INTERNATIONAL MONETARY FUND

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WP/22/28

2022
FEB

WORKING PAPER

 WP/22/28

IMF Working Paper
Research Department

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

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Authorized for distribution by Prachi Mishra
February 2022

ABSTRACT: This paper reexamines the relationship between monetary policy, exchange rates and international trade in a world characterized by the dominant currency paradigm and global value chains. Using a three-country dynamic stochastic general equilibrium (DSGE) model, it documents key differences between the response of gross and value added trade flows to interest rate shocks, and offers a framework to test them in the data. The exercise uncovers a new margin of adjustment where value added trade flows react significantly to shocks, even as gross trade flows that are typically measured in the data remain relatively flat. This provides a reconciliation between the output effects of textbook models that assume producer currency pricing and no value chains, and the low aggregate exchange rate passthrough and muted adjustment of gross trade flows that has been documented in the data.

JEL Classification Numbers:	F4, E3
Keywords:	Dollar invoicing; global value chains; exchange rates; monetary policy.
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*We would like to thank the editor Martin Uribe, Rudolfs Bems, Alessandro Borin (discussant), Michael Devereux, Charles Engel, Gunes Kamber, Jinill Kim (discussant), Amartya Lahiri, Ben Tomlin, Jian Wang (discussant), James Yetman and three anonymous referees, as well as seminar participants at the Bank for International Settlements, Hong Kong Monetary Authority, ESCB Emerging markets workshop (Bank of Italy), IMF, Indian Statistical Institute, Midwest Macro Meetings and the Reserve Bank of India for helpful comments and suggestions. We are grateful to Zhi Wang for sharing the data on decomposition of bilateral exports and Justine Pedrono for excellent research assistance. All errors are our own.
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1 Introduction

This paper examines the implications of two empirically documented features of the evolving international trade system that call for a more detailed analysis of the export channel of monetary policy. The first feature is the dominant currency pricing (DCP) of international trade (see for instance Gopinath et al. (2020) and Boz et al. (2017)). Globally, a large share of exports are priced in key "vehicle" currencies such as the US dollar and the Euro. 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 the importer's currency (Betts and Devereux (2000)). When export firms price their goods in a currency other than their own (such as under DCP), the passthrough of exchange rates into relative prices of exports is significantly reduced, and the export competitiveness effects of exchange rate adjustment are muted. Instead, adjustment occurs primarily through imports, where passthrough is close to complete for economies other than the dominant currency issuer (see for instance Cook and Devereux (2006a), Cook and Devereux (2006b), Goldberg and Tille (2009) and Gopinath et al. (2020)).

The second feature is the increasing dominance in international trade of global value chains (GVC), in which intermediate materials cross borders multiple times before the value added reaches the final consumption destination (Johnson and Noguera (2012), Hummels et al. (1998) and Koopman et al. (2014)). When countries process imported materials for further export, gross export levels differ from the domestic value added embedded in exports. GVCs therefore introduce another export based channel of exchange rate adjustment. The pass-through of exchange rates into import prices changes the competitiveness of imported materials relative to using domestically produced content for exports. Exchange rate adjustment can then induce limited adjustment of *gross* exports accompanied by sharp adjustment in *value added* exports.

To understand these channels, we model the effects of monetary policy shocks in a three country New Keynesian DSGE economy where two "regional" economies trade with each other, as well as trade outside the region with a dominant global economy. The model includes a simple global value chain operating within the region. 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. Though the model itself is generic, we base our parameterization on the importance of intra-regional and extra-regional trade in emerging Asia-Pacific economies.

We examine the equilibrium response of a regional economy to exogenous monetary policy shocks that originate either in the domestic or the global economy. When a regional central bank unilaterally cuts interest rates and depreciates its own currency, DCP limits the expansion in domestic gross exports. This contrasts with a textbook PCP model in which depreciation passes through into export prices, making exports more competitive. In the DCP models, trade adjusts primarily through declining imports (unlike LCP models). However, if a DCP model includes a value chain, then the depreciation will allow adjustment through an increase in value added exports, as the export platform shifts away from imported materials and towards domestic content. This hidden adjustment of exports along the value chain closes some of the gap between DCP and textbook models in terms of the export channel of monetary policy transmission. However, the model also suggests that a full consideration of the channel requires measuring exports at the level of net value added rather than focusing solely on gross export data.

A monetary tightening in the global economy has sharp negative spillovers to regional exports in DCP models (relative to LCP or textbook PCP models). When the dominant currency appreciates relative to both regional currencies, intra-regional trade becomes uncompetitive as all imports are priced in the appreciating currency. Trade within the intra-regional value chain faces the sharpest contraction due to declining final demand in the global economy. Thus, we find the sharpest decline in gross exports when the model includes a value chain. However, when we measure exports in value added terms, the decline in gross exports is offset by increasing domestic value-added content of exports. In particular, we find that a DCP model augmented with a value chain displays a similar contraction in value added exports as in a DCP model in which all trade is in final goods. This shows that in a model with substantial trade in materials, a disruption in trade induces a strong shift of the export platform toward domestic value added content, an avenue of adjustment that is not detected when focusing on gross exports. The global value chain intensifies the contraction in gross exports, but this is offset in value added terms by the switch toward domestic content.

We identify two testable predictions of the model on the impact of an external monetary policy tightening of the dominant currency. First, the model predicts that value added exports to the regional economy contract by more than value added exports to the dominant economy due to the pricing of regional trade in the dominant currency. Second, the domestic value added content of exports to the dominant economy increases relative to gross exports, due to the disruption in materials trade brought about by a depreiciation of regional currencies relative to the global currency.

We confront these results with data by looking at the response of trade flows to US interest rates. Testing these predictions of the model is challenging using standard international trade databases that do not capture global value chain activity. 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 et al. (2017a), Wang et al. (2017b) and Wang et al. (2013) 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 decline much less in response to US interest shocks than does trade to other countries, which is in line with DCP. Changes in the global value of the US dollar directly affects 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 their domestic currency. We also document suggestive evidence 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.

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-Cicco and García-Schmidt (2020).

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 in response to shocks. Section 4 discusses the data and presents empirical results motivated by the model. Section 5 concludes with a summary of the main messages.

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)), price elasticities (Friberg (1998)), currency hedging (Goldberg and Tille (2008)), imported inputs (Novy (2006)), financial market development and openness

(Ito and Chinn (2014) and Ito and Kawai (2016)), market size (Bacchetta and Van Wincoop (2005)), 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 (2022)), the number of independent currencies, (Devereux and Shi (2013)) and currency of financial contracts (Gopinath and Stein (2021)).

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 (2014) and Boz et al. (2022). Devereux et al. (2017) and Goldberg and Tille (2016) identify the currency invoicing choice of Canadian importers. Zhang (2022), 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 et al. (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 most defining facets of globalization over the last few decades (Baldwin and Lopez-Gonzalez (2014)). Hummels et al. (2001) and Hummels et al. (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 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 et al. (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 et al. (2017a), Wang et al. (2017b) and Wang et al. (2013) have extended the framework of Koopman et al. (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 et al. (2019) study how real effective exchange rates should be interpreted in a world with global value chains.

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. Our paper is motivated by trade in the East Asia/Pacific region, where regional and global value 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. We index all of the economies with $j = A, B, W$ and use $d = A, B$ on occasion for regional economies. Regional economies (A and B) operate export platforms that combine value added from regional and global producers for ultimate final export to the global economy. Each of these countries import goods for final use. An international risk free bond, priced in global currency, is traded.

2.1 Household

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

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

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.

Regional country A prices are priced at PA_t^j 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:[1]

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

Households save by holding bonds(B_t^j) denominated in international dollars. 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 budget constraint is given by

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

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

$$\Omega_t^j W_t^j = \Gamma_j L_t^{j\,\frac{1}{\theta}} \tag{2.7}$$

$$\Omega_t^j CPI_t^j = C_t^{j\,\frac{-1}{\zeta}} \tag{2.8}$$

$$1 = E_t[\beta \frac{\Omega_{t+1}^j}{\Omega_t^j}(1+i_t^j)] = E_t[\beta \frac{\Omega_{t+1}^j}{\Omega_t^j}\frac{S_{t+1}^j}{S_t^j}(1+r_t^j)]$$

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 is produced with labor according to a linear production function

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

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

where Y_t^j is output. The domestic currency marginal cost of production goods (denoted MCY_t^j) is given by wages ($MCY_t^j = W_t^j$)

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

$$V_t^d = \left(e_d^{\frac{1}{\gamma}} \left\{ VR_t^d \right\}^{\frac{\gamma-1}{\gamma}} + (1-e_d)^{\frac{1}{\gamma}} \left\{ VW_t^d \right\}^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}} \tag{2.10}$$

Optimal demand is given by:

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

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.

$$VR_t^d = \left(f_d^{\frac{1}{\nu}} \left\{ VA_t^d \right\}^{\frac{\nu-1}{\nu}} + (1-f_d)^{\frac{1}{\nu}} \left\{ VB_t^d \right\}^{\frac{\nu-1}{\nu}} \right)^{\frac{\nu}{\nu-1}} \tag{2.12}$$

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

$$\frac{VA_t^d}{V_t^d} = f_d \left(\frac{PA_t^d}{MCRV_t^d} \right)^{-\nu} \qquad \frac{VB_t^d}{V_t^d} = (1-f_d) \left(\frac{PB_t^d}{MCRV_t^d} \right)^{-\nu} \tag{2.13}$$

where VA_t^d and VB_t^d are materials used in d sourced from A and B respectively, and MCV_t^d and $MCRV_t^d$ are defined implicitly by $MCV_t^d = \left(e_d \left\{ MCRV_t^d \right\}^{1-\nu} + (1-e_d) \left\{ PW_t^d \right\}^{1-\nu} \right)^{\frac{1}{1-\nu}}$ and $MCRV_t^d = \left(f_d \left\{ PA_t^d \right\}^{1-\nu} + (1-f_d) \left\{ PB_t^d \right\}^{1-\nu} \right)^{\frac{1}{1-\nu}}$ respectively.

The weights $\{a_j, b_j, e_d, f_d\}$ determine the degrees of home and regional bias. 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. In the textbook producer currency pricing (PCP) model, exports are priced in the currency of the producer. In order to be concise, we use $P_t^j \in \{PA_t^j, PB_t^j, PW_t^j\}$ as placeholders for the implied customer currency price under each scenario.

2.3 Distribution Firms and Sticky Prices

For each producer and destination, there exists a distribution industry that combines 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 as follows: $H_t^j = \left[\int h_{l,t}^{\frac{\phi-1}{\phi}} dl\right]^{\frac{1}{1-\phi}}$, where

$$CA_t^A + VA_t^A = H_t^A, \qquad CB_t^B + VB_t^B = H_t^B, \qquad CW_t^W = H_t^W \tag{2.14}$$

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,

$$EX_t^j = \left[\int ex_{l,t}^{\frac{\phi-1}{\phi}} dl\right]^{\frac{1}{1-\phi}}, j \in \{A, B\} \tag{2.15}$$

where

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

For regional exports 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 $IPI_t^j EX_t^j \equiv \int \{ipi_{l,t}ex_{l,t}\}\, dl$. For $j \in \{A, B\}$,the regional export price is denominated in global dollars in the DCP model, in exporter j currency under PCP, and in importer currency under LCP.

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

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

The exports to the global economy, $xpi_{l,t}^j$, are always priced in global dollars where the price index is defined $XPI_t^j M_t^j \equiv \int \left\{xpi_{l,t}m_{l,t}\right\} dl$.

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 reset 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 reset price in period t is:

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

where τ is defined as a subsidy provided to potentially 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 $j \in \{A, B, W\}$, the domestic prices targeting the domestic sector are sticky in domestic currency given by $PA_t^A = PPI_t^A, PB_t^B = PPI_t^B,$ and $PW_t^W = PPI_t^W$.

The optimal reset price for the global export distribution sector for $d = (A, B)$ is given by

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

This yields the following aggregate price index,

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

The nature of invoicing also affects the pricing of exports to the regional economies. The prices of goods imported into regional economies $d \in \{A, B\}$ from exporter $j \in \{A, B, W\}$

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 $E_t^{j:d}$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 (DCP), the invoicing currency is global dollars, such that $E_t^j = S_t^j$. Under local currency pricing (LCP), the destination country's currency is used as the invoicing currency, so we can write the relevant exchange rate as the cross rate $E_t^{j:d} = \frac{S_t^j}{S_t^d}$ to convert the price into the target market economy's currency. In the producer currency pricing (PCP) case, $E_t^j = 1$, so that exports are priced in exporter currency.

In the case of LCP, $PA_t^B = IPI_t^{B:A}$ and $PB_t^A = IPI_t^{A:B}$ while $PW_t^d = IPI_t^{W:d}$ 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 $PB_t^j = S_t^B IPI_t^{j:B}$ for $j = A, W$. 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. In the case of PCP, $PA_t^B = \frac{S_t^A}{S_t^B} IPI_t^{B:A}$ and $PB_t^A = \frac{S_t^B}{S_t^A} IPI_t^{A:B}$, while $PA_t^W = S_t^A IPI_t^{WA}$and $PB_t^W = S_t^B IPI_t^{WB}$, so exchange rate changes pass through immediately into effective prices. In the DCP and LCP models $PA_t^W = XPI_t^A$ and $PB_t^W = XPI_t^B$. In the PCP model, $PA_t^W = \frac{XPI_t^A}{S_t^A}$ and $PB_t^W = \frac{XPI_t^B}{S_t^B}$.

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.

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

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

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

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

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

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

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

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

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

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; 3) about 55% of foreign value added comes from within the region; 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 inter-temporal substitutability of consumption, ζ, and the

Table 1 *– Pricing and Trade Pattern Assumptions in the Four Models Studied in Figures 3.1 and 3.2*

	Value Chain	No Value Chain
Dominant Currency	(1) Benchmark	(2) DCP-NoVC
Local Currency	(3) LCP	
Producer Currency		(4) Textbook

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, $\kappa = .75$. The subjective discount factor, $\beta = .99$, 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-Grohé and Uribe (2003)).

To highlight the effect of the interaction of dominant currency pricing and the global value chain, we compare the response of the main DCP model ("Benchmark") with the effects of a similar interest rate shock under three alternative models summarized in Table 1. In particular, to illustrate the effects of dominant currency pricing, we compare to a model with LCP using the benchmark trade weights. To illustrate the impact of the interaction between DCP and GVC, we consider two additional alternatives with the no value chain trade weights. In the NoVC trade weight 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. The two variants of the NoVC model that we consider are (a) a Textbook model under PCP with the NoVC trade weights, labelled "Textbook" and (b) a DCP-NoVC model.

3.1 Domestic Monetary Policy Shocks

To illustrate the impact of domestic monetary policy in regional economies with DCP, 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 features the response of the Regional Economy A under the four scenarios summarized in Table 1.

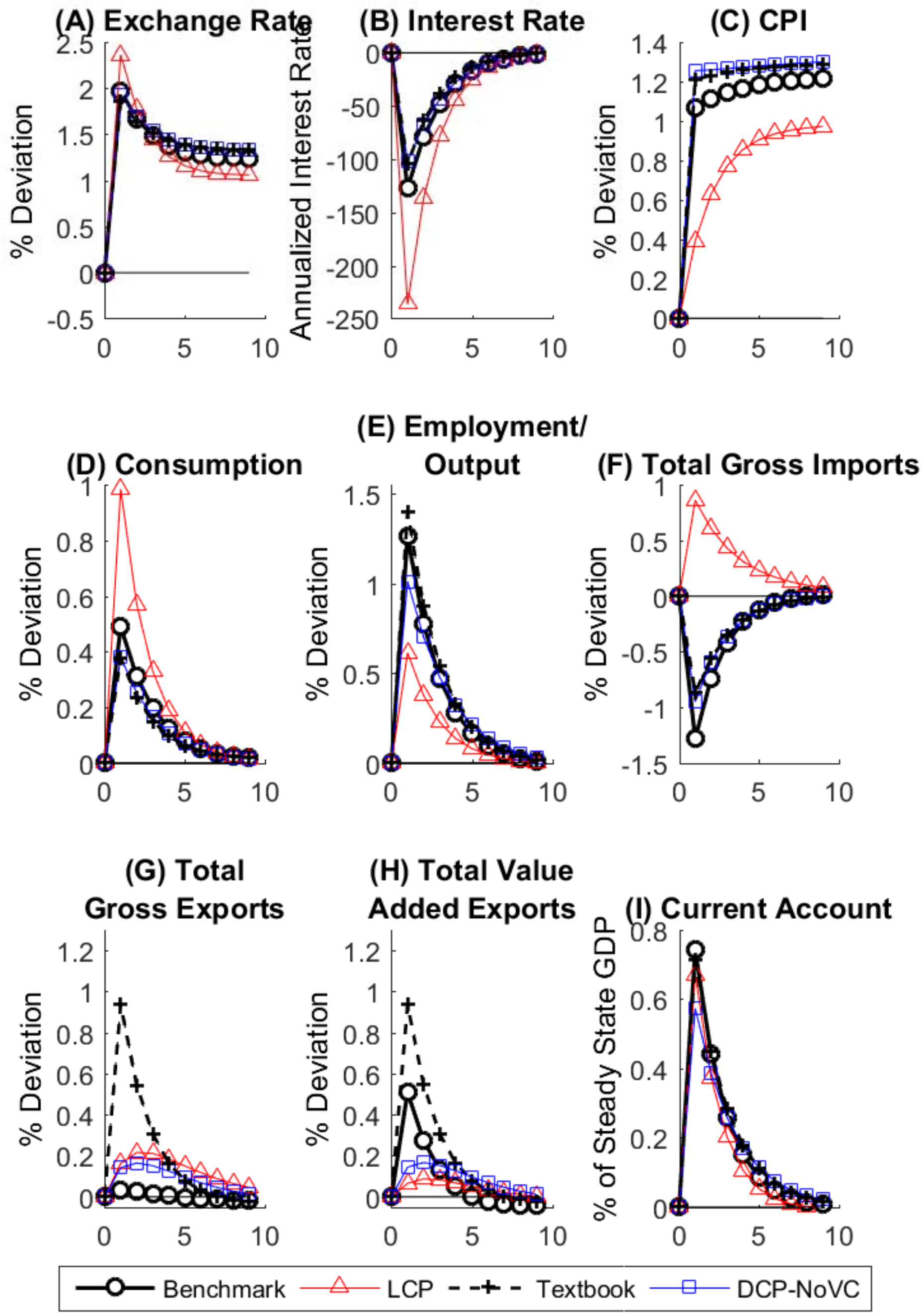
The policy shock leads to a close to equivalent exchange rate depreciation in the Benchmark, Textbook and the DCP-NoVC cases; the shock generates a slightly larger exchange rate response under LCP (see Fig 3.1, Panel A). The depreciation raises the price of imported goods which passes through into the CPI (Panel C). The initial pass-through to CPI is minimal under LCP and is stronger in the Textbook and NoVC models since all imports go to consumer goods and the import content of consumption is large relative to the other models. The CPI targeting Taylor rule implies that the interest rate response differs under alternative models (Panel B) depending on pass-through. The decline in interest rates is similar in the NoVC and Textbook cases, slightly sharper in the Benchmark case (due to the stronger CPI response) and sharply larger under LCP (due to the weaker CPI response). As per the Euler equation, the persistent cut in interest rates leads to a proportional expansion in consumption (Panel D). This is sharpest under LCP, roughly equivalent under NoVC and Textbook, and intermediate under NoVC in accordance with the size of the interest rate response.

Panel F shows the response of gross imports. The volume of imports increases proportionally with domestic demand under LCP. By contrast, imports contract in the other models despite the rise in domestic consumption. Whether imports are priced in the currency of the global economy or the regional trading partner, the domestic depreciation makes imports more expensive and leads to expenditure switching toward domestic goods. In the Textbook and DCP-NoVC case, imports are concentrated toward consumption, and as consumption overall is rising, imports fall by less than in the Benchmark model where imports are partially for materials.

Under the Textbook model, the depreciation immediately improves both regional export competitiveness and increases gross exports (Panel G). In other models, either local or dominant currency pricing limit the pass-through of the depreciation into import prices in destination markets. Thus, the exchange rate depreciation leads to small increases in gross exports. The gross export response is particularly limited in the Benchmark DCP economy. The export platform faces increasing costs of imported materials which reduces exports to the global economy.

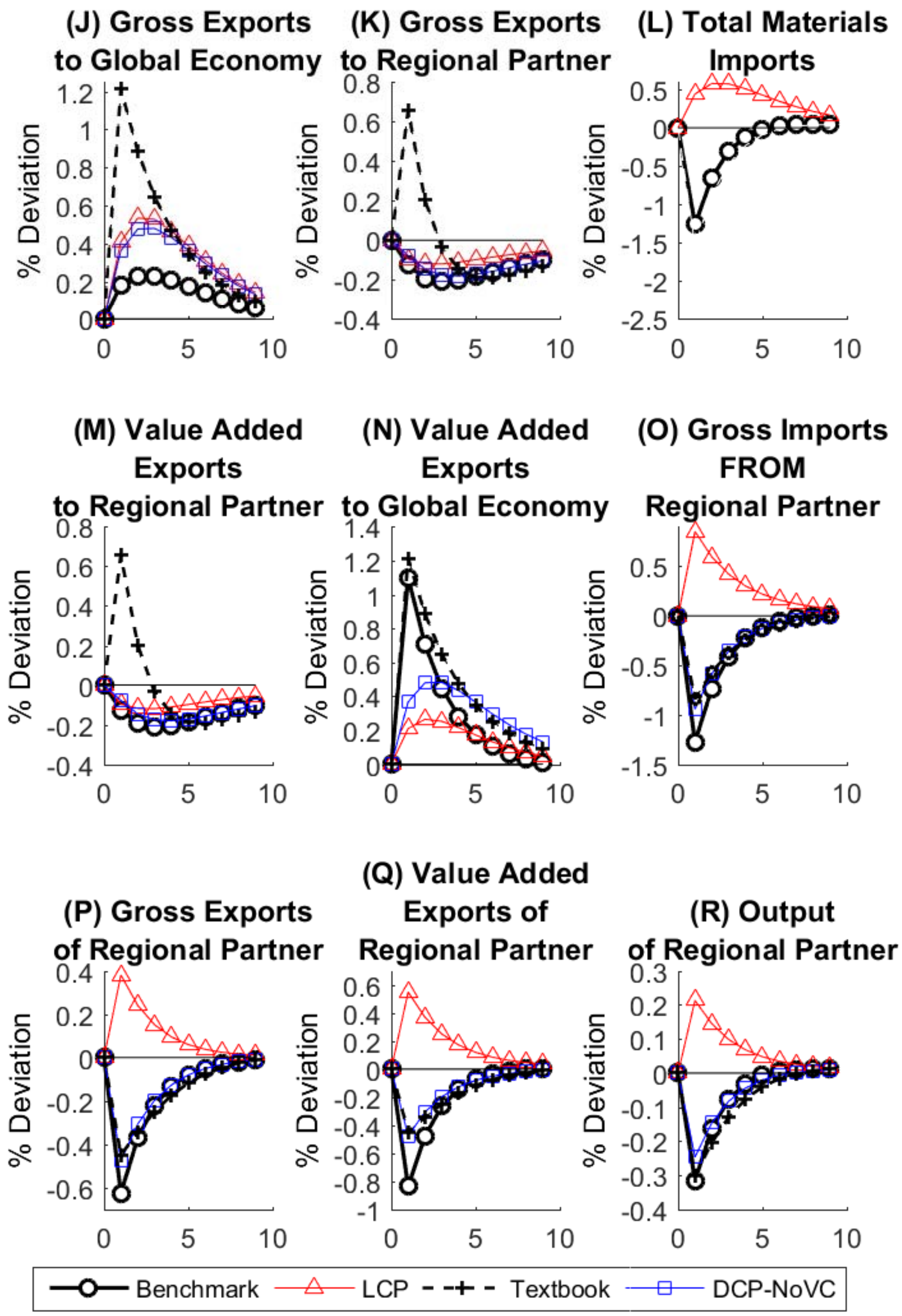
Though DCP insulates gross exports from exchange rate depreciation, this is not true for exports measured in value added terms due to value chain trade. We specify value added exports of economy A as $EXV^A_t = CA^B_t + VH^A_t + VA^B_t$, which is the export of

Figure 3.1



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 – *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%.

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. Under the Benchmark DCP economy, the very muted expansion in gross exports in panel G masks a sharp increase in exported value added. The increase in the prices of imported materials leads the domestic platform to switch to domestic content. Though expenditure switching has negligible impact on gross exports, there is a substantial direct expenditure switching effect on domestic value embedded in exports. In the absence of increasing import prices (LCP), there is no motivation to switch to domestic content and the increase in value added exports. In the Textbook and DCP-NoVC cases, gross export and value added exports are the same.

Domestic output increases in all cases (Panel E), though the impact of the shock depends on the strength of the exchange rate channel on imports and exports. The strong export response in the Textbook model leads to the strongest response of domestic output. In the Benchmark model, there is no increase in gross exports, but value added exports increase through increasing domestic content in exports. Output increases by almost as much in the Benchmark model as in the Textbook model, and by more than the DCP-NoVC case, which does not include this avenue of export adjustment. The increase in demand for domestic goods is smallest in LCP case, as in this case there is no decline in imports.

Panel I shows the response of the current account, measured in global dollars as $B_t^A - B_{t-1}^A$. 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. In other models, the decline in volume of imports along with whatever increase in volume of value added exports improve the current account.

Panel J and K show gross exports to the global economy, CA_t^W, and to the regional trading partner, $CA_t^B + VA_t^B$. In the Textbook model, gross exports to both markets increase as depreciation passes through immediately into the effective prices. In other models, the increase in gross exports of the platform to the global economy is weak due to pricing of exports in global currency. This is especially true in the Benchmark case where the increase in the cost of imported materials mute any improvement in competitiveness. Exports to the regional partner are mildly crowded out in the Benchmark, LCP, and DCP-NoVC cases. In all of these cases (unlike the Textbook), depreciation does not improve regional competitiveness due to the invoicing structure of trade.

Panel L shows the response of imported materials, VB_t^A. 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 final exports.

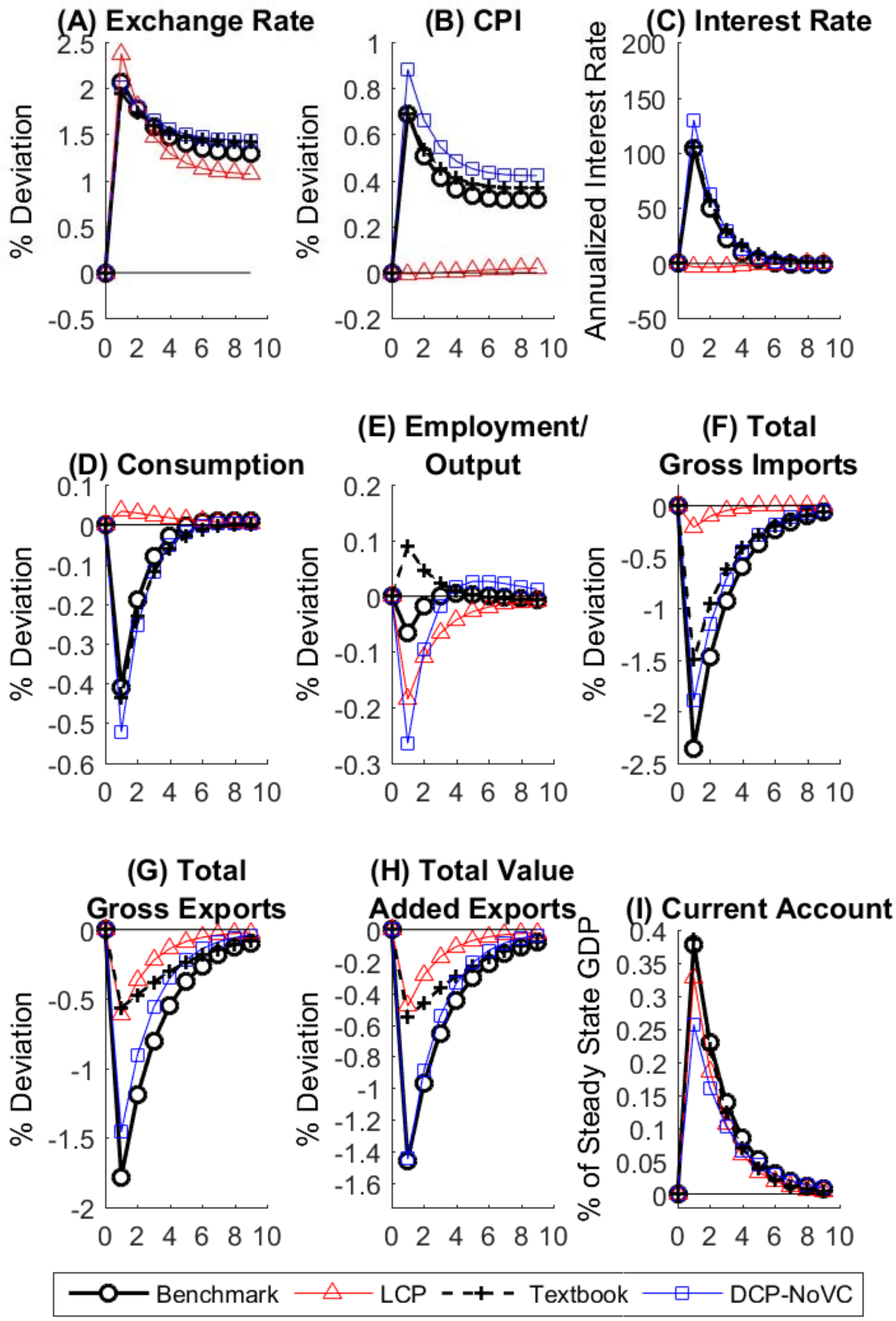
Panel M shows that value added exports to the regional economy, CA_t^B, are not much affected by depreciation, except in the Textbook model. Panel N shows that the Benchmark shift toward domestic content implies that domestic value added embedded in exports to the global economy, $VH_t^A + VA_t^B$, increase immediately, even though gross exports to the global economy display more modest change. The LCP model does not include the shift toward domestic content on the platform. Imported materials are always zero in the Textbook and DCP-NoVC case and gross and value added exports are identical.

Panels O-R summarize the spillovers of a monetary shock in economy A to economy B. When regional imports are priced either in global dollars or producer currency, a domestic exchange rate depreciation causes them to lose competitiveness to domestic goods and imports from the regional partner fall. This decline is concentrated in imported value chain materials in the Benchmark since platform exports to the global economy increase less than domestic demand. Therefore, cross-regional trade falls by more in the Benchmark than in the Textbook and DCP-NoVC case (see Panel O). Under LCP, imports from the regional partner rise as the depreciation has little effect on their competitiveness. Gross 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 inter-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).The value added exports of the regional partner decline by a similar amount (Panel Q). In the LCP case, the spillover of the monetary expansion to the regional partner's production is positive through increasing imports of consumer goods. In the other cases, imports from B and B's production face a negative spillover. The decline in imports from the regional partner leads to a small decline in output in the regional trading partner (see Panel R).

3.2 Global Interest Rate Shocks

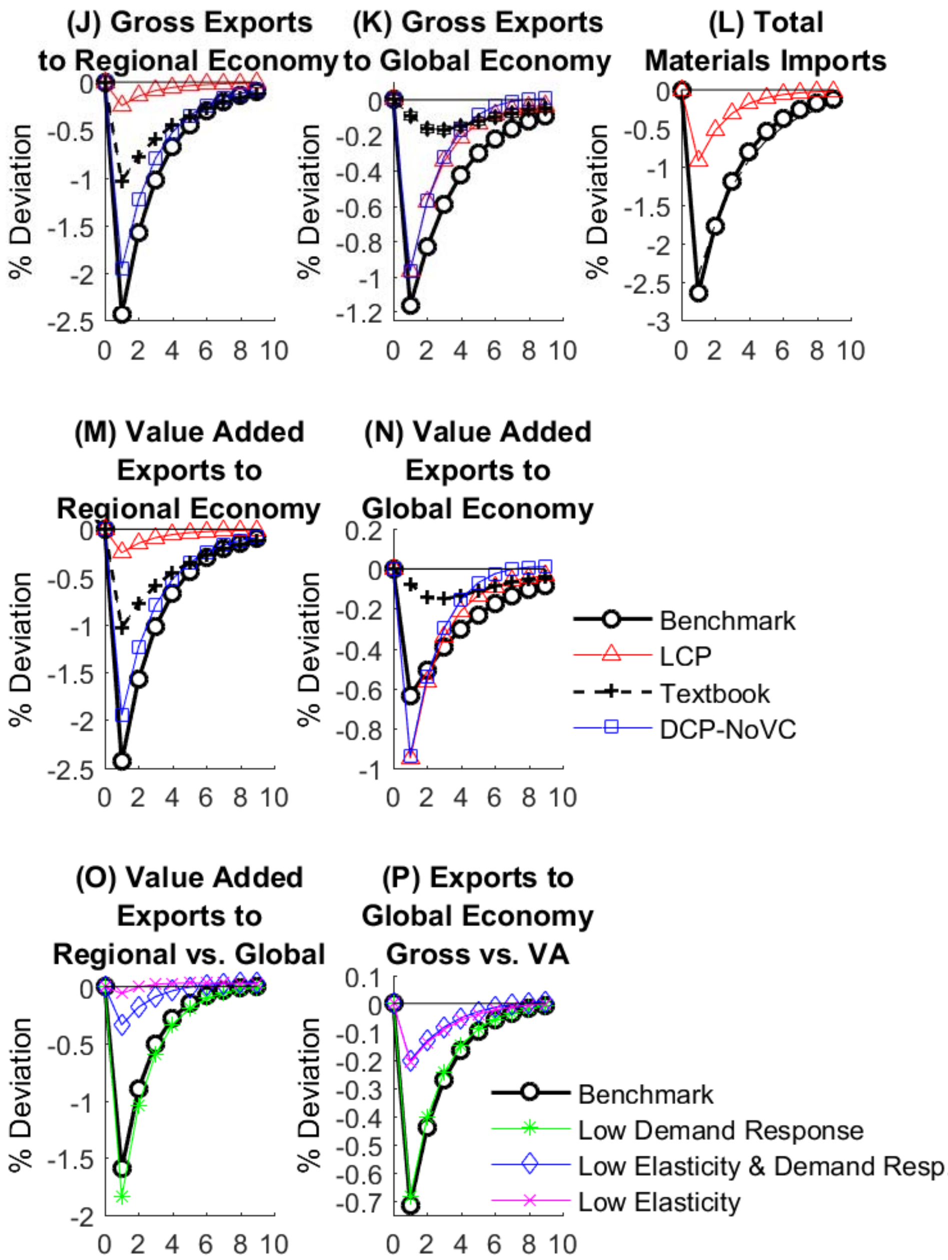
Next, we examine the effects of an exogenous increase in policy interest rates in the Global economy. This takes effect as a one time shock to the interest rate rule at period 1, such that $\lambda_{t=1}^W = 1.0075$, which generates an equilibrium increase in interest rates slightly greater than 200 annualized basis points in the Global economy and generates a 2% appreciation of the dominant currency relative to both regional currencies. Due to interest smoothing, there is a persistent rise in the nominal interest rate in the global economy, along with a decline in consumption and output as is usual in a New Keynesian economy. Figure 3.2 shows the response of either regional economy to this global monetary contraction in all four models. The figure shows only the response of country A, with country B's response being symmetric.

Figure 3.2



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 *– 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.

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 sharper in the LCP case due to a weaker domestic policy rate response to the global shock. As shown in Panel B, exchange rate depreciation passes through into consumer prices to the degree consumer goods are priced in global currency. The exchange rate pass-through into CPI is largest in the DCP-NoVC case as imported consumer goods priced in dominant currency are the largest share of the consumer market basket (all imports are for consumer and all imports priced in dominant currency). In the Textbook case, imported regional consumer goods are not priced in global dollars and do not face inflation. In the Benchmark model, imports are a smaller fraction of consumer goods. Therefore, the response of CPI is a bit weaker in both the Benchmark and Textbook cases than in the DCP-No GVC case. In the LCP case, there is no pass-through and virtually no CPI response. The increase in the CPI leads to a monetary tightening whose strength reflects the CPI rise observed in each model. Panel C shows that interest rates rise by 100 annualized basis points in Benchmark and Textbook cases, more so in the DCP-NoVC case, but rise little in LCP. Rising interest rates lead to a decline in consumption (Panel D), which reflects the rise in interest rates.There is a negligible response of consumption under LCP.

We see different responses of the pattern of trade depending on the pricing model. Under LCP, imports are invoiced in the currency of the destination country so imports are insulated from depreciation. 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 from all locations. The global value chain intensifies this effect for reasons discussed in subsequent paragraphs. Under the Textbook model, regional imports are priced in the exporter's currency. As the global shock does not affect cross rates within the region, regional imports face less exposure to the shock and the decline in overall imports is smaller than the Benchmark.

Likewise, the interaction between depreciation and dominant currency pricing disrupts gross exports and this too is intensified by global value chain (Panel G). Under LCP, exchange rates have little immediate impact on exports and the decline in exports reflects mainly the decline in both regional and global consumption. Under the Textbook model, depreciation against the global currency mostly insulates exports to the global economy from the downturn in global demand. Further, regional exports are not priced in global currency so are not disrupted by global currency appreciation. Therefore the decline in exports is small in both the Textbook and LCP cases. Under DCP-NoVC, there is a substantially larger decline in gross exports than under LCP or Textbook. But the Benchmark shows an even larger decline in gross exports, driven by the decline in platform exports to the global economy where demand is declining, along with the parallel decline in exports to the regional partner's platform.

However, the decline in the value added content of exports are quite similar in the Benchmark and DCP-NoVC case (Panel H). Materials imports from both the regional and global economy are priced in global dollars and become more expensive with the appreciation. Regional platforms respond to this by shifting to domestic content. Thus, value added exports fall by less than gross exports in the Benchmark model. There is no difference between gross and value added exports in the Textbook and DCP-NoVC model. The global value chain is not disrupted under LCP so the response of gross and value added exports are also similar.

In the LCP model, domestic consumption and imports display limited response to the shock, but exports decline, leading to a decline in output (Panel E). Under the Benchmark and NoVC model (both with dominant currency pricing), the sharp decline in imports due to the disruption in global trade imply that output falls by less than the decline in domestic consumption and exports. The very small decline in exports under Textbook combined with a relatively large decline in imports lead to a small increase in output.

In all cases, there is an increase in the current account (Panel I). This reflects an increase in net balance of trade in volume terms under the Benchmark, Textbook, and DCP-NoVC model and reflects valuation effects under LCP.

Panel J and K show the change in direction of gross exports. Under the Benchmark, 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 for processing into exports to the contracting global economy makes the disruption in regional trade more intense in the Benchmark relative to the DCP-NoVC case. Under LCP, the decline in regional trade is minimal. There is a sharper decline in regional exports in the PCP case relative to LCP, due to larger interest-rate led decline in regional consumption. However, the region-wide depreciation against the global currency does not disrupt regional trade so the decline in regional trade is smaller than in either DCP case.

All models show a decline in gross exports to the global economy, primarily driven by the decline in aggregate demand within the global economy. In the Textbook model, depreciation against the global currency mostly insulates exports from this decline. The DCP-NoVC and LCP model show sharper declines as their exports to the global economy are priced in global currency. The value chain intensifies the decline in gross exports to the global economy in the Benchmark 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. Likewise (Panel L), materials imports decline sharply under the Benchmark in response to the global appreciation. The disruption of imported materials trade is much smaller under LCP as invoicing in destination currency insulates materials trade from the global appreciation.

Value added exports to the regional economy also fall in a similar pattern as gross exports to the same destination (Panel M). This is not true for exports to the global economy under the Benchmark. The Benchmark model shows the largest decline in gross exports to the global economy relative to other models (Panel K). However, materials imports decline by even more in the Benchmark economy (Panel L). The domestic content share of exports increases to replace expensive imported materials, so that the decline in the value added exports to the global economy is substantially smaller than the decline in gross exports (again narrowing part of the gap with the Textbook model). In the LCP case, materials trade is minimally disrupted so the decline in gross and value added exports to the global economy are similar (and identical in the Textbook and DCP-NoVC case due to the lack of materials trade).

Robustness checks on the main testable implications of the model

We conclude this section by highlighting two testable implications of the model that we take to the data in the next section, and check the robustness of these to alternate parameterizations.

Our first testable implication comes from comparison panels M and N in Figure 3.2. It shows that in value added terms in response to a US monetary contraction, value added exports to the US decline by much less than value added exports to the rest of the world in the Benchmark model. We can see 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 inter-temporal substitution 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. (2011),and inter-temporal elasticity of substitution, $\zeta = .2$, consistent with Best et al. (2020). The low inter-temporal elasticity of demand implies global demand for final goods demonstrates a small response to changes in the interest rate. This stabilizes the demand response to monetary policy. In this scenario, we also assume low elasticity of labor supply so that output changes are not large. We assume both stable demand and supply so that monetary policy does not create large trade imbalances.

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 responses 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.

The other main takeaway from Figure 3.2 is that in the Benchmark model, exports to the US decline much more sharply when measures in gross terms as compared to value added terms, in contrast to the other models. 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 it equally impacts the numerator and the denominator.

To summarize, these results suggest that while alternate parameterizations affect the magnitudes, the two main testable impactions of the model remain qualitatively robust. We therefore focus our empirical section on the direction of the effects, rather than precise magnitudes.[2]

[2]Indeed, a more precise quantitative assessment would also warrant a role for features such as financial frictions where the value of the dollar also plays a key role-see for instance Hofmann et al. (2022).

4 Empirical Analysis

While our contribution is primarily on the modeling front, this section provides suggestive evidence on key predictions of the model regarding the elasticity of different measures of trade flows to US interest rates. The typical limitation of standard data sources on international trade data 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.

To overcome this limitation, we use a granular decomposition of exports proposed by Wang et al. (2013) and Wang et al. (2017b). 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. In the first empirical exercise we focus on the bilateral 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.

- 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.

- 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.

- IVAF and IVAB: Indirect value added exports (forward and backward): parts of value added bilateral flows that are intermediated explicitly via third 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.

As shown by Wang et al. (2017b) , 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 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

$$R_x = \frac{x_{\text{non-US}_{destination}}}{x_{US}}; x \in \{VAF, VAB, IVAF, IVAB\} \tag{4.1}$$

one testable implication of the model is that r_x should fall in response to US interest rate increases.

Estimation and Results

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

$$r_{x,t+h}^{i,j}(s) = \alpha_h^{i,j}(s) + \eta_h r_{xt-1}^{i,j}(s) + \beta_h i_{us,t} + \delta_h X_t^{ij} + \epsilon_{t+h}^{i,j}(s) \tag{4.2}$$

Here, $r_{x,t+h}^{i,j}(s)$ denotes the measure of trade as defined in equation 4.1 (in logs) 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 (2018). We use a first stage regression to orthogonalize the interest rate with respect to contemporaneous and lagged values of US GDP and inflation.

X_t^{ij} is a vector of controls and includes contemporaneous and lagged values of the bilateral exchange rate between the importer and the exporter, real GDP of the importer, exporter and the US, total imports by the importer, as well as the unit labor cost in the exporting country and inflation in the importing country. A quadratic time trend and a dummy for the financial crisis years (2008 and 2009) is also included in the regressions. The impulse responses are computed using the local projection method developed in Jordà (2005).

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, which is particularly important given the small time dimension in our data (15 years). Second, it reduces endogeneity concerns, since sector-level trade flows are less likely to influence aggregate macro variables such as US 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.[3]

The main data source is the world input output database (WIOD).[4] The available sample runs from 1995-2011 (annual) and covers 35 sectors in 40 countries . The sample thus contains 54600 (=40*39*35) bilateral export observations at the sector level for each year. Of these, we exclude observations where the exporting and the importing country is in Europe as dollar invoicing is likely to be limited in these cases, and data availability on covariates reduces the sample somewhat further (See Appendix C for the full list of countries and countries, sectors and their categorization.)

Figure 4.1 summarizes the main results from the estimation of equation 4.2 for non-US countries, and excluding intra-European trade. 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.

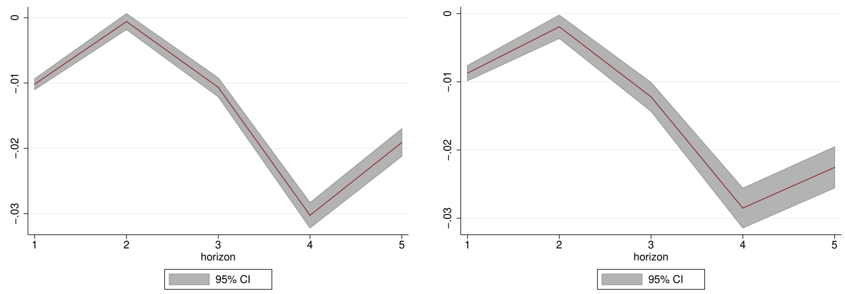
Forward and backward export measures react quite similarly, which is consistent with the finding that there is a significant positive correlation between forward and backward

[3]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.

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

Figure 4.1 – *Response of bilateral value added exports to US monetary contractions*

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



Notes: Each term represents the response (in % change) of the corresponding ratio as in equation 4.1 to a 1% increase in the US interest using a dynamic panel fixed effects model with country-sector-importer fixed effects.

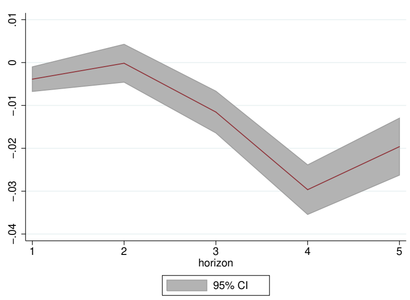
GVC participation across sectors in the first place (Wang et al. (2017b)). To account for the endogeneity concerns emanating from the inclusion of the lagged dependent variable (Nickell (1981)), these regressions are estimated with a GMM estimator based on Arellano and Bond (1991), using the forward orthogonal deviation transformation (see for instance Arellano and Bover (1995)). That said, the results using the linear fixed effects estimator yield similar results (Online Appendix A, Figure A.1).

Since many commodities are traded in global markets, their prices are likely to be fairly flexible, and hence the role of invoicing may be substantially lower for commodities exports. Motivated by this, we attempt to uncover differences across sectors by estimating equation 4.2 by splitting the sample into three broad categories by export sector-primary, secondary and tertiary. Figure 4.2 shows the results. We find the dynamics of primary sectors, which are dominated by commodities, to indeed be somewhat different on impact from the other sectors, although the ratio still declines sharply beyond two years similar to secondary and tertiary sectors. One reason for this 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 over time before it reaches the final consumer . In that case, the invoicing channel would still be present in the value chain even if it originates in the primary sector.

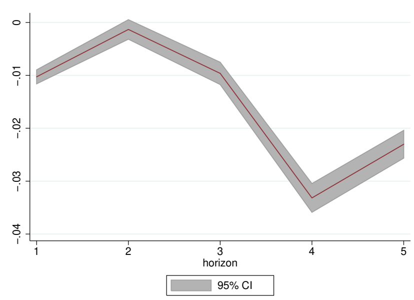
Online Appendix B shows that the patterns uncovered in figures 4.1 and 4.2 also hold when we restrict attention to only indirect value added exports, i.e the subset of bilateral value added exports that entail explicit involvement of third countries.

Figure 4.2 – *Response of bilateral value added exports to US monetary contractions by sector*

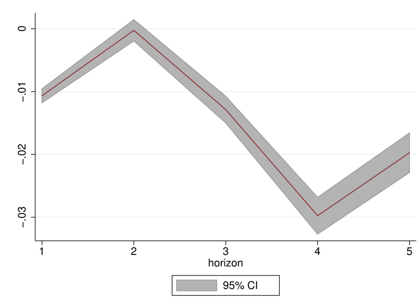
(a) VA_F (primary)



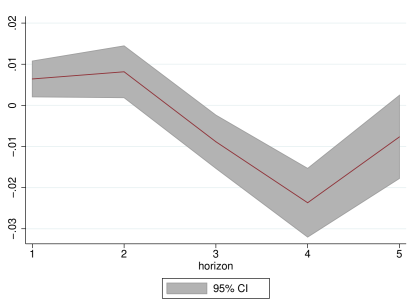
(b) VA_F (secondary)



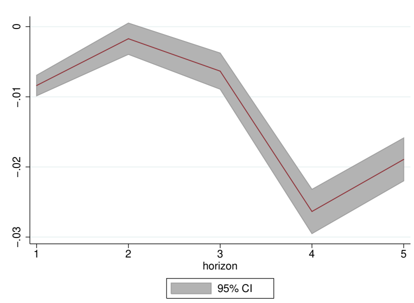
(c) VA_F (tertiary)



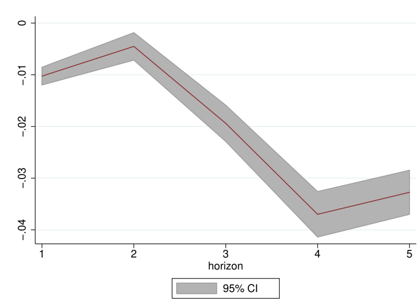
(d) VA_B (primary)



(e) VA_B(secondary)



(f) VA_B (tertiary)

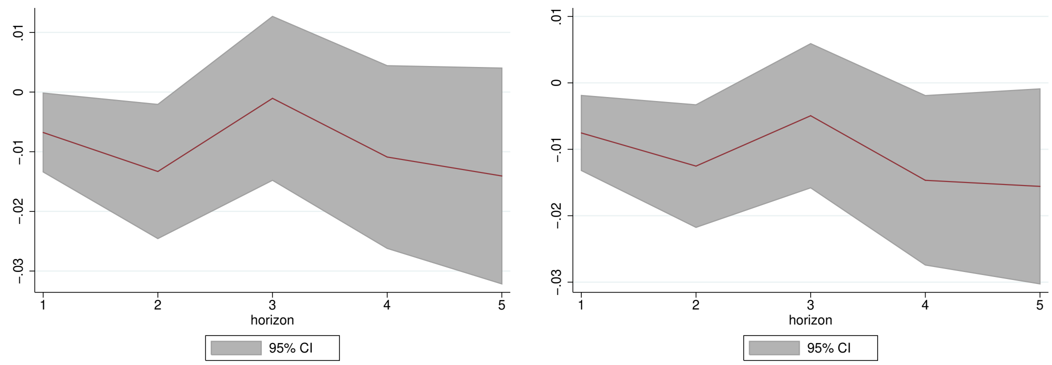


Notes: Each term represents the response (in % change) of the corresponding ratio as in equation 4.1 to a 1% increase in the US interest using a dynamic panel fixed effects model with country-sector-importer fixed effects.

Figure 4.3 *– 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. Pooled OLS estimates with standard errors clustered at country-sector-destination level.

Response of gross vs value added exports to the US

The differential response of gross and value added exports to the US is another 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. While the smaller sample and high comovement between the two variables in the data make these patterns more challenging to disentangle via specifications with saturated sets of fixed effects as above, OLS estimates in Figure 4.3 nevertheless provide indicative evidence that both forward and backward based ratio of gross to value added exports to the US do decline in line with the predictions of the model. Figure B.3 in the Online appendix shows that these patterns continue to hold even when we use only indirect value added exports in the denominator, i.e the value added exports that are explicitly routed via third countries.

To summarize, this section provides a framework to exploit differences in the response of bilateral sector level value added and gross trade flows by destination, and demonstrates that the their differential responses are in line with models that feature a prominent role for both global value chains as well as dollar invoicing.

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 global value chain structure that combines imported materials with domestic value added for exports to the 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. We discuss how these findings rule out alternative specifications in terms of currency of invoicing and absence of production chains, including a textbook model with no global value chain and producer currency pricing. In doing so, we highlight how value chains add a margin of adjustment in terms of the domestic content of exports that helps bring some of the implications of the model closer to the textbook model than other departures such as local currency pricing.

Given that DCP and GVC combine to bring the dynamics of output and inflation more in line with the textbook model, our results hint that the well understood policy implications of textbook models (eg Benigno and Benigno (2003)) may not be as far out of line even in a world with GVCs and DCP combined. At the same time, the gap between the two models is not entirely closed, as evidenced most clearly in the response of trade to an external monetary shock. Policy implications from the textbook model therefore need not carry over more broadly. A full-fledged normative policy analysis is beyond the scope of this paper, which focuses on the implications for and empirical assessment of the export response, but is likely to be a fruitful avenue for future research.

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 into different components to 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 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 value added exports to other trading partners. We also show that countries exporting to the US increase the domestic content of their exports in response to changes in the US interest rate in a manner consistent with the model.

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 is likely to affect trade flows in a world with dollar invoicing and the rising prevalence of global value chains. Lastly, while our results provide qualified support for the main predictions of the model, investigating the relationship between gross and value added exports in response to different types of shocks (including domestic shocks) using higher frequency data and tighter identification schemes remains a fruitful area for future research.

References

Arellano, M., Bond, S., 1991. Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. The review of economic studies. 58 (2), 277–297.

Arellano, M., Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. Journal of econometrics. 68 (1), 29–51.

Bacchetta, P., Van Wincoop, E., 2005. A theory of the currency denomination of international trade. Journal of international Economics. 67 (2), 295–319.

Baldwin, R., Lopez-Gonzalez, J., 2014. Supply-chain trade: A portrait of global patterns and several testable hypotheses. The World Economy.

Benigno, G., Benigno, P., 2003. Price stability in open economies. The Review of Economic Studies. 70 (4), 743–764.

Best, M. C., Cloyne, J. S., Ilzetzki, E., Kleven, H. J., 2020. Estimating the elasticity of intertemporal substitution using mortgage notches. The Review of Economic Studies. 87 (2), 656–690.

Betts, C., Devereux, M. B., 2000. Exchange rate dynamics in a model of pricing-to-market. Journal of international Economics. 50 (1), 215–244.

Boz, E., Casas, C., Georgiadis, G., Gopinath, G., Le Mezo, H., Mehl, A., Nguyen, T., 2022. Patterns of invoicing currency in global trade: New evidence. Journal of international economics. 136, 103604.

Boz, E., Gopinath, G., Plagborg-Møller, M., 2017. Global trade and the dollar.Technical report, National Bureau of Economic Research.

Chetty, R., Guren, A., Manoli, D., Weber, A., 2011. Are micro and macro labor supply elasticities consistent? a review of evidence on the intensive and extensive margins. American Economic Review. 101 (3), 471–75.

Cook, D., Devereux, M. B., 2006a. Accounting for the east asian crisis: a quantitative model of capital outflows in small open economies. Journal of Money, Credit and Banking. 721–749.

——— 2006b. External currency pricing and the east asian crisis. Journal of International Economics. 69 (1), 37–63.

Dent, C. M., 2017. East asian integration: Towards an east asian economic community.Technical report, ADBI working Paper.

Devereux, M. B., Dong, W., Tomlin, B., 2017. Importers and exporters in exchange rate pass-through and currency invoicing. Journal of International Economics. 105 187–204.

Devereux, M. B., Engel, C., Storgaard, P. E., 2004. Endogenous exchange rate pass-through when nominal prices are set in advance. Journal of international economics. 63 (2), 263–291.

Devereux, M. B., Shi, S., 2013. Vehicle currency. International Economic Review. 54 (1), 97–133.

Egorov, K., Mukhin, D. et al., 2019. Optimal monetary policy under dollar pricing. In: Meeting Papers. 1510.

Forbes, K., Hjortsoe, I., Nenova, T., 2018. The shocks matter: improving our estimates of exchange rate pass-through. Journal of International Economics. 114 255–275.

Friberg, R., 1998. In which currency should exporters set their prices? Journal of international Economics. 45 (1), 59–76.

García-Cicco, J., García-Schmidt, M., 2020. Revisiting the exchange rate pass through: A general equilibrium perspective. Journal of International Economics. 127, 103389.

Goldberg, L. S., Tille, C., 2008. Vehicle currency use in international trade. Journal of International Economics. 76 (2), 177–192.

——— 2016. Micro, macro, and strategic forces in international trade invoicing: Synthesis and novel patterns. Journal of International Economics. 102 173–187.

Goldberg, L., Tille, C., 2009. Macroeconomic interdependence and the international role of the dollar. Journal of Monetary Economics. 56 (7), 990–1003.

Gopinath, G., Boz, E., Casas, C., Díez, F. J., Gourinchas, P.-O., Plagborg-Møller, M., 2020. Dominant currency paradigm. American Economic Review. 110 (3), 677–719.

Gopinath, G., Stein, J. C., 2021. Banking, trade, and the making of a dominant currency. The Quarterly Journal of Economics. 136 (2), 783–830.

Hofmann, B., Patel, N., Wu, S. P. Y., 2022. Original sin redux: a model-based evaluation. BIS Working Papers. (1004).

Hummels, D., Ishii, J., Yi, K.-M., 2001. The nature and growth of vertical specialization in world trade. Journal of international Economics. 54 (1), 75–96.

Hummels, D., Rapoport, D., Yi, K.-M., 1998. Vertical specialization and the changing nature of world trade. Federal Reserve Bank of New York Economic Policy Review. 4 (2), 79–99.

Ito, H., Chinn, M. D., 2014. The rise of the'redback'and the people's republic of china's capital account liberalization: An empirical analysis of the determinants of invoicing currencies.

Ito, H., Kawai, M., 2016. Trade invoicing in major currencies in the 1970s–1990s: Lessons for renminbi internationalization. Journal of the Japanese and International Economies. 42 123–145.

Johnson, R. C., 2014. Trade in intermediate inputs and business cycle comovement. American Economic Journal: Macroeconomics. 6 (4), 39–83.

Johnson, R. C., Noguera, G., 2012. Accounting for intermediates: Production sharing and trade in value added. Journal of International Economics. 86 (2), 224–236.

Jordà, Ò., 2005. Estimation and inference of impulse responses by local projections. American economic review. 161–182.

Kamps, A., 2006. The euro as invoicing currency in international trade.

Koopman, R., Wang, Z., Wei, S.-J., 2014. Tracing value-added and double counting in gross exports. The American Economic Review. 104 (2), 459–494.

Lombardi, M. J., Zhu, F., 2018. A shadow policy rate to calibrate us monetary policy at the zero lower bound. 56th issue (December 2018) of the International Journal of Central Banking.

Mukhin, D., 2022. An equilibrium model of the international price system. American Economic Review. 112 (2), 650–88.

Nickell, S., 1981. Biases in dynamic models with fixed effects. Econometrica: Journal of the Econometric Society. 1417–1426.

Novy, D., 2006. Hedge your costs: Exchange rate risk and endogenous currency invoicing. Warwick Economic Research Paper. (765).

Obstfeld, M., Rogoff, K., 1995. Exchange rate dynamics redux. Journal of political economy. 103 (3), 624–660.

Patel, N., Wang, Z., Wei, S.-j., 2019. Global value chains and effective exchange rates at the country-sector level. Journal of Money, Credit and Banking. 51 7–42.

Portes, R., Rey, H., 1998. The emergence of the euro as an international currency.

Schmitt-Grohé, S., Uribe, M., 2003. Closing small open economy models. Journal of International Economics. 61 (1), 163–185.

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., Vries, G. J., 2015. An illustrated user guide to the world input–output database: the case of global automotive production. Review of International Economics.

Wang, Z., Wei, S.-J., Yu, X., Zhu, K., 2017a. Characterizing global value chains: Production length and upstreamness.Technical report, National Bureau of Economic Research.

——— 2017b. Measures of participation in global value chains and global business cycles.Technical report, National Bureau of Economic Research.

Wang, Z., Wei, S.-J., Zhu, K., 2013. Quantifying international production sharing at the bilateral and sector levels. National Bureau of Economic Research (No. w19677).

World Bank, 2020. World development report 2020: Trading for development in the age of global value chains.

Zhang, T., 2022. Monetary policy spillovers through invoicing currencies. The Journal of Finance. 77 (1), 129–161.

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

David Cook and Nikhil Patel

November 2023

*We would like to thank the editor Martin Uribe, Rudolfs Bems, Alessandro Borin (discussant), Michael Devereux, Charles Engel, Gunes Kamber, Jinill Kim (discussant), Amartya Lahiri, Ben Tomlin, Jian Wang (discussant), James Yetman and three anonymous referees, as well as seminar participants at the Bank for International Settlements, Hong Kong Monetary Authority, ESCB Emerging markets workshop (Bank of Italy), IMF, Indian Statistical Institute, Midwest Macro Meetings and the Reserve Bank of India for helpful comments and suggestions. We are grateful to Zhi Wang for sharing the data on decomposition of bilateral exports and Justine Pedrono for excellent research assistance. All errors are our own. The views expressed here are those of the authors and do not necessarily represent those of the International Monetary Fund.

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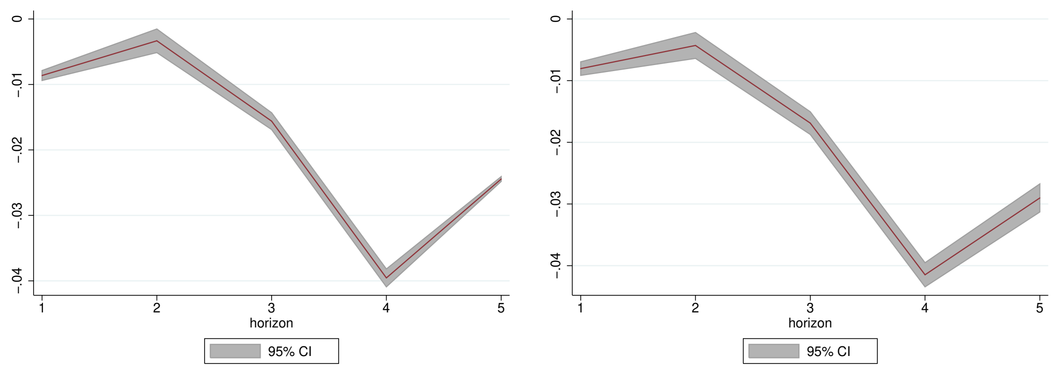
A Simple dynamic fixed effect regressions without controlling for the Nickell (1981) bias (Figure A.1)

Figure A.1 *– Response of bilateral value added exports to US monetary contractions*

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



Notes: Each term represents the response (in % change) of the corresponding ratio as in equation 4.1 to a 1% increase in the US interest using a panel fixed effects model with country-sector-importer fixed effects.

B Response of bilateral indirect value added exports to US monetary shocks

This Appendix shows that the patterns uncovered in figures 4.1 and 4.2 in the main text also hold for indirect value added exports, i.e the subset of bilateral value added exports that exclude direct shipments between the origin and ultimate destination of value added. Recall the definitions of forward and backward value added exports:

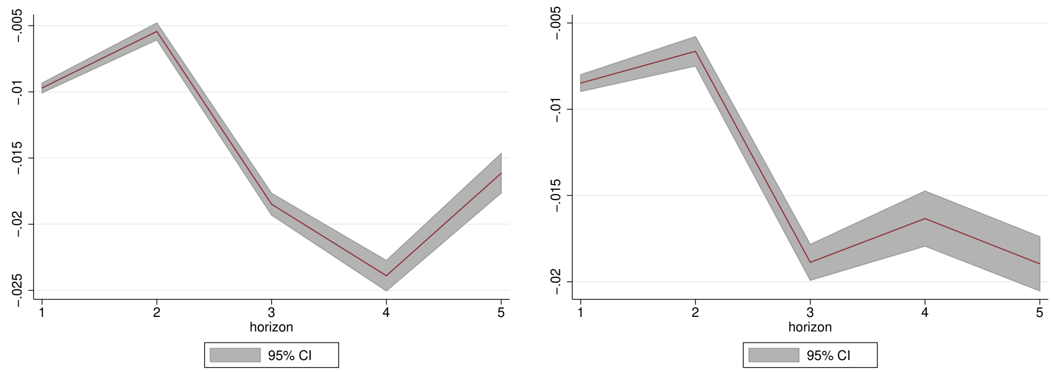
- VAF: Value added exports (forward) of the country sector that are eventually consumed as final demand in a particular destination country. "Forward" means that this measure includes indirect exports of this sector via other sectors in the same country.

- 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.

The indirect components of thse value added exports are in turn defined as follows:

Figure B.1 *– Response of bilateral indirect value added exports to US monetary contractions*

(a) IVAF **(b)** IVAB



Notes: Each term represents the response (in % change) of the corresponding ratio as in equation 4.1 to a 1% increase in the US interest using a dynamic panel fixed effects model with country-sector-importer fixed effects.

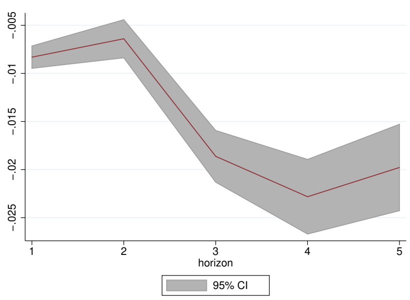
- IVAF: Indirect value added exports (forward) by the country sector to the destination country. This is a subset of VAF which captures the value added by the source country-sector that is consumed by a particular destination country as final demand, but is not exported directly (i.e it is part of a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

- 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.

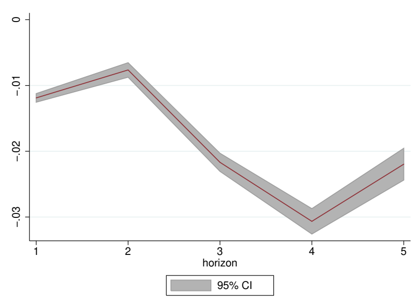
As an example, if the commodity sector in country A provides x units of inputs to the electronics processing sector in the same country A, which in turn exports its entire output of $y(> x)$ units to country B, then the value added forward exports (VAF) of the commodity sector would equal x, even though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

Figure B.2 *– Response of bilateral indirect value added exports to US monetary contractions by sector*

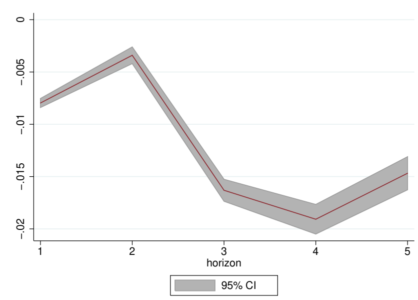
(a) IVA_F (primary)



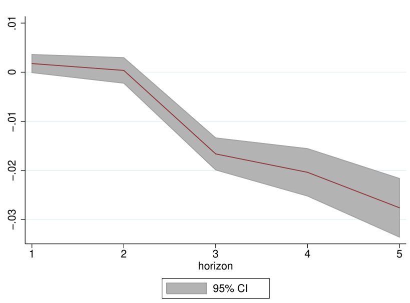
(b) IVA_F (secondary)



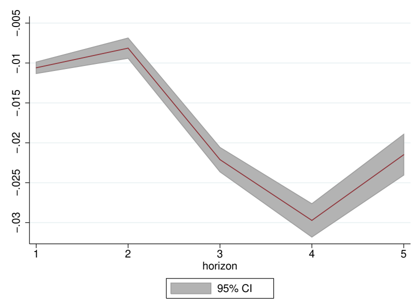
(c) IVA_F (tertiary)



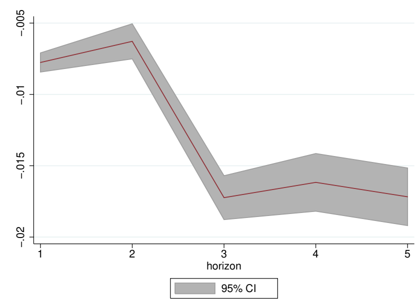
(d) IVA_B (primary)



(e) IVA_B(secondary)



(f) IVA_B (tertiary)

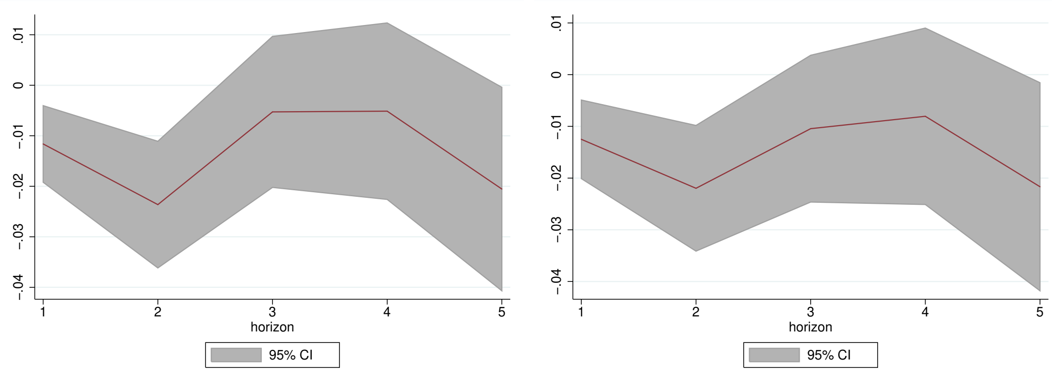


Notes: Each term represents the response (in % change) of the corresponding ratio as in equation 4.1 to a 1% increase in the US interest using a dynamic panel fixed effects model with country-sector-importer fixed effects.

Figure B.3 – *Response of the ratio of gross to indirect value added exports to the US to a US monetary contraction*

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

(b) Response of the ratio of gross to indirect 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. Pooled OLS estimates with standard errors clustered at country-sector-destination level.

C List of countries and sectors

List of countries: Australia Austria Belgium Bulgaria, Brazil*Canada, China, Cyprus*, Czech Republic, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Hungary, Indonesia* (non-Eurpean sample), India* (non-Eurpean sample), Ireland, Italy, Japan (non-Eurpean sample), Korea (non-Eurpean sample), Lithuania, Luxembourg, Latvia, Mexico, Malta*, Netherlands, Poland, Portugal, Romania*, Russia*, Slovak Republic, Slovenia, Sweden, Turkey*, Taiwan, United States.

* excluded as exporter in baseline regressions due to missing or incomplete data on unit labor cost

Table A.1 *– 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 A.1 *– 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

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

Working Paper No. WP/2022/028