to the global economy

$$V_t^d = \int \{m_{l,t}\}\, dl \quad = \quad DW_t^d M_t^d \tag{2.28}$$

$$DW_t^d \equiv \left[\int \left(\frac{xpi_{l,t}}{XPI_t^j} \right)^{-\phi} dl \right] \tag{2.29}$$

External interest rates are set at a risk premium over the exogenous interest rate r_t. The risk premium is a decreasing function of wealth, B_t^j .

$$1 + r_t^d = \{1 + (i_t^W e^{-\eta B_t^j})\} \qquad 1 + r_t^W = 1 + i_t^W \tag{2.30}$$

Domestic interest rates follow a CPI targeting Taylor Rule with persistence.

$$\frac{1 + i_t^j}{1 + i} = \left(\frac{1 + i_{t-1}^j}{1 + i} \right)^{\chi_i} \cdot \left(\frac{CPI_t^j}{CPI_{t-1}^j} \right)^{\chi_\pi (1-\chi_i)} \cdot \left(\frac{Y_t^j}{Y} \right)^{\chi_Y (1-\chi_i)} \lambda_t^j \tag{2.31}$$

where λ_t^j, is an exogenous monetary policy shock. Finally, equilibrium in the international bond market implies:

$$B_t^A + B_t^B + B_t^W = 0 \tag{2.32}$$

3 Calibration and simulation results

We examine an approximate numerical solution of our model. We match the benchmark trade weights of our calibration, $\{a_j, b_j, e_d, f_d\}$ to the East Asian region where the global value chain is quite significant (see World Bank, 2020). In particular, we assume that 1) the size of total exports of the regional economies as a share of GDP is 50%, calculated by authors as the average of China, Indonesia, Korea, Malaysia, Philippines, Thailand, and Vietnam between 2010 and 2018; 2) foreign value added is 25% of exports, as in 2018 in East Asia & the Pacific (World Bank, 2020); 3) about 55% of foreign value added comes from within the region (World Bank 2020); 4) about 50% of the trade of the regional economy is with the regional trading partner (Dent, 2017); 5) the preferences of the two regional economies are identical; 6) the preferences of the global economy treat each regional economy identically. The parameter Γ_d is normalized so that steady state employment in the regional economies are $L_d = 1$ while Γ_W is set so that the world economy is twice as large as either regional economy.

The substitutability of domestic and foreign goods (ξ, ψ, ν, γ) determines the response of trade to exchange rates and the intertemporal substitutability of consumption, ζ, and the Frisch elasticity of labor, θ, determine the demand response to interest rates. We set $\xi = \psi = \nu = \gamma = 2$; ζ=0.5; and θ=2 following Gopinath, et al, (2020), but also consider alternative specifications in a subsequent robustness check.

We set the parameters of the interest rate and price stickiness parameters to the standard values in the business cycle literature. The elasticity of substitution between differentiated goods, $\phi = 11$, is consistent with an markup of 10% gross of subsidy. We assume a subsidy, $\tau \frac{\phi}{\phi - 1} = 1$, so that net steady state markup is zero. We set price stickiness so that prices adjust on an annual average basis, implying $\kappa = .75$. The subjective discount factor (β) is set to 0.99, consistent with an annualized interest rate near 4%. Our benchmark interest rate smoothing parameter is $\chi_i = .75$. The policy rule parameters $\{\chi_\pi, \chi_Y\}$ are set to a standard value of $\{1.5, \frac{0.5}{4}\}$. We calibrate around a zero inflation, zero current account steady state with the risk premium parameter set just large enough to ensure long-term convergence ($\eta = -.0001$; see Schmitt-Grohe and Uribe, 2003).

3.1 Domestic Monetary Policy Shocks

To illustrate the impact of domestic monetary policy in regional economies with Dominant Currency Pricing along the Global Value Chain, we examine the effects of an exogenous *decrease* (i.e. leading to exchange rate depreciation) in policy interest rates in regional

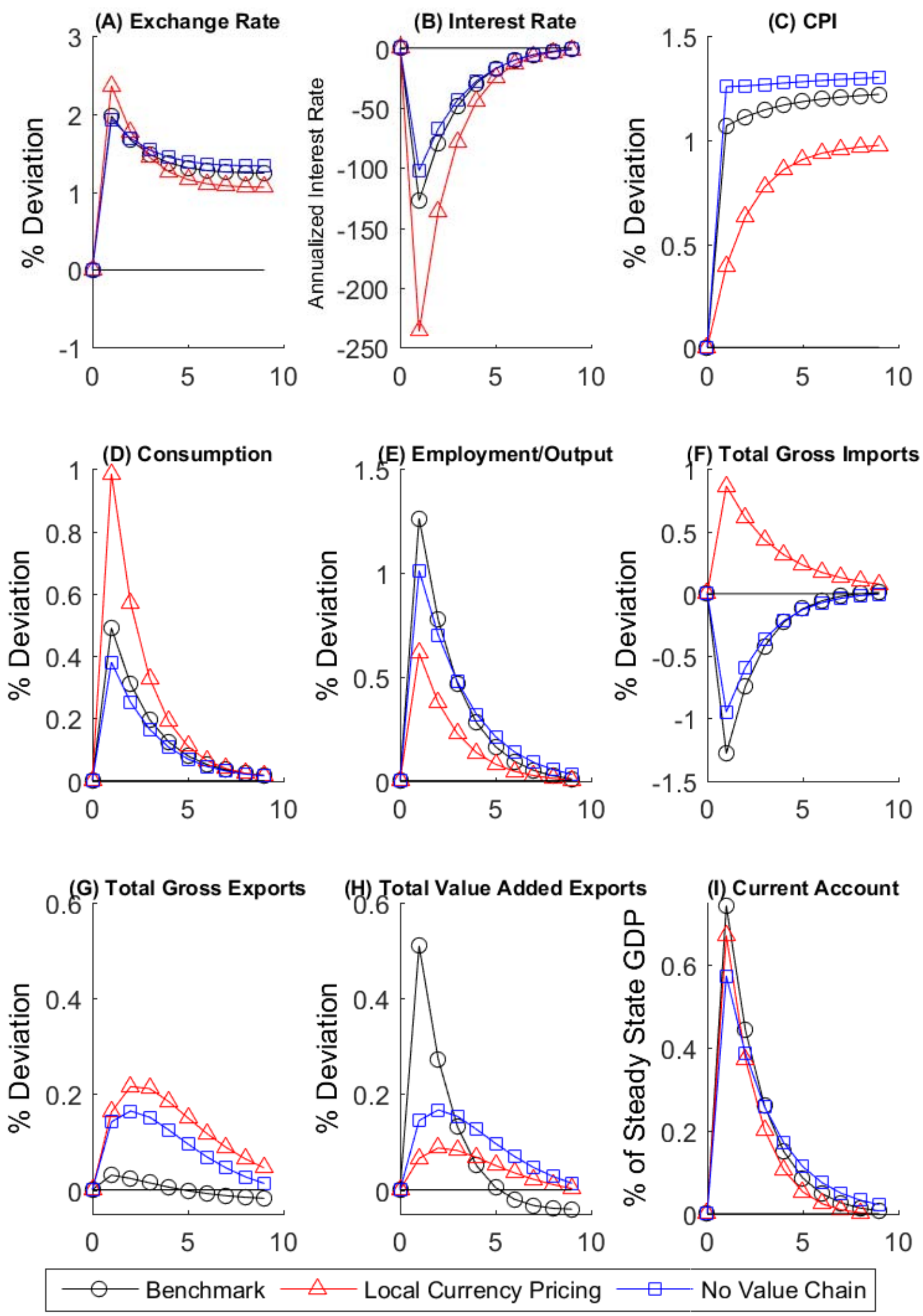
economy A. This takes effect as a one time shock to the interest rate rule at period 1, such that $\lambda^A_{t=1} = .9925$, calibrated to generate an equilibrium domestic exchange rate depreciation of approximately 2% in the benchmark economy. Figure 3.1 shows the response of Regional Economy A under the Benchmark scenario (black dotted lines). To highlight the effect of the interaction of dominant currency pricing and the global value chain, we compare the effects of a similar interest rate shock under two alternatives. We show the response to the same shock (a) under local currency pricing (LCP) under the Benchmark parameterization featuring a global value chain,[13] and (b) the response of the DCP model with a No Value Chain (NVC) parameterization. In the NVC parameterization, each regional economy uses 100% domestic value added for exports to the global economy ($e_d = 1; f_A = 1; f_B = 0;$), while exports are 50% of GDP and 50% of exports are to the regional economy. Note the counter-factual nature of the NVC specification, which posits a very high trade share and regional integration without any trade in intermediate materials.

The policy shock leads to a close to equivalent exchange rate depreciation in the Benchmark and the No Value Chain economy. The shock generates a slightly larger exchange rate response under LCP (see Fig 3.1, Panel A). The exchange rate depreciation raises the price of imported goods which passes through into the CPI (Panel C). The initial pass-through is minimal under LCP relative to DCP where imports are priced in dollars and pass-through is 100%. The pass-through of the exchange rate to the CPI is strongest in the No Value Chain model in which all imports go directly to consumer goods. The CPI targeting Taylor rule implies that the interest rate response differs under alternative models (Panel B). The decline in interest rates is similar in the No GVC case, though slightly smaller in the initial period due to the stronger CPI response. The decline under LCP is persistently larger due to the relatively slow CPI pass-through. As per the Euler equation, the persistent cut in interest rates leads to an expansion in consumption. This is sharper under LCP than under DCP due to the stronger interest rate response. The consumption increase is weakest in the NVC case.

Domestic output increases in all cases (Panel E). However, the response of domestic output is strongest in the Benchmark case and weakest in the LCP case. Under Dominant Currency Pricing, the exchange rate induced rise in import prices leads to expenditure switching away from imported goods and toward domestic goods. Thus, demand for domestic goods increases more intensively than the LCP case. Panel F shows the response of gross imports. The volume of imports increases proportionally with domestic demand under LCP. By contrast, expenditure switching under DCP implies a contraction in imports. In

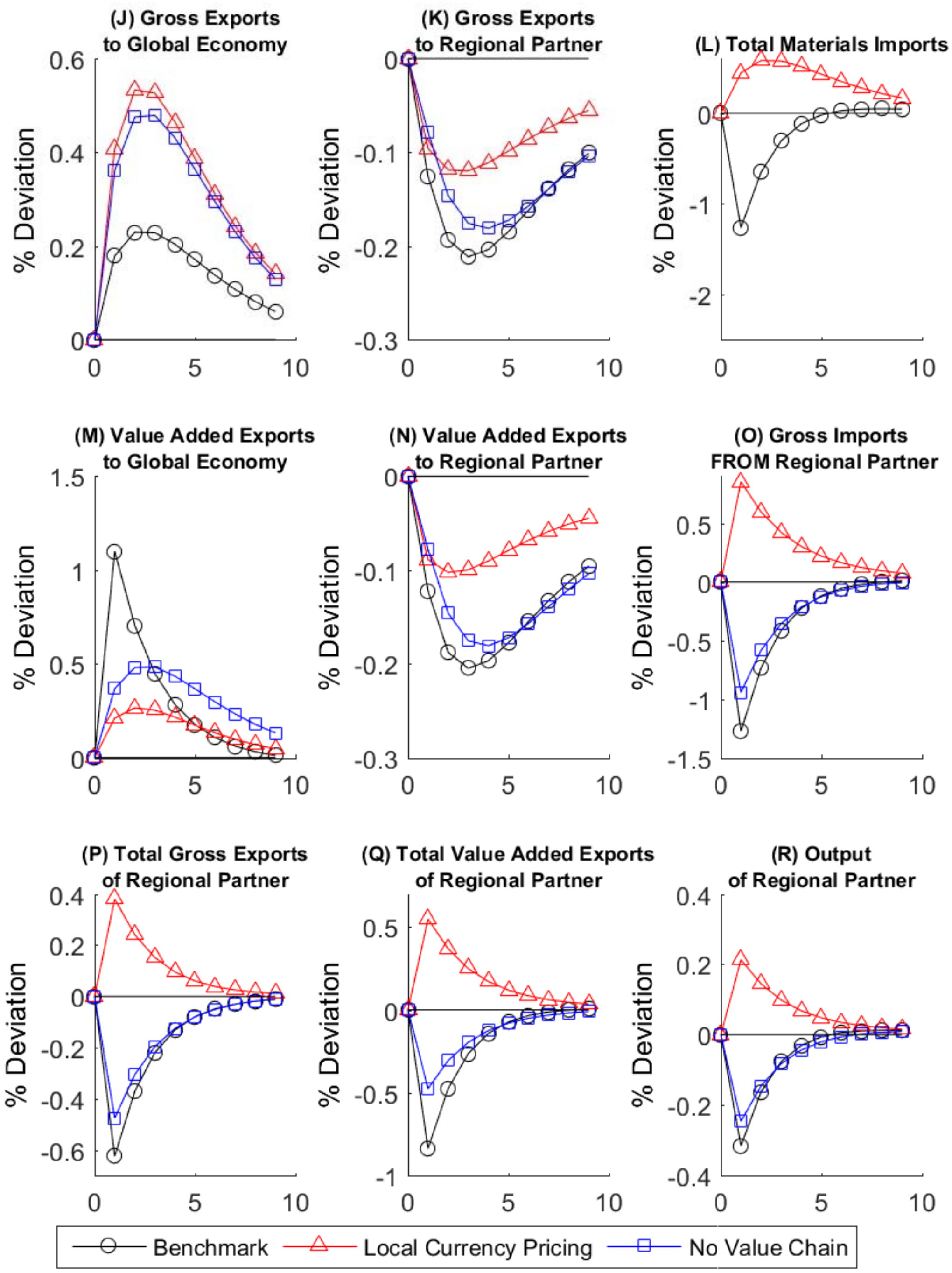
[13]For parsimony, we omit consideration of producer currency pricing (PCP), which would predict a large increase in export competitiveness in contradiction to the data.

Figure 3.1 *– Impulse response to domestic monetary policy easing*



Notes: Impulse response of one regional economy to an exogenous domestic monetary policy shock that reduces policy rates in that economy and depreciates the domestic currency by approximately 2%.

Figure 3.1 – *Impulse response to domestic monetary policy easing (cont.)*



Notes: Impulse response of one regional economy to an exogenous domestic monetary policy shock that reduces policy rates in that economy and depreciates the domestic currency by approximately 2%.

the No GVC case, expenditure switching in imports is somewhat weaker than in the Benchmark case. This is due to the face that in the NVC case, the decline in competitiveness of imports for final consumption is offset by an increase in overall domestic demand, which is less true for materials imported for subsequent export. As materials are an important share of imports in the Benchmark model, overall imports decline by more.

The exchange rate depreciation leads to small increases in the measured volume of gross exports under all specifications. Under both DCP and LCP, exports are not priced in domestic currency. Therefore, domestic exchange rates pass-through to exports only slowly. Under the Benchmark model, the gross export response is weakest since (as explained subsequently) exports go to the global economy through a value chain which is disrupted by the exchange rate depreciation. Much of the value exported through the platform comes from prior imports. As such, an improvement in competitiveness of exports from the exchange rate depreciation is muted both by invoicing in global dollars and an immediate increase in the costs of imported materials.

Though DCP and GVC work in combination to insulate gross exports from exchange rate fluctuations, this is not true for exports measured in terms of value added. We specify value added exports of economy A as $EXV_t^A = CA_t^B + VH_t^A + VA_t^B$, which is the export of materials and final goods to the regional partner along with the domestic content of exports to the global economy. Panel H shows the response of value added exports. It shows that under the Benchmark economy, the very muted expansion in gross exports in Panel G masks a sharp increase in value added exports. The increase in the prices of imported materials leads the domestic platform to switch to domestic content. Thus, though expenditure switching has negligible impact on gross exports, there is a substantial direct expenditure switching effect on domestic value embedded in exports.

Panel I shows the response of the current account to the domestic depreciation, where the current account is measured in global dollars as $B_t^A - B_{t-1}^A$. Under DCP, trade is denominated in global dollars and the current account reflects the increase in exports and the decline in imports. As value added exports and imports each shift more in the Benchmark parameterization, the current account improves more than in the No GVC case. In the LCP case, the current account improves through valuation effects. Imports priced in local currency cost less in global dollar terms due to the exchange rate depreciation.

Panel J and K show gross exports to the global economy, CA_t^W, and to the regional trading partner, $CA_t^B + VA_t^B$. Pricing in either global (DCP) or consumer currency (LCP) means the competitiveness effects of exchange rate depreciation are weak, especially in the presence of imported materials. The response of exports to the global economy are weakly positive and particularly weak in the Benchmark case. The competitiveness effects relative

to the trading partner are also weak. The depreciation in economy A has negative spillovers on demand for economy B goods, which reduces wages and costs of production in country B. Country B shifts toward domestic goods and exports to country B decline, though weakly.

Panel L shows the response of imported materials to an exchange rate depreciation. When imports are priced in global dollars as in the Benchmark, imported materials lose competitiveness and platform production shifts toward domestic content. When imports are priced in local currency, imported materials increase in parallel with exports. Imported materials are always zero in the NVC case. Panel M shows that this implies that under the Benchmark, domestic value added embedded in exports to the global economy, $VH_t^A + VA_t^B$, increase immediately and sharply, though gross exports to the global economy display more modest change. Conversely, the value added of exports in the LCP and NVC case move in parallel with gross exports. Gross exports and value added exports, CA_t^B, to the regional partner move in parallel in all specifications (Panel N).

Panels O-R summarize the spillovers of a monetary shock in economy A to economy B. When regional imports are priced in international dollars, a domestic exchange rate depreciation causes them to lose competitiveness to domestic goods and imports from the regional partner fall. This fall will be more significant along the global value chain since exports to the global economy increase less than domestic demand. Cross-regional trade threfore falls by more in the Benchmark economy than in the NVC case (see Panel O). Under LCP, imports from the regional partner rise as the depreciation has little effect on their competitiveness. Exports of the regional partner B to the global economy are little affected by country A's monetary policy under any specification. Therefore, gross exports of country B reflect the change in intra-regional trade, but since only a part of country B's exports are affected, the percentage change is smaller than the change in direct exports to the regional partner (Panel P). In the Benchmark model, since intra-regional exports are a greater share of the value added exports, value added exports decline by a greater percentage than does gross exports (Panel Q). As a result, in DCP models, the decline in exports from the regional partner leads to a decline in production which is larger in the Benchmark model than in the No GVC case (see Panel R).

3.2 Global Interest Rate Shocks

Next, we examine the effects of an exogenous increase in policy interest rates in the Global economy. This takes effect as a one time shock to the interest rate rule at period 1, such that $\lambda_{t=1}^W = 1.0075$, which generates an equilibrium increase in interest rates slightly greater than 200 annualized basis points in the Global economy and generates a 2% appreciation of

the dominant currency relative to both regional currencies. Due to smoothing in the interest rate rule, this leads to a persistent rise in the nominal interest rate in Country W, along with a decline in consumption and output as is usual in a New Keynesian economy. Figure 3.2 concentrates on showing the (symmetric) response of either regional economy to this global monetary contraction in the Benchmark, LCP and No GVC parameterizations. It therefore shows the response of only country A, recognizing that country B's response is symmetric.

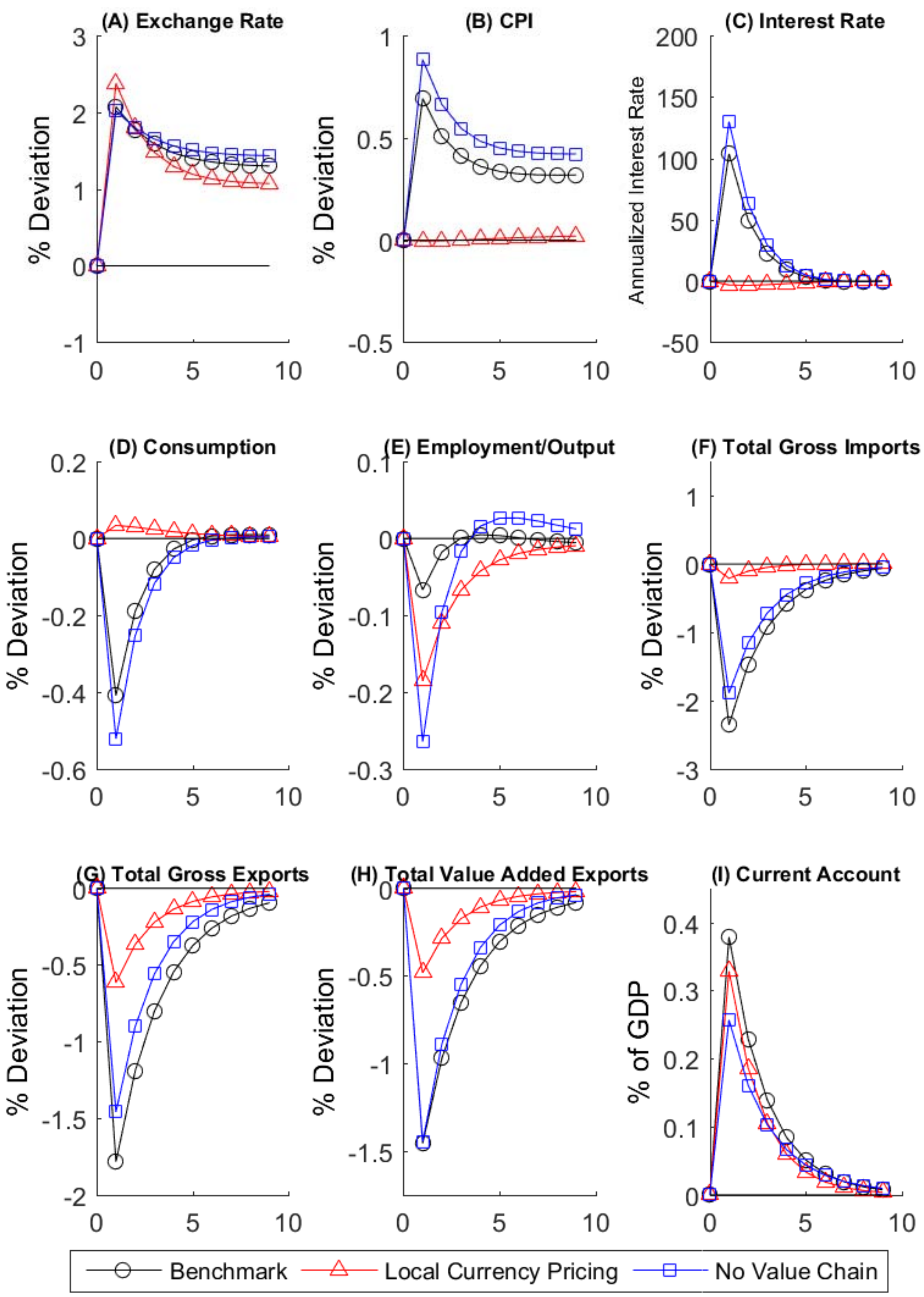
Panel A shows that regional exchange rates depreciate temporarily by nearly 2% relative to the global dollar as suggested by (near) uncovered interest parity. The depreciation is somewhat higher in the LCP case due to differentials in domestic policy response. As shown in Panel B, exchange rate depreciation passes through into consumer prices with the CPI increasing. The exchange rate pass-through is largest in the No GVC case as imported consumer goods are a larger share of the consumer market basket. The increase in the CPI leads to a monetary tightening under the strong pass-through of DCP. Under the low pass-through of LCP on the other hand, the Taylor rule prescribes a moderate cut in interest rates. Panel C shows that interest rates rise by 100 annualized basis points in the Benchmark economy and more so in the No GVC case. The rise in interest rates leads to a decline in consumption (Panel D) which is strongest in the No GVC case. However, this decline in consumption is concentrated on imported goods due to the depreciation. On the other hand, there is a small positive response under LCP.

We see a distinct difference between LCP and DCP when it comes to response of the pattern of trade. Under LCP, the competitiveness of imports is insulated from a temporary depreciation due to the fact that they are invoiced in the currency of the importing country. Therefore, there is only a small decline in imports (Panel F). Conversely, under DCP, all imports are invoiced in global dollars and depreciation versus the global economy sharply and immediately reduces gross imports. The global value chain intensifies this effect for reasons discussed in subsequent paragraphs. Interestingly, we see that *both* the global value chain and dollar currency pricing cause an externally driven depreciation to lead to a decline in exports, the opposite of the traditional thinking. Under LCP with a value chain, there is a small decline in exports due to the effect of the foreign contraction of demand. Under DCP with no GVC, there is a substantially larger decline in exports than under LCP. But the Benchmark economy shows an even larger decline in exports, driven by the size of the decline in platform exports to the global economy.

Panel H shows that the value added content of exports declines by substantially less than gross exports in the Benchmark economy.[14] Panel I shows the response of the current account (measured in global currency). The depreciation leads to a decline in imports that

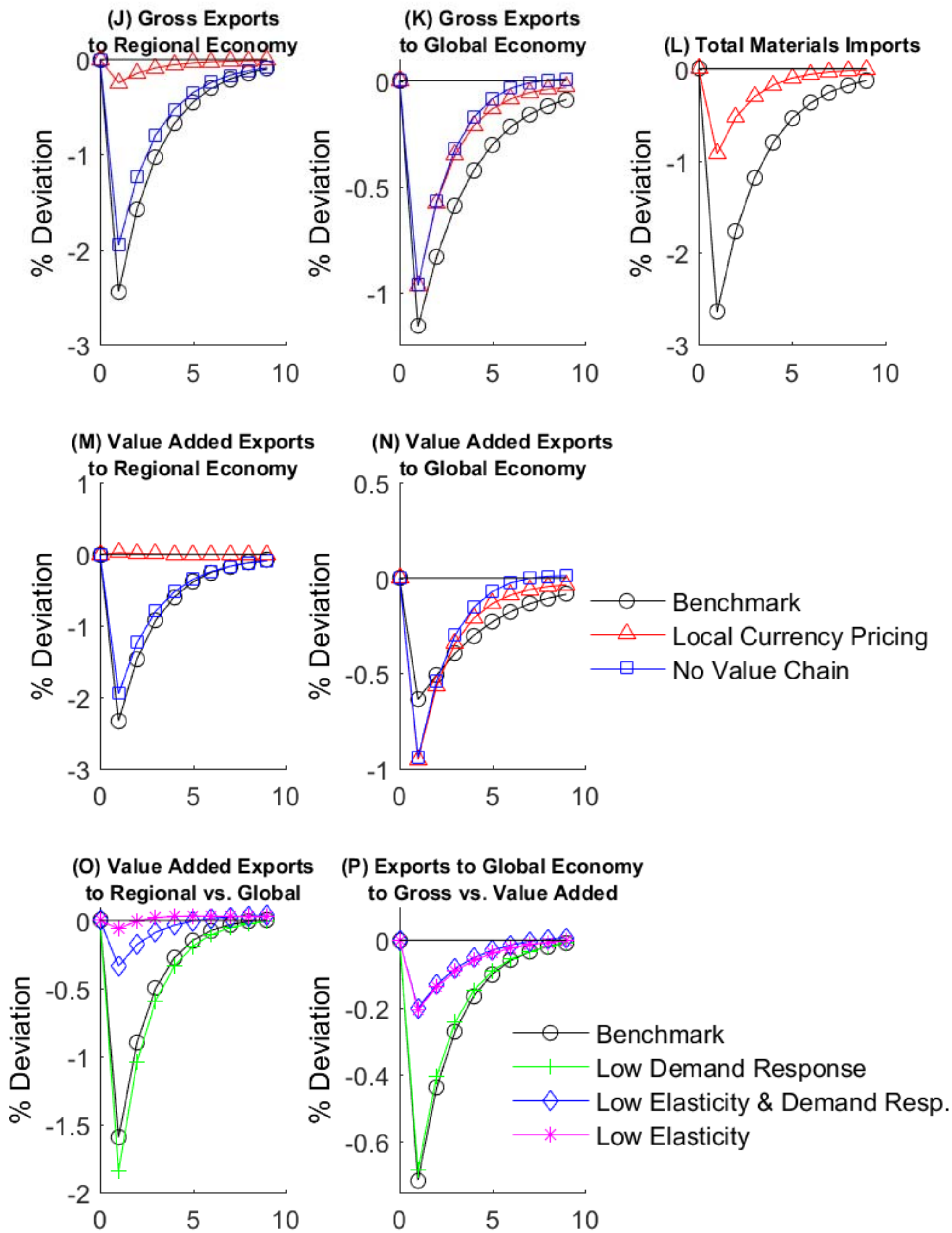
[14]Gross and value added exports are identical in the No GVC case.

Figure 3.2 *– Impulse response to global monetary policy tightening*



Notes: Impulse response of one regional economy to an increase in global currency monetary policy rates sufficient to create a 2% appreciation of the global currency.

Figure 3.2 *– Impulse response to global monetary policy tightening (cont.)*



Notes: Impulse response of one regional economy to an increase in global currency monetary policy rates sufficient to create a 2% appreciation of the global currency.

is larger than the decline in exports under DCP, and the current account improves under either specification. Due to the sharper decline in imports under the Benchmark model, there is a larger improvement in the Benchmark current account than the No GVC case. We see again that the valuation effects from the exchange rate depreciation lead to a current account improvement measured in global currency under LCP.

Panel J and K show the direction of gross exports. Under DCP, the appreciation of the international dollar makes *imports from* the regional partner less competitive and symmetrically reduces *exports to* the regional partner. The decline in regional materials trade makes the disruption in regional trade more intense in the Benchmark case relative to the No GVC case. Under LCP, the decline in regional trade is minimal. We also see a decline in gross exports to the global economy, primarily driven by the decline in aggregate demand within the global economy. However, the value chain intensifies the decline in gross exports to the global economy. The export platform relies on imported materials which rise in price when the global currency appreciates. To the limited extent to which higher materials prices pass-through into platform export prices, platform exports to the global economy are reduced. As shown in Panel L, materials imports decline sharply under DCP in response to the global appreciation (both from the global economy and the regional partner). The disruption of imported materials trade is much smaller under LCP as invoicing insulates materials trade from the global appreciation.

Each category of exports to the regional partner, materials and final goods, are entirely comprised of domestic value added content and are disrupted by global dollar appreciation. Thus, value added exports to the regional economy fall as sharply as gross exports to the same destination (Panel M). This is not true for exports to the global economy. Under the Benchmark, there is a mild decline in gross exports (Panel K) and a larger decline in materials inputs (Panel L). This combination requires a large increase in the domestic content of exports to the global economy. Thus, the decline in value added exports to the global economy is substantially smaller than the decline in gross exports to the global economy for the benchmark case (Panel N vs Panel K). This is not true in either the No GVC case (where there is no materials trade) or the LCP case (where materials trade is minimally disrupted). As in the previous case, gross and value added exports to the regional partner respond similarly.

3.2.1 Robustness checks and summary of main results and testable implications

In the next section, we provide evidence that, on a value added basis, exports to non-US countries decline more in response to an increase in US interest rates than do exports to the US as a final destination just as in the Benchmark model (see Panels M and N in Figure

3.2). So far we have seen that this is not true in the LCP model, but it is true in a DCP model and intensified by the Global Value Chain. This outcome, however, depends on the particular parameterization of the model. Exports to the regional partner decline during a global dollar appreciation because it causes the partner to substitute toward their own domestic content. If the substitutability between domestic content and imports is weak, then the effect of appreciation on regional trade will be weakened. Exports to the global economy decline due to the negative effect of interest rates on aggregate demand in the global economy. If this demand effect is large, then the decline in exports to the global economy would be larger. In an economy with sufficiently low expenditure switching combined with sufficiently interest sensitive aggregate demand, exports to the global economy may fall more than exports to the regional economy.

In Panel O of Figure 3.2, we show the response of the ratio of value added exports destined for the regional economy relative to value added destined for the global economy. Under the Benchmark this ratio declines by about 1.5%. We examine this response with some alternative parameterizations. Johnson (2014) considers elasticities of substitution as low as $\xi = \psi = \nu = \gamma = 0.5$. We call this the Low Elasticity case. Parameterizations of domestic elasticities based on micro level studies often find relatively inelastic intertemporal substition and labor supply elasticities. We consider a Low Demand Response case with the Frisch elasticity of labor supply, $\theta = 0.75$, as suggested by Chetty et al. (2014), and inter temporal elasticity of substitution, $\zeta = .2$, consistent with Best (2020) et al. We find that when we use the Benchmark demand response and the Low substitution parameterization, the response of exports to regional partners is nearly as large as the response of exports to the global economy. However, we see that even in the Low Substitution case, if the demand response is also low, then we observe regional exports falling more than value added exports.

This robustness exercise suggests that it is important to account for the potential demand response when testing for the presence of the substitution effect as it might mask the impact of dominant currency pricing. In our empirical specification, we control for GDP of the US and relevant parties to concentrate on identifying the direct impact of DCP.

Another key implication of the Benchmark model is that platform exports to the global economy switch toward domestic content following an appreciation of the global currency due to the disruption of materials trade. In the empirical section, we provide evidence that gross exports to the US decline more in response to an increase in US interest rates than does the domestic value added content in exports. In Panel P, we show the response of the ratio of gross exports to the US to value added exports to the US under the Benchmark, Low Elasticity, Low Demand Response, & Low Elasticity and Demand Response cases. We see that in all cases this ratio declines. The decline is more intense when the substitutability

is high as this will make it easier to shift toward domestic content. The demand response in the global economy is less important as that equally impacts the numerator and the denominator.

4 Empirical evidence

This section tests the key predictions of the model regarding the response of trade flows to a US interest rate shock.[15] The typical limitation of standard data sources on international trade such as those available under national balance of payment statistics is that they are in gross terms and only capture direct trade between an importer and an exporter. They do not capture the growing phenomenon of global value chains as modeled in this paper, where goods cross borders multiple times before being consumed as final goods.

Some data sources do provide a split between intermediate, final and capital goods exports. This is still not sufficient to test models of global value chains, since the classification still only captures the nature of the trade flow up to the first border crossing, and not beyond. For example, intermediate goods exports in our model end up in export platforms and are eventually re-exported to the global economy. In the data however, majority of exports classified as "intermediate" are not re-exported, but are consumed by the direct importer (see Appendix Table 2).

To overcome this limitation, we use a granular decomposition of exports proposed by Wang, Wei and Zhu (2013, 2017 a and b). Their framework decomposes total bilateral exports into gross and value added components and further categorizes the share that is absorbed in the immediate destination and the share that is reexported, identifying the ultimate destination where final goods consumption takes place. We focus in particular on the value added exports dimension of their decomposition. For each country pair, this decomposition provides the value added generated by one country that is absorbed in the other country as final demand, after single or potentially multiple border crossings and round tripping.

We consider the following measures at the country-sector-destination level.

1. VAF: Value added exports (forward) of the country sector that are eventually consumed as final demand in a particular destination country. "Forward" means that this measure includes indirect exports of this sector via other sectors in the same country.

[15] We choose to test the predictions of the model for external interest rate shocks (Figure 3.2) as opposed to domestic monetary policy shocks (Figure 3.1) because of complications associated with identifying the latter from time series macroeconomic data, particularly for a large set of emerging market economies. That said, a careful analysis using domestic monetary shocks remains a fruitful avenue for future research.

2. VAB: Value added exports (backward) of the country sector that are eventually consumed as final demand in a particular destination country. “Backward” means that this measure includes indirect exports of other sectors in the same country via this sector.

3. IVAF: Indirect value added exports (forward) by the country sector to the destination country. This is a subset of VAF which captures the value added by the source country-sector that is consumed by a particular destination country as final demand, but is not exported directly (i.e it is part of a value chain that involves at least one more country that is different from the source and the ultimate destination)

4. IVAB: Indirect value added exports (backward) by the country sector to the destination country. This is a subset of VAB which captures the value added by the source country-sector that is consumed by a particular destination country as final demand, but is not exported directly but rather indirectly as part of a value chain involving at least three countries.

As an example, if the commodity sector in country A provides x units of inputs to the electronics processing sector in the same country A, which in turn exports its entire output of $y(> x)$ units to country B, then the value added forward exports (VAF) of the commodity sector would equal x, even though it does not export anything directly. The VAB for the electronics processing sector would in turn equal y. In country B uses its imports of y, adds value equal to z, and exports the resulting output to country C, then for the commodity sector in country A, IVAF to country C would equal x, and IVAB for the electronics sector in country A to country C would equal y.

As shown by Wang, Wei and Zhu (2017 a), there is large heterogeneity across both countries and sectors in terms of their forward and backward value added exports and GVC participation. For example, the mining sector has larger forward exports compared to backward across all countries, reflecting its upstream position and the fact that its exports are re-exported by many downstream sectors. The same is true for broader country level exports for commodity exporters like Australia, Russia and Norway. On the other hand, several sectors (such as electronics processing) in China tend to specialize in more downstream segments of value chains, making intensive use of inputs in their production. As such, their backward exports are high, since their gross exports include intermediate inputs from other sectors. While export data at the sector level can shed some light on these differences, our measures that compute these measures within each country-sector are more informative , since there is heterogeneity in forward and backward exports even within the same sector

across countries. For example, the refined petroleum sector in Russia has higher forward exports than backward, whereas the opposite is true for the same sector in Japan.

For each of the above four variables (say x), one prediction of our model is that in response to a US interest rate rise, the value of x destined for eventual final consumption in the US should fall by less than the corresponding value for other countries. In other words, if we define the ratio

$$r_x = \frac{x_{\text{sum across all non US destinations}}}{x_{US}}; x \in \{VAF, VAB, IVAF, IVAB\} \tag{4.1}$$

Our main prediction is that r_x should fall in response to US monetary contractions.

Estimation and results

We study the response of r_x to changes in the US interest rate using the following empirical specification.

$$r_{x,t+h}^{i,j}(s) = \alpha^{i,j}(s) + \eta r_{xt-1}^{i,j}(s) + \beta i_{us,t} + \delta X_t + \epsilon_t^{i,j}(s) \tag{4.2}$$

Here, $r_{x,t+h}^{i,j}(s)$ denotes a measure of trade as defined in equation 4.1 for source country i and sector s, to destination country j. $i_{us,t}$ is the US policy rate, which is proxied by the shadow rate in Lombardi and Zhu (2014).[16] X_t is a vector of controls and includes contemporaneous and lagged values of changes in US GDP and inflation, the bilateral exchange rate between the importer and the exporter, change in real GDP and inflation of the importer and exporter, change in total imports by the importer, and change in total imports and exports by the importing country with the US, as well as the change in unit labor cost in the exporting country. A quadratic time trend is also included in the regressions. The impulse responses are computed using the local projection method developed in Jorda (2005).[17] To account for the endogeneity concerns emanating from the inclusion of the lagged dependent variable (Nikell, 1981), the regressions are estimated with a GMM estimator based on Arellano and Bond (1992), using the forward orthogonal deviation transformation from (see for instance Arellano and Bover (1995)).[18]

[16]We use a first stage regression to orthogonalized the interest rate with respect to lagged US GDP and inflation. In robustness checks, we also redo the main regressions without this first stage, and considered a shock component of the US interest rate, compiled by taking the sum of all interest rate moves around monetary policy announcements, as in Gertler and Karadi (2015).

[17]The large dimension of the dataset (where we have over half a million data points) makes the typical alternative of using vector autoregression less attractive.

[18]That said, results using the linear fixed effects estimator yield similar results (Appendix A)

Although our model is specified at the country level, we choose to exploit more granular information available in the data and estimate all regressions at the bilateral country-sector-destination level. The sectoral dimension offers several advantages. First, it increases the sample size and allows more observations to be included in the estimation exercise to provide more robust results. Second, it reduced endogeneity concerns, since sector-level trade flows are less likely to influence aggregate macro variables such as GDP and interest rates compared to country level trade flows. Third, it allows for better measurement of value added trade flows between countries, compared to aggregate country level trade flows.[19]

The main data source is the world input output database (WIOD).[20] The sample runs from 1995-2011 (annual) and covers 35 sectors in 40 countries (See Appendix C for the full list of countries and sectors). The available sample thus contains 54600 (=40*39*35) bilateral export observations at the sector level for each year. Of these, we exclude ones in which the exporting and the importing country is in Europe, since dollar invoicing in less likely in such cases.

Figure 4.1 summarizes the main results from the estimation of equation 4.2. For both direct and indirect value added exports measures, the ratio r_x declines persistently in response to a US monetary contraction. This indicates that as predicted by the model, trade that serves final demand outside the US contracts by more than the global value chain oriented trade that eventually serves final demand in the US. Forward and backward export measures react quit similarly, which is consistent with the finding that there is a significant positive correlation between forward and backward GVC participation across sectors in the first place (Wang, Wei and Zhu, 2017a). The response of both these variables is highly persistent, with a reversion to the mean beginning only at time period 4 (which corresponds to sixteen quarters).

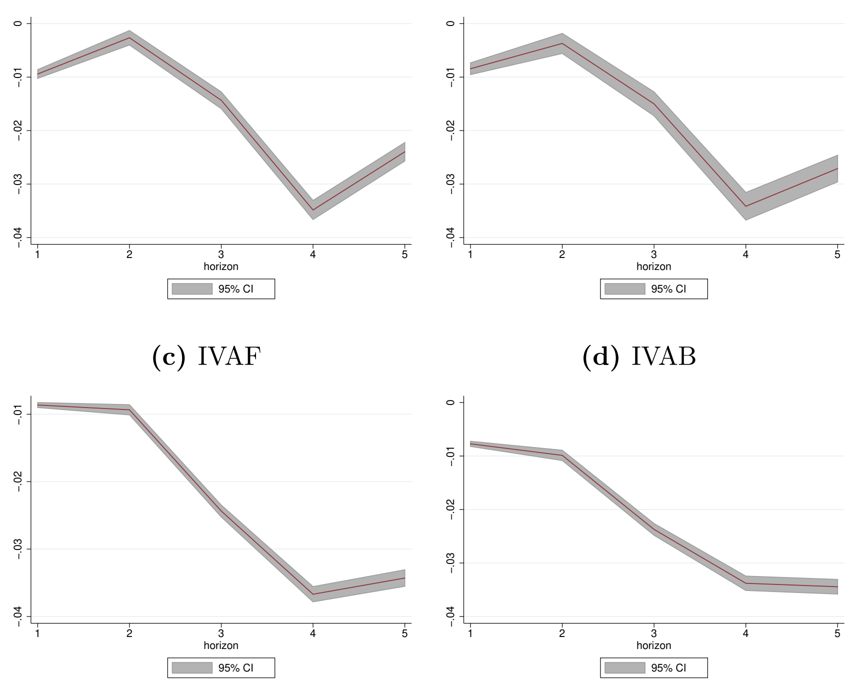
Gopinath et al (2020) argue that the role of invoicing may be substantially lower for commodities exports, since their prices are fairly flexible. Indeed, many commodities are traded on organized exchanges where prices fluctuate at a high frequency. Motivated by this, we attempt to uncover differences across sectors by estimating our baseline empirical model (equation 4.2) by splitting the sample into three broad categories by export sector-primary, secondary and tertiary.[21] Figures 4.2 and 4.3 show the results. We do not find the dynamics for primary sectors, which are dominated by commodities, to be very different from the rest. One reason for this could be that the underlying input–output data used to estimate our value added export decomposition relies heavily on interpolations across

[19]See Patel et al (2019) for a discussion of advantages of using sector level data to measure global value chain activity, and the biases induced by aggregation to country level counterparts.

[20]See Timmer et al (2015) for a detailed description of the database.

[21]see appendix C for the precise details of this classification.

Figure 4.1 *– Response of value added exports to non US countries and US to US monetary contractions*

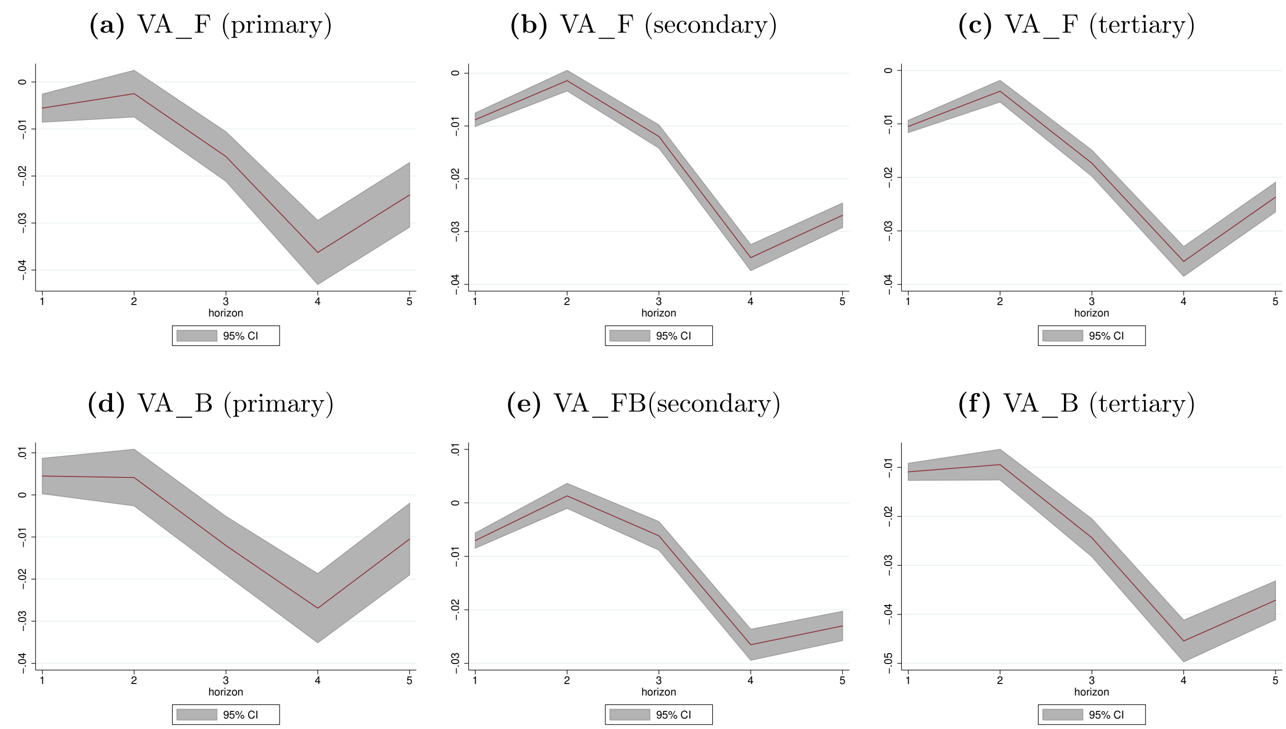


(a) VA_F **(b)** VA_B **(c)** IVAF **(d)** IVAB

Notes: Each term represents the response (in % terms) of the corresponding ratio as in equation 4.1 to a 1% increase in the US monetary policy rate. In particular, it is the dependent variable is the ratio of value added exports to all non US countries, divided by value added exports to the US.

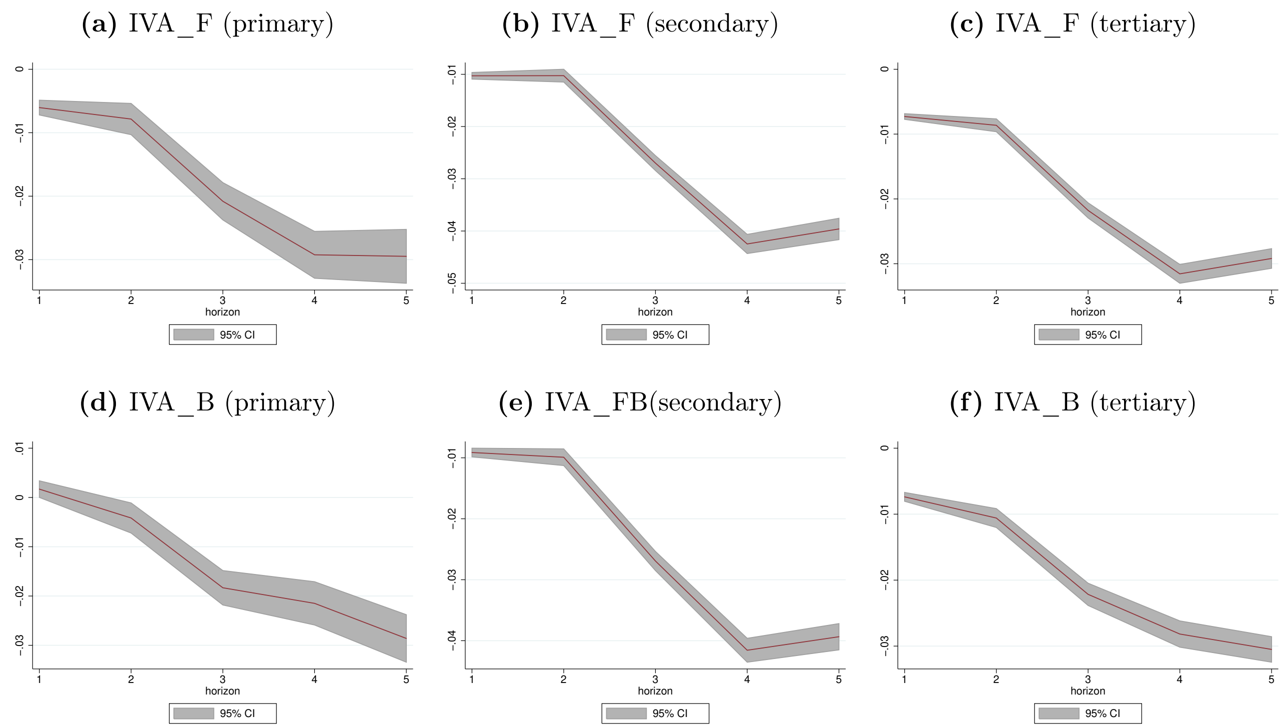
sectors (see details on the interpolations, see Timmer el al, 2015), so the measurement of commodities trade in our database may not be as accurate as in direct customs trade data. A second reason could be that we can only control for the fact that one of the sectors in a particular bilateral value added trade flow is primary, but it could be the case that other sectors, including manufacturing and services, are involved in the value chain before it reaches the final consumer. In that case, the invoicing channel would still be present in the trade flow even if the value chain originates in a primary sector.

Figure 4.2 *– Response of value added exports to non US countries and US to US monetary contractions by sector*



Notes: Each term represents the response (in % terms) of the corresponding ratio as in equation 4.1 to a 1% increase in the US monetary policy rate. In particular, it is the dependent variable is the ratio of value added exports to all non US countries, divided by value added exports to the US.

Figure 4.3 – *Response of indirect value added exports to non US countries and US to US monetary contractions by sector*



Notes: Each term represents the response (in % terms) of the corresponding ratio as in equation 4.1 to a 1% increase in the US monetary policy rate. In particular, it is the dependent variable is the ratio of value added exports to all non US countries, divided by value added exports to the US.

Response of gross vs value added exports to the US

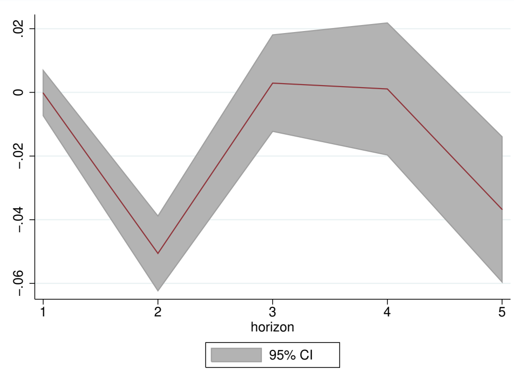
The differential response of gross and value added exports to the US is another key prediction of the model (Figure 3.2, Panels K, N and P). To test this, we estimate the response of the ratio of gross to value added exports from non-US country-sectors to the US using a framework similar to equation 4.2. Figure 4.4 shows the results. Irrespective of whether the ratios are computed using forward or backward based value added exports to the US, the conclusion is the same, and in line with the prediction of the model.

Gross and final goods exports

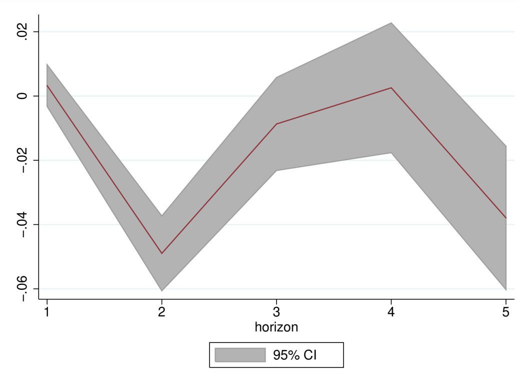
Figure 4.5 displays the response of total gross exports and its constituents (intermediate and final) in response to a monetary contraction in the US obtained using the same specification and controls as in equation 4.2. While both measures of exports decline persistently, Panel 4.5d shows that there is no discernible difference between the responses. This

Figure 4.4 – *Response of the ratio of gross to value added exports to the US to a US monetary contraction*

(a) Response of the ratio of gross to value added exports (Forward)



(b) Response of the ratio of gross to value added exports (Backward)



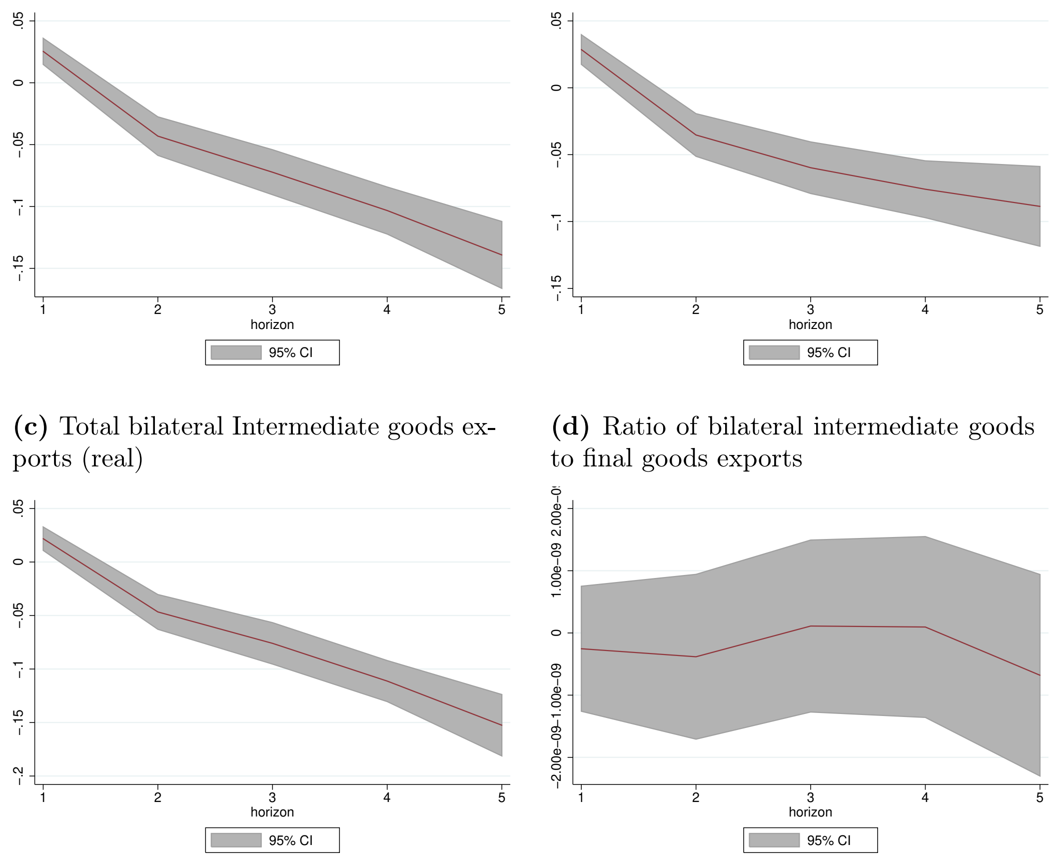
Notes: Percentage deviations from steady state. The shaded error band is the 95% confidence interval for the pooled sample. Linear and quadratic trend included in the regression. Importing country restricted to the US (no fixed effects).

indicates that due to the complex nature of global value chains in the data, a mere two way decomposition of trade data into intermediate and final goods trade that is typically available from standard data sources is not rich enough to capture the dynamics of global value chain related trade. Indeed, in our model, intermediate imports are used heavily in the production of exports, whereas in the data, they are mostly used to satisfy domestic demand. We therefore need to go to the granular database that we use above to isolate value added trade flows and multiple border crossings.

While data on gross trade flows and its split between intermediate and final goods does not allow us to test the predictions of the model vis-a vis GVCs, it does provide an opportunity to test the differences across predictions of the model under different pricing regimes. A decline in bilateral trade between non-US countries evident in Figure 4.5, particularly final goods trade, is most consistent with dollar invoicing, as opposed to producer currency pricing which would for instance not imply such a decline.

We further test the relevance of dollar invoicing by combining annual cross-country data on the share of dollar invoicing in exports and imports from Boz et al (2020) at the country level with our main dataset. The results show that the stotistically significant decline in final goods exports is driven largely by the country-year pairs with the highest share of dollar invoicing in imports and exports (Figure 4.6).

Figure 4.5 *– Response of total and final goods bilateral exports from non US, non EU exporters to non-US non EU importers in response to a US monetary policy tightening shock*



(a) Total bilateral exports (real)

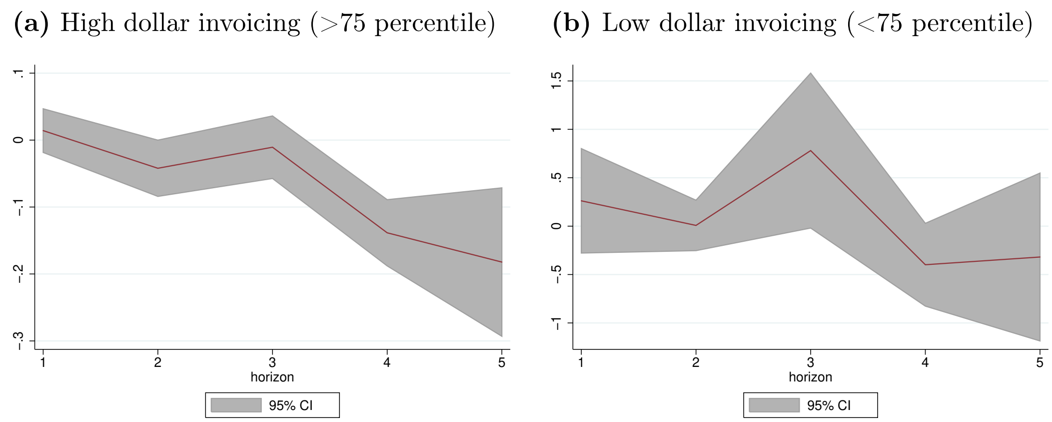
(b) Total bilateral final goods exports (real)

(c) Total bilateral Intermediate goods exports (real)

(d) Ratio of bilateral intermediate goods to final goods exports

Notes: Response of real exports between non US countries to 1%b increase in the US policy rate. Percentage deviations from steady state. The shaded error band is the 95% confidence interval for the pooled sample. Since an export price index is not available in the database, sector level gross output price indices are used to convert nominal values to real ones.

Figure 4.6 – Response of final goods bilateral exports from non US, non EU exporters to non-US non EU importers in response to a US monetary policy tightening shock. Comparison between high and low dollar invoicing.



Notes: Percentage deviations from steady state. The shaded error band is the 95% confidence interval for the pooled sample. Since an export price index is not available in the database, sector level gross output price indices are used to convert nominal values to real ones.

5 Conclusion

This paper studies how the prominence of dominant currency pricing and global value chains alters the relationship between monetary policy, exchange rates and international trade flows. We model a world economy consisting of a large global economy, and a regional trading system comprising of a couple of small economies with two key features: a platform export sector that combines imported materials with domestic value added for exports to a global economy, and sticky import and export prices denominated in an external global currency.

We find that an appreciation of the global currency disrupts the use of imported materials and shifts the regional economy toward producing domestic content for exports to the global economy. To test the implications of the model in the data, we exploit the most granular classification of exports available in a multi-country setting to decompose bilateral trade at the sector level for 35 sectors in 40 countries into different components and isolate value added trade flows by origin country-sector and destination country. Specifically, focussing on trade flows between two foreign countries in response to changes in US interest rates, we use the decomposition of bilateral value added trade flows of Wang, Wei and Zhu (2013, 2017 a and b) to show that the components of international trade flows that are global value chain oriented and directed toward US consumers are less affected than gross exports or exports with other trading partners. We also show that countries exporting to the US adjust the

domestic content of their exports in response to changes in the US interest rate in a manner consistent with the model. We discuss how these findings rule out alternative specifications in terms of currency of invoicing and absence of production chains.

While we focus on two shocks (domestic and foreign monetary policy), the results are relevant more generally since they inform how other shocks that move the exchange rate are likely to influence trade flows. This in turn offers a better understanding to policymakers on how exogenous shocks as well as their own policy actions affect trade flows in a world with dollar invoicing and the rising prevalence of global value chains.

Despite our attempts to use GVC data to ensure as close a correspondence between the model and the data as possible, a qualification is in order when interpreting the results. In the model, all platform exports go to a single dominant global economy. Our empirical work focuses on exports to the United States. Our focus has been driven by the large share (around 30% of value added in 2015 according to the OECD TiVA database) of exports to the US from the dollar centric East & Southeast Asian regional system. Considering the response to US monetary policy of value added exports from the regional system to alternative dominant currency zones in Europe is an important topic of future research. Intuition suggests that the response would depend on the invoice currency of exports from the region to Europe and elsewhere as well as the aggregate demand response in those destination countries.

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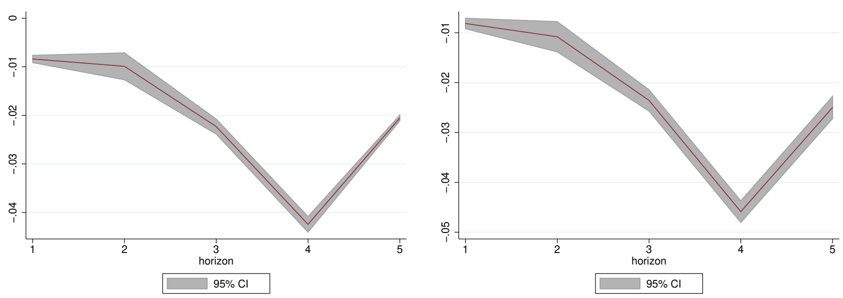
Appendix

A Simple dynamic fixed effect regressions without controlling for the Nickel (1981) bias (Figure A.1)

Figure A.1 *– Response of value added exports to non US countries and US to US monetary contractions*

(a) VA_F **(b)** VA_B



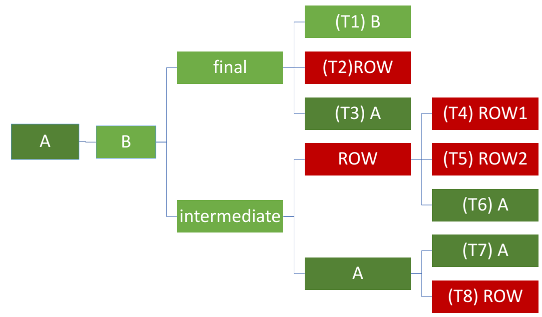
Notes: Each term represents the response (in % terms) of the corresponding ratio as in equation 4.1 to a 1% increase in the US monetary policy rate. In particular, it is the ependent variable is the ratio of value added exports to all non US countries, divided by value added exports to the US.

B Decomposition of intermediate goods trade (Wang, Wei and Zhu 2013)

Starting with an initial shipment of a good from particular sector in the exporting country to a particular importing country, this section summarizes a framework to track and classify the flow according to its subsequent journey all the way to the final destination until it is consumed as part of a final good somewhere in the world-which could be either in the importing country, the exporting country itself (back and forth trade) or a third country which is different from both the initial exporter or importer (global value chain trade). For instance, it can separately identify and track the fraction of the initial shipment which remains in the importing country and is used to produce final goods which are either exported or consumed domestically, and the part which is exported by the importing country as further (second-round) intermediate inputs for further processing, either to a third country or back to the source country.

Table 1 provides a summary of the different components of international trade flows that are tracked by this framework, and Figure B.1 provides a schematic illustration of the eight-term decomposition. In Figure B.1, the starting point is an initial shipment of goods from

Figure B.1 – *Schematic Representation of Intermediate export decomposition*



Notes: The diagram illustrates the eight-term decomposition of bilateral intermediate goods trade proposed in Wang, Wei and Zhu (2013, 2017)

country A to country B. This shipment can be used either to produce final goods, or to produce intermediate goods. The former can either be consumed in B itself (T1), or it can be exported, either back to country A (T3) or to the global economy (T2). Likewise, the frameworks also traces the subsequent journey of the part of initial intermediate shipments that is used to profuce further intermediate goods as part of deeper global value chains. The Figure uses green to indicate trade flows that remain in the region (constituted by A and B), and red to indicate trade flows that are ultimately absorbed outside the region, i.e in the global economy. As discussed above, the model has different implications for the dynamics of these two categories in response to changes in interest rates.

Table 2 shows the median shares of each of the eight components of intermediate goods exports across all the sectors and countries in the sample for select years in the sample. As is evident, the largest fraction of intermediate exports (>60%) end up being absorbed in the direct importing country itself (T1), which contradicts their use as proxies of global value chain trade, as from the perspective of models of global value chains like the one proposed in this paper, these flows are akin to final goods trade flows as they only cross international borders once. That said, as shown in Figure B.2, the share of this component has declined over time, whereas the share of all other components which reflect deeper production fragmentation has ibeen on the rise.

C List of countries and sectors

List of countries: Australia (non EU) Austria Belgium Bulgaria, Brazil(non EU) Canada (non EU) China (non EU) Cyprus Czech Republic Germany Denmark Spain Estonia Finland France United Kingdom Greece Hungary Indonesia (non EU) India (non EU) Ireland Italy

Table 1 – *Decomposition of intermediate goods trade flows*

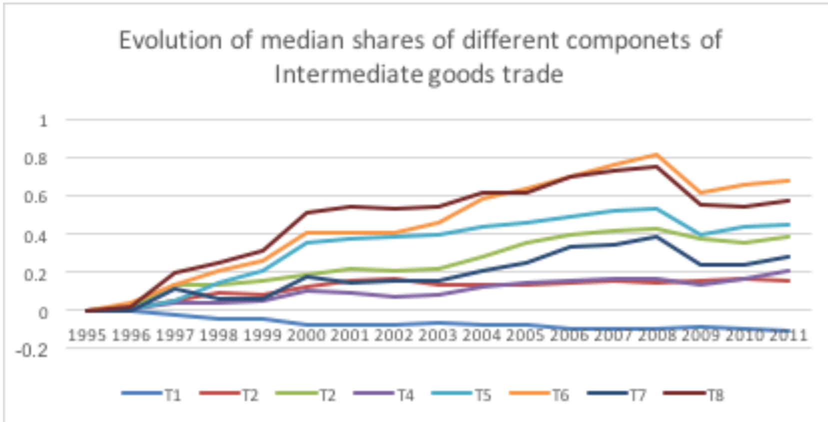
1. Used by direct importer to produce final goods directly , and then used as:(Figure B.1)
   (a) domestic final goods consumed by the direct importer (T1)
   (b) exported final goods consumed by third countries (T2)
   (c) exported final goods consumed by the source (exporting) country (T3)
2. Used by the direct importer to produce intermediate exports, and then:
   (a) first used by direct importer to produce intermediate goods exports, then used by third countries to produce final goods which are subsequently used as:
      i. domestic final goods consumed in the third country (T4)
      ii. exported final goods consumed by countries other than the source country(exporting country) (T5)
      iii. exported final goods consumed by the source (exporting) country (T6)
   (b) first used by direct importer to produce intermediate exports shipped back to the source (exporting) country as intermediate imports to produce final goods
      i. domestic final goods consumed by the source (exporting) country (T7)
      ii. exported final goods consumed by other countries (T8)

Source: Wang, Wei and Zhu (2013)

Table 2 – *Evolution of shares of different components in intermediate exports*

Year	1995	2008	2009	2011
T1	69.38	62.75	63.8	62.46
T2	11.09	12.79	12.97	12.91
T3	0.05	0.08	0.07	0.07
T4	14.54	17.18	16.62	17.81
T5	2.74	4.63	4.06	4.27
T6	0.02	0.05	0.04	0.04
T7	0.09	0.13	0.11	0.12
T8	0.02	0.04	0.03	0.03

Figure B.2 *– Evolution of median shares of different componets of Intermediate goods trade*



Japan (non EU) Korea (non EU) Lithuania Luxembourg Latvia Mexico (non EU) Malta Netherlands Poland Portugal Romania Russia (non EU) Slovak Republic Slovenia Sweden Turkey(non EU) Taiwan(non EU) United States (non EU)

Table 3 *– Sectoral classification and description*

WIOD sector	Sector description	NACE code	Broad 3 sector Classification (Primary, secondary and tertiary)
c01	AGRICULTURE, HUNTING, FORESTRY AND FISHING	AtB	Primary
c02	MINING AND QUARRYING	C	Primary
c03	FOOD , BEVERAGES AND TOBACCO	15t16	Primary
c04	Textiles and textile	17t18	Secondary
c05	Leather, leather and footwear	19	Secondary
c06	WOOD AND OF WOOD AND CORK	20	Secondary
c07	PULP, PAPER, PAPER , PRINTING AND PUBLISHING	21t22	Secondary
c08	Coke, refined petroleum and nuclear fuel	23	Secondary
c09	Chemicals and chemical	24	Secondary
c10	Rubber and plastics	25	Secondary
c11	OTHER NON-METALLIC MINERAL	26	Secondary
c12	BASIC METALS AND FABRICATED METAL	27t28	Secondary
c13	MACHINERY, NEC	29	Secondary
c14	ELECTRICAL AND OPTICAL EQUIPMENT	30t33	Secondary
c15	TRANSPORT EQUIPMENT	34t35	Secondary
c16	MANUFACTURING NEC; RECYCLING	36t37	Secondary
c17	ELECTRICITY, GAS AND WATER SUPPLY	E	Secondary
c18	CONSTRUCTION	F	Secondary
c19	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	50	Tertiary
c20	Wholesale trade and commission trade, except of motor vehicles and motorcycles	51	Tertiary

Table 3 *– Sectoral classification and description cont.*

WIOD sector	Sector description	NACE code	Broad 3 sector Classification (Primary, secondary and tertiary)
c21	Retail trade, except of motor vehicles and motorcycles; repair of household goods	52	Tertiary
c22	HOTELS AND RESTAURANTS	H	Tertiary
c23	Other Inland transport	60	Tertiary
c24	Other Water transport	61	Tertiary
c25	Other Air transport	62	Tertiary
c26	Other Supporting and auxiliary transport activities; activities of travel agencies	63	Tertiary
c27	POST AND TELECOMMUNICATIONS	64	Tertiary
c28	FINANCIAL INTERMEDIATION	J	Tertiary
c29	Real estate activities	70	Tertiary
c30	Renting of m&eq and other business activities	71t74	Tertiary
c31	PUBLIC ADMIN AND DEFENSE; COMPULSORY SOCIAL SECURITY	L	Tertiary
c32	EDUCATION	M	Tertiary
c33	HEALTH AND SOCIAL WORK	N	Tertiary
c34	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES	O	Tertiary
c35	PRIVATE HOUSEHOLDS WITH EMPLOYED PERSONS	P	Tertiary

PUBLICATIONS

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