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International energy trade and inflation dynamics: The role of invoicing currency use during the low carbon transition

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ABSTRACT

In most international energy trades, the US dollar is the invoicing currency. Our empirical and theoretical analysis examines how this affects inflation dynamics in energy trade. Empirical results reveal that countries' with higher shares of trade invoiced in dollars would experience more inflation in their energy sector, primarily because of exchange rate fluctuations. Theoretical modeling, based on a new open economy Keynesian framework, demonstrates that when all products are priced in US dollars, imported inflation varies with exchange rates. We observe that the dominant issuer's monetary policy has greater spillover effects than non-dominant countries. Furthermore, in a counterfactual analysis, we consider invoicing conventional energy products in dollars while invoicing renewable energy products in alternative currencies. The results highlight two benefits of currency coordination in renewable energy products: a domestic monetary policy would be more effective, and the foreign monetary policy produces fewer spillovers to domestic inflation.

1. Introduction

During the Global Financial Crisis and the COVID-19 pandemic, countries experienced significant inflation, marked by high volatility. Elevated energy prices adversely affected household well-being. The pivotal role of monetary policies in mitigating inflation during these periods has been intensively discussed. However, the weakness of these currencies relative to the US dollar may diminish the effectiveness of monetary policy, particularly in emerging countries with substantial import dependencies, especially for energy and a significant proportion of dollar-denominated imports (IMF, 2022).[1] Gopinath et al. (2020) proposes that a 10% increase in the share of imports invoiced in US dollars would lead to a 3.5% increase in US dollar contemporaneous pass-through. Hence, the dominant role of the US dollar in the relationship between inflation dynamics and international trade is never more evident.

Similar to currency usage across various sectors, the predominant practice is invoicing energy-related products in US dollars, particularly in conventional energy trade. The "dominant currency pricing (DCP)" paradigm has received comparatively less attention in studies on international energy trade. The selection of an invoicing currency is crucial in elucidating the relationship between the exchange rates, prices of the traded goods, and inflation. Recent research indicates that even with identical import and export shares, domestic macroeconomic responses vary when the share of the invoicing currency differs (Gopinath and Rigobon, 2008; Gopinath et al., 2020). To illustrate this, we develop a small open economy New Keynesian model, demonstrating the influence of nominal exchange rates on inflation dynamics across different invoicing currencies. Specifically, we simulate nominal exchange rate responses to exogenous monetary shocks originating from different countries.[2]

This model elucidates that a country with a higher proportion of trade invoiced in the US dollar would experience increased inflation in its energy sector. In the scenario of dominant currency pricing, where all traded products are invoiced in US dollars, the country's energy sector may encounter heightened inflationary pressures. This arises from exchange rate fluctuations triggered by monetary policies, which leads to proportional price increases in these goods, exacerbating inflation. Conversely, when firms opt to use their producer currencies, their products prices are shielded from the exchange rate influence. As a result, the aggregate import prices are lower as the proportion of trade invoiced in US dollars decreases. Furthermore, the choice of invoicing currency affects relative prices. Under DCP, both imports

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[1] https://www.imf.org/en/Blogs/Articles/2022/10/14/how-countries-should-respond-to-the-strong-dollar

[2] Two reasons support our consideration of monetary policy. First, recent studies have demonstrated that monetary policy shocks are primary drivers of exchange rate fluctuations (Forbes et al., 2018). Thus, an exchange rate response is central to setting monetary policy. Second, the frequent adjustments to the US monetary policy have been raising concerns for other economies.

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and exports undergo price changes in similar proportions, maintaining internal relative price levels. This distinguishes dominant currency pricing from when firms set prices in their currency (producer currency pricing, PCP) or when all firms set prices in the destination currency of their trading partners (local currency pricing, LCP). In both PCP and LCP cases, relative prices change, leading to real effects on the economy owing to monetary policies. Additionally, in line with previous empirical results (Goldberg and Tille, 2009; Albagli et al., 2019), we document asymmetric spillover effects when monetary policy originates in the US and other emerging countries. Monetary policy from the dominant currency issuer (the US) can exert substantial spillovers on the price level than policies from other non-dominant issuing countries. Therefore, this issue warrants greater attention.

This study contributes to the literature on energy price dynamics and the US dollar-energy relationship, (as surveyed by Beckmann et al., 2020). Researchers have investigated the impact of exchange rates on energy prices from both demand and supply perspectives in the long run (Yousefi and Wirjanto, 2004; Akram, 2009; Fratzscher et al., 2014). A stronger dollar diminishes the purchasing power of the domestic currency, leading to decreased demand for oil outside the US and subsequent drops in oil prices. Moreover, oil-exporting countries tend to adjust prices in response to exchange rate fluctuations. However, in the short run, prices tend to be sticky. Depreciating domestic currency results in higher short-term prices for energy-related goods invoiced in US dollars, potentially increasing inflation rates. The direct impact of invoiced currency appreciation on short-term energy trade has received less attention in the existing literature. This study fills the gap by providing empirical evidence of the relevance of invoiced currency, inflation, and exchange rates. The results demonstrate that countries with higher shares of trade invoiced in the US dollar would experience greater inflation in the energy sector, primarily because of the exchange rate variations. Specifically, when the domestic currency depreciates against the US dollar, a proportional increase in the prices of dollar-invoiced imported goods can be observed. Further, it has been observed that countries with higher import dependencies on conventional energy experience more pronounced inflation rates, aligning with existing literature by Chen (2009) and Choi et al. (2018). To mitigate the adverse effects of exogenous exchange rate shocks and imported inflation in the energy sector, strategies to reduce the proportion of international energy trade invoiced in US dollars may be considered. However, the selection of invoicing currency in the field of conventional energy is prominently influenced by major suppliers. Typically, countries with abundant fossil fuel reserves transact in their domestic or dominant currencies, such as the US dollar. Emerging economies with lower energy market endowments and demand tend to adapt to the invoicing preferences of dominant suppliers. Conversely, the selection of invoicing currency for renewable energy is less affected by resource endowments and increasingly by technological advancements, including innovations in solar, wind, and other renewable technologies. Additionally, owing to the growing demand for low-carbon transitions, renewable energy partially substitutes the impact of crude oil on energy market and dollar-energy relationships (Yahya et al., 2021; Liu et al., 2022). Hence, we explore the impacts of different currency choices in the conventional and renewable energy sectors, respectively.

Furthermore, this model contributes to the prevailing dominant currency of the pricing (DCP) literature (Gopinath et al., 2020; Mukhin, 2022), where we incorporate the nominal rigidities, (Gopinath and Itskhoki, 2010; Corsetti et al., 2008) price discrimination (Goldberg and Hellerstein, 2008), and currency choices (Devereux et al., 2015; Gopinath et al., 2020) to explain the heterogeneous effect of exchange rate pass-through on inflation. Contrary to the full DCP in existing literature, we account for currency choice heterogeneity across countries and sectors. This study highlights the differences in currency preferences between conventional energy and renewable energy fields: conventional energy trade primarily employs the US dollar for invoicing, while the invoicing currency in global renewable energy trade is more diverse. Notably, to the best of our knowledge, only Georgiadis and Schumann (2021) analyzes spillover effects on output under partial DCP. Their model allows for less than 100% of the exports and imports to be priced in the dominant currency. Nonetheless, our model incorporates two sectors to encompass more substitutable features of international trade.

This paper further emphasizes the benefits of coordination to trade with an alternative currency. The benefits are reflected in two perspectives. First, it improves the effectiveness of domestic monetary policies. When countries coordinate the price of renewable energy products in a one currency, the dollar-invoiced share decreases, reducing overall price sensitivity to the monetary policies. Further, as currency coordination causes only a minimal change in terms of trade, the output level will not be affected substantially. Consequently, the output-inflation ratio improves. Second, under similar principles, we find that coordinating trade with a diverse set of currencies can restrict the spillover of foreign monetary policy on domestic inflation without significantly changing foreign demand for goods. This result can be considered an extension of the study on gains from invoicing all products in US dollars (Devereux et al., 2007; Kim, 2023), We document the benefits in scenarios where not all the products are coordinated using the same currency.

The remainder of this paper is organized as follows. In Section 2, we outlines the data and presents our empirical results. Section 3 introduces the open economy New Keynesian dynamic Stochastic General Equilibrium Model. In Section 4, we present our performed numerical analysis. Section 5 elucidates the mechanism underlying the pass-through of exchange rates to domestic prices in the context of dominant currency pricing. Section 6 expounds upon the analysis of monetary policies under alternative invoicing currency. Finally, Section 7 presents our conclusions.

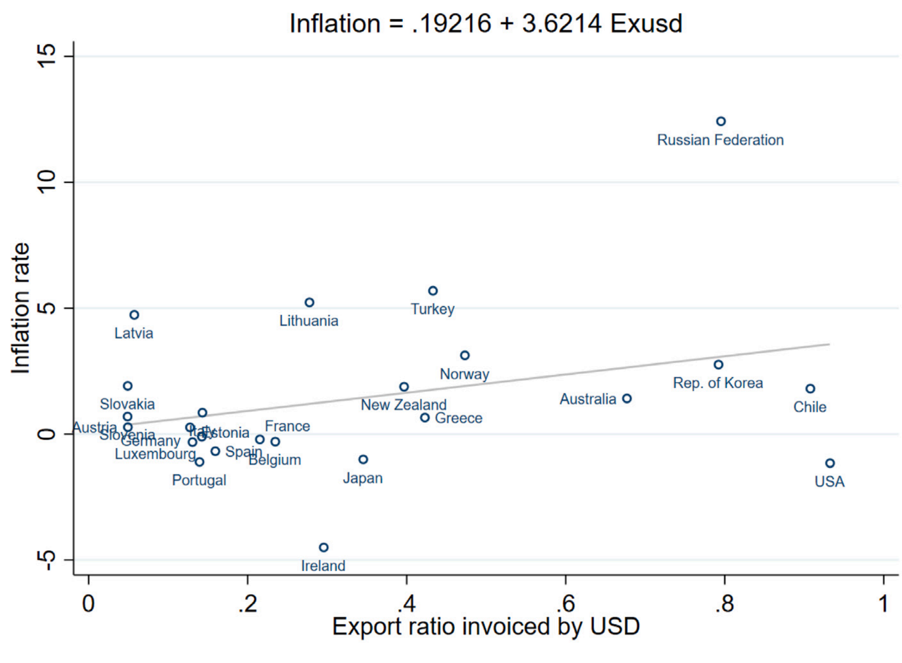
2. Stylized facts and empirical evidence

In this section, we first sketch the relationship between the inflation rate and the share of international trade in the dominant currency as US dollar during the global financial crisis when most countries faced excess liquidity and inflation. As shown in Figs. 1(a) and 1(b), we consider the second quarter of 2009 as an example, where countries with significant volumes of exports and imports invoiced in US dollars experienced high inflation rates.[3] Specifically, emerging countries with a higher share of trade invoiced in US dollars, such as the Russian Federation and Chile, experienced significant spikes in import inflation. Given the positive relationship between inflation and the share of trade in US dollars, we empirically estimate the relationship between inflation rate and trade invoiced in US dollars through a comprehensive sample analysis.

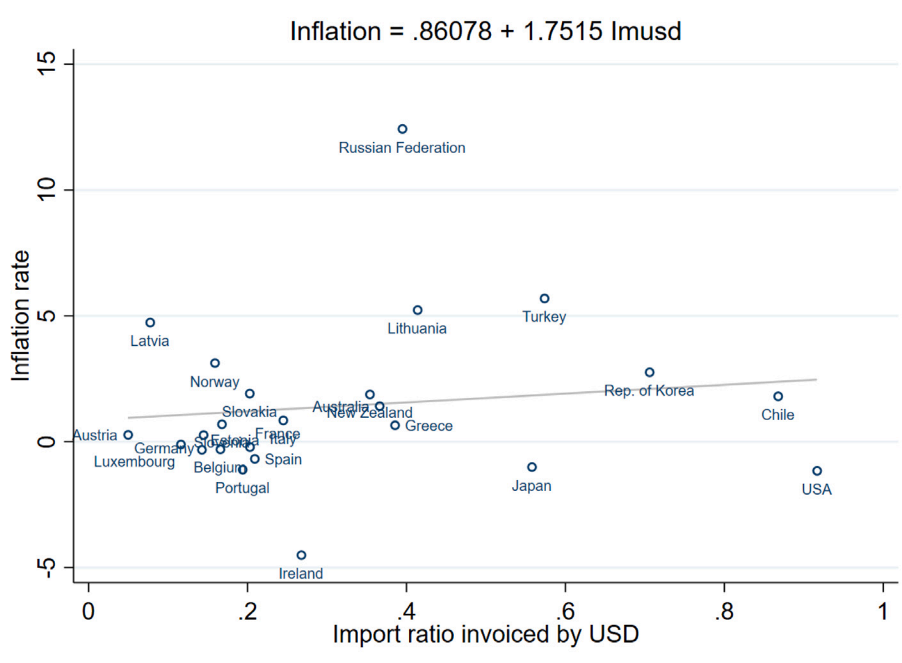
A preliminary estimation is conducted based on quarterly data from 28 Organisation for Economic Cooperation and Development (OECD) countries from 2002Q1 to 2019Q4.[4] Inflation rates in the energy and food sectors of each country were obtained from Federal Reserve Economic Data (FRED). We further obtain the share of exports and imports invoiced in US dollars from Boz et al. (2022). Nominal exchange rates of the US dollar against other currencies are obtained from the Pacific Exchange Rate Service, and the quarterly Exchange rates were calculated as the average value for each month. An increase in the exchange rate value indicates appreciation currency and vice versa.

[3] Excluding control variables, a 10% increase in the import ratio invoiced in the US dollar is associated with an inflation rate increase of 0.175%. Conversely, regarding the export ratio, this increase would be higher at 0.362%.

[4] 28 OECD countries include Austria, Belgium, Switzerland, Chile, Germany, Spain, Estonia, Finland, France, Greece, Ireland, Iceland, Israel, Italy, Japan, South Korea, Lithuania, Luxembourg, Latvia, Netherlands Norway, New Zealand, Portugal, Russia, Slovakia, and Slovenia Turkey and the United States.



(a) Export ratio



(b) Import ratio

Fig. 1. Relationship between trade and inflation rate during global financial crisis.

Control variables include percentage change in gross domestic product (GDP) from the previous quarter and interest rates obtained from the OECD database. Additionally, we calculate the share of exports and imports of conventional energy of each country for which data are retrieved from the UN Comtrade database.[5] For instance, the share of conventional energy materials in Chinese energy trade is exhibited in Fig. 2. We find that the share of conventional energy in the energy trade exhibits a downward trend; in 2021, the share fell to 0.68.

The baseline model is as follows:

$$Infla_{i,t} = \alpha + \beta_1 Exusd_{i,t} + \beta_2 Imusd_{i,t} + \beta_3 Imusd_{i,t} * D_{conv} + \gamma Z_{i,t} + \lambda_i + \lambda_t + \epsilon_{i,t}, \quad (1)$$

[5] According to the Harmonized System (HS) codes for conventional energy and renewable energy by the International Trade Administration and the International Centre for Trade and Sustainable Development, this study distinguishes between conventional energy and renewable energy trade. It also calculates the proportion of conventional energy trade in each country.

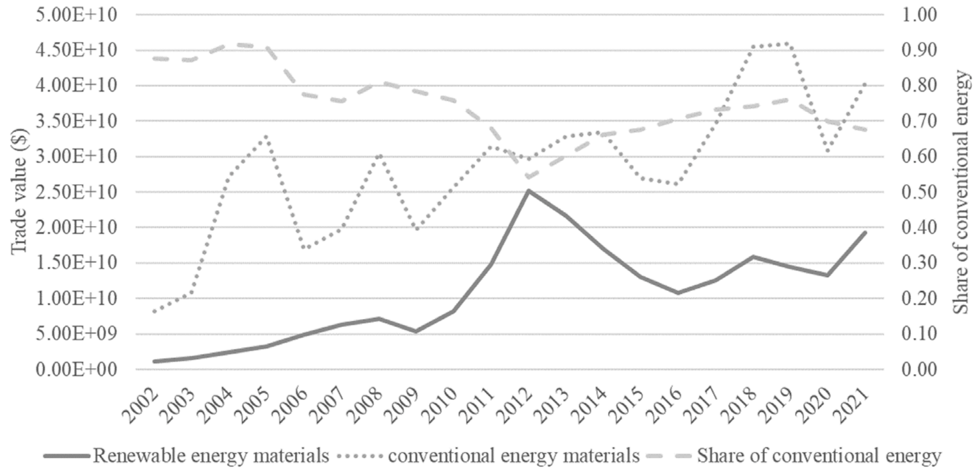


Fig. 2. Chinese trade of conventional and renewable energy materials.

Table 1
Impact of exports and imports invoiced by USD on inflation.

Variables	(1) Energy	(2) Energy	(3) Energy	(4) Energy	(5) Food	(6) Food
$Exusd_{i,t}$	0.027	0.055*	0.052	0.063*	−0.004	0.024
	(0.035)	(0.032)	(0.032)	(0.036)	(0.024)	(0.023)
$Imusd_{i,t}$	0.111***	0.069**	0.048	0.018	0.041**	0.029
	(0.032)	(0.029)	(0.031)	(0.032)	(0.021)	(0.023)
$Imusd_{i,t} \times D_{conv}$			0.114**			
			(0.051)			
Exchange rate				−8.821***		−3.434*
				(2.160)		(1.848)
Constant	−2.221	−12.899***	−16.010***	−5.122*	1.354	1.879
	(5.143)	(2.115)	(2.601)	(2.924)	(1.818)	(2.332)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	No	Yes	Yes	Yes	Yes	Yes
Observations	1,760	1,681	1,681	1,406	1,697	1,422
R-squared	0.623	0.731	0.732	0.744	0.509	0.516

Notes: The table reports the influence of the international trade invoiced by USD on the inflation rate of the energy and food sectors. Dependent variable refers to the inflation rate of the energy or food sector for country i in quarter t. $Exusd_{i,t}$ and $Imusd_{i,t}$ are the ratio of exports and imports invoiced by US dollars among the corresponding country's whole exports and imports, respectively. D_{conv} is a dummy variable that equals one of the country's imported conventional energy shares over the median level of all countries in 2019. Control variables include the change in GDP and interest rate. We also consider the impact of the exchange rate, which could be considered a channel for the impact of imports invoiced by USD on inflation. Robust standard errors are in parentheses.

* $p < 0.1$

** $p < 0.05$

*** $p < 0.01$

where $Infla_{i,t}$ refers to the energy inflation rate or food sector of country i in quarter t. $Exusd_{i,t}$ and $Imusd_{i,t}$ are the ratios of exports and imports invoiced in US dollars among the corresponding countries' exports and imports. D_{conv} is a dummy variable that equals one if the country's imported conventional energy shares is over the median level of all countries in 2019. $Z_{i,t}$ denotes a vector of control variables, including changes in GDP and interest rates. Additionally, the estimation also controls a set of country fixed effects, λ_i, year fixed effect, λ_t.

Table 1 presents the empirical results for the impact of the share of US dollars in the inflation trade. Columns (1)–(4) present the results on the effect of the inflation rate in the energy sector. The results indicate that a country's export and import ratios in dollars are positively associated with the inflation rate of the energy sector. The impact of import share invoiced in dollars is significant at the 5% level regardless of the control variables, whereas the effect on export share is not significant at the 5% level. Estimated coefficients of an interaction term between $Imusd_{i,t}$ and D_{conv} are positive and significant. This indicates that when the import share invoiced in dollars increases, the country with a higher share of imported conventional energy experiences a higher inflation rates in the energy sector. We also examine the impact of the exchange rate, which can be considered a channel for the impact of imports invoiced in the US dollar on inflation. We find that when we include the exchange rate variable, the coefficients for $Imusd_{i,t}$ are insignificant, whereas that for the exchange rate variable is significantly negative at the 1% level. When a country's currency depreciates, the prices in the energy sector increase. The results for inflation in the food sector in columns (5) and (6) share a pattern similar to that in the energy sector. These imply that the relationship between international trade and the inflation rate depends on shocks that lead to exchange movement rate, which is in line with the standard open economy macroeconomic theory.

Based on data of the invoicing currency for total imports and exports of a country, we empirically analyze the relationship between the inflation rate of energy sector, the share of trade in the dominant currency, and the ratio of conventional energy trade. However, given the absence of data on invoicing currencies for conventional and renewable energy trade, we employ a structural model to estimate the impacts of different invoicing currency choices on the relationship between the international energy trade and inflation dynamics.

3. A three-country open economy structural model

We develop a three-country, small, open-economy structural model. This model is designed to simulate the effect of a monetary policy transmission on the energy sector, particularly when a proportion of products is priced in an alternative currency. It builds upon the recent dominant-currency pricing (DCP) literature (Gopinath et al., 2020; Mukhin, 2022), while incorporating two different invoicing currencies in both sectors. To be specific, we divide the production side into the conventional energy-related product sector and the renewable energy-related product sector. These two products are symmetrical to consumers. The only difference is in the steady-state share, which is controlled for according to the household preference parameters. This extension offers several advantages. First, by employing a two-sector framework, we could clearly illustrate the differences in price responses when products are traded using different currencies. Second, the two-sector model allows for an imperfect substitution between conventional and renewable energy products. Thus, this assumption reconciles real-world conditions in which consumers and industries may not easily switch between these categories, affecting price dynamics. Third, the asymmetry in the home biases of the two sectors reflects observed trade differences. Our model encompasses three economies: H (the domestic country), U (the US, which also serves as the dominant currency issuer), and R (emerging countries for the rest of the world). These three countries trade their intermediate products. Intermediate goods producers are pricing-to-market, and prices are sticky in their used currency. The three economies share similar structures comprising seven agents: households, two specialized intermediate goods producers, two specialized final goods producers, a consumption goods bundler, and the government. To save space, we present only the domestic optimization problem country H.

3.1. Households

Country i is populated by a continuum of symmetric households. indexed as $h \in [0,1]$. In each period, household h in country i consumes $C_{i,t}$ in its final consumption of goods. Each household allocates labor to produce $L_{i,t} = L^C_{i,t} + L^R_{i,t}$. Labors in country i are homogeneous and free-mobile across sectors, which implies a common $W_{i,t}$. The lifetime utility function is given as follows:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_{i,t}, L_{i,t}) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\sigma_c} C_{i,t}^{1-\sigma_C} - \frac{\kappa}{1+\varphi} L_{i,t}^{1+\varphi} \right]$$

where $\sigma_C > 0$ represents the household's relative risk aversion. $\varphi > 0$ is the inverse of Frisch's elasticity of labor supply and κ controls for the disutility of labor.

The final consumption goods $C_{i,t}$ are a composite of the conventional $C^C_{i,t}$ and renewable goods $C^R_{i,t}$:

$$C_{i,t} = \left(\eta_t^{1/\rho} (C^C_{i,t})^{\frac{\rho-1}{\rho}} + (1-\eta_t)^{1/\rho} (C^R_{i,t})^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}$$

where $\eta_t \in [0,1]$ is the steady-state share of conventional energy products. ρ is the elasticity of substitution of the two goods.

Each consumption good $C^e_{i,t}$ $e \in \{C, R\}$ combines a continuum of the final products of sector e produced from both the domestic and foreign countries, and each type of composite goods is aggregated by Kimball (1995):

$$\gamma_i \int_0^1 \Upsilon \left(\frac{C^e_{ii,t}(\omega)}{\gamma_i C^e_{i,t}} \right) d\omega + \sum_j \gamma_j \int_0^1 \Upsilon \left(\frac{C^e_{ji,t}(\omega)}{\gamma_j C^e_{i,t}} \right) d\omega = 1 \tag{2}$$

where $\gamma \in (0,1)$ denotes the bias reflecting trade cost or preference for goods in country j requires $\gamma_i + \sum_j \gamma_j = 1$. Υ is an increasing and concave function with $\Upsilon(1) = 1$. $\Upsilon'(\cdot) > 0$ and $\Upsilon''(\cdot) < 0$. This demand structure allows the strategic complementaries to set prices, resulting in variable markups and pricing to market.

Households earn wages from labor supply and receive local firms' profit $\Pi_{i,t}$. They spend their income on consumer goods and trade two risk-free bonds dominating US dollars. $B^{\$}_{i,t}$ and local bonds dominated in local currency $B_{i,t}$. The budget constraint in the currency is given by

$$P_{i,t} C_{i,t} + \frac{\epsilon_{i\$,t} B^{\$}_{i,t}}{R^{\$}_t} + \frac{B_{i,t}}{R_t} = W_{i,t} N_{i,t} + \Pi_{i,t} + \epsilon_{i\$,t} B^{\$}_{i,t-1} + B_{i,t-1}$$

where $P_{i,t}$ is the aggregate price index of household consumption derived from

$P_t = \left(\eta (P^C_{i,t})^{1-\rho} + (1-\eta)(P^R_{i,t})^{1-\rho} \right)^{\frac{1}{1-\rho}}$, $R^{\$}_t$ and R_t denote the US and domestic nominal interest rates, respectively. $\epsilon_{i\$,t}$ denote the bilateral exchange rate between country i and the US, an increase in $\epsilon_{i\$,t}$ indicates that the currency depreciates.

By solving the household utility maximization problem, first-order conditions for $C_{i,t}$, $B^{\$}_{i,t}$, $B_{i,t}$, $N_{i,t}$ are given by

$$\frac{W_{i,t}}{P_{i,t}} C_{i,t}^{-\sigma_C} = \kappa (L^C_{i,t})^{\varphi} \tag{3}$$

$$\frac{W_{i,t}}{P_{i,t}} C_{i,t}^{-\sigma_C} = \kappa (L^R_{i,t})^{\varphi} \tag{4}$$

$$C_{i,t}^{-\sigma_C} \frac{1}{R^{\$}_t} = \beta \mathbb{E} \left(C_{i,t+1}^{-\sigma_C} \frac{1}{\pi_{i,t+1}} \frac{\epsilon_{i\$,t+1}}{\epsilon_{i\$,t}} \right) \tag{5}$$

$$C_{i,t}^{-\sigma_C} \frac{1}{R_t} = \beta \mathbb{E} \left(C_{i,t+1}^{-\sigma_C} \frac{1}{\pi_{i,t+1}} \right) \tag{6}$$

where $\pi_{i,t+1} = \frac{P_{i,t+1}}{P_{i,t}}$ denotes gross inflation rate.

3.2. Production

Production, import, and export flows are multilayered production structures, as shown in Fig. 3.

3.2.1. Consumption goods bundlers

Each country has two different sectors: renewable and conventional product sectors. On the top layer, the consumption-goods bundler combines the final products of these sectors with CES technology and sells the consumption bundle to domestic consumers.

3.2.2. Final goods producers

In the second layer, a continuum of final good producers in sector e operate in a perfectly competitive market. They assemble the intermediate products using Kimball technologies

$$\gamma_i \int_0^1 \Upsilon \left(\frac{Y^e_{ii,t}(\omega)}{\gamma_j Y^e_{i,t}} \right) d\omega + \gamma_j \int_0^1 \Upsilon \left(\frac{Y^e_{ji,t}(\omega)}{\gamma_j Y^e_{i,t}} \right) d\omega = 1 \tag{7}$$

The intermediate products can be purchased from domestic producers or imported from other countries. $Y^e_{ii,t}$ and $Y^e_{ji,t}$ denote the amount of intermediate goods from the country and the foreign country $j \in \{D, R\}$. The production function yields the following demand for intermediate goods, as follows:

$$Y^e_{ii,t}(\omega) = \gamma_i h \left(\frac{P^e_{ii,t}(\omega) D^e_{i,t}}{P^e_{i,t}} \right) Y^e_{i,t} \quad \text{and} \quad Y^e_{ji,t}(\omega) = \gamma_j h (\frac{P^e_{ji,t}(\omega) D^e_{i,t}}{P^e_{i,t}}) Y^e_{i,t} \tag{8}$$

where γ_i and γ_j coincide with trade bias coefficient as in Eq. (2). $h(\cdot) \equiv \Upsilon'^{-1}(\cdot)$ denotes the demand curves that depend on the real price of the domestic and foreign goods, as well as the overall demand level. $D^e_i \equiv \int_0^1 g\left(\frac{C^e_{ii}(\omega)}{(1-\gamma) C^e_i} \right) (\frac{C^e_{ii}(\omega)}{C^e_i}) d\omega + \int_0^1 \int_0^1 g\left(\frac{C^e_{ji}(\omega)}{\gamma C^e_i} \right) (\frac{C^e_{ji}(\omega)}{C^e_i}) d\omega dj$. The price index $P^e_{i,t}$ is defined as the expenditure required to produce a unit final good. The price index is given as $P^e_{i,t} = \gamma_i \int_0^1 h\left(\frac{P^e_{ii,t}(\omega) D^e_{i,t}}{P^e_{i,t}} \right) P^e_{ii}(\omega) d\omega + \gamma_j \int_0^1 h\left(\frac{P^e_{ji}(\omega) D^e_i}{P^e_i} \right) P^e_{ji}(\omega) d\omega$.

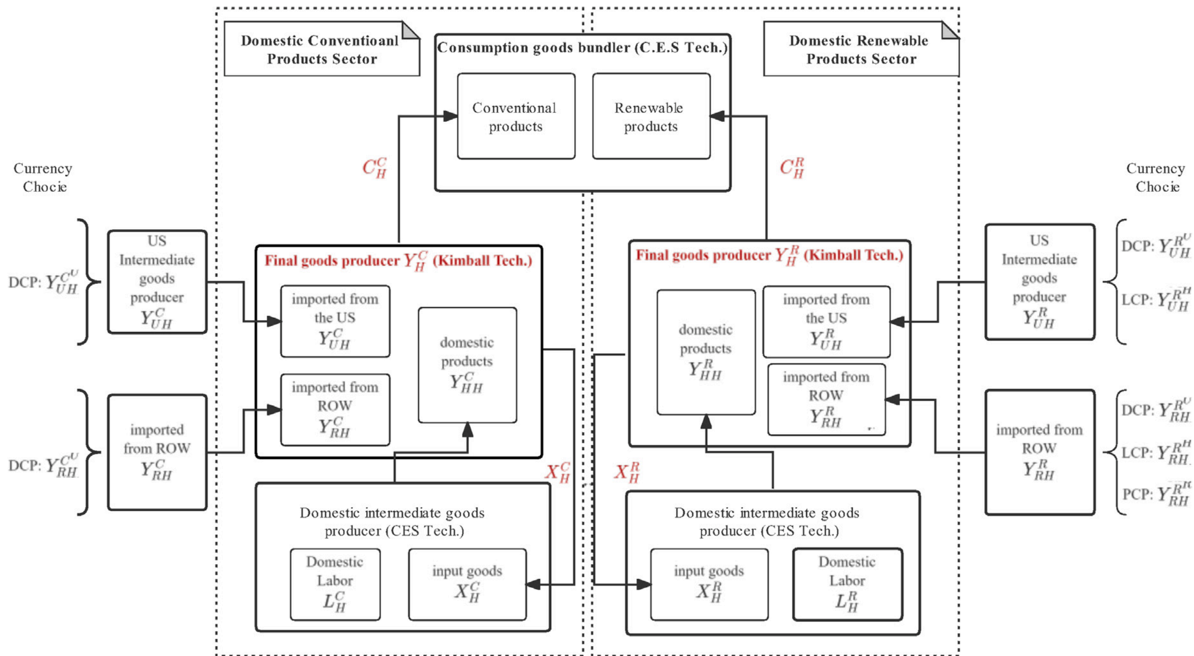


Fig. 3. The structure of the production side.

Symmetrically, the domestic exports to country j are foreign demands for domestic products. The export quantity is

$$Y_{ij,t}^{e}(\omega) = \gamma_i h(\frac{P_{ij,t}^{e}(\omega)D_{j,t}^{e}}{P_{j,t}^{e}})Y_{j,t}$$

where $D_{j,t}^{e}$ is foreign demand for product e.

3.2.3. Intermediate goods producers

The lowest layer is a continuum of intermediate firms that use labor L and sector-specific final products X^e as input factors for production. We adopted the Cobb–Douglas production technology:

$$Y_{i,t}^{e}(\omega) = A_{i,t}L_{i,t}^{e}(\omega)^{1-\alpha}X_{i,t}^{e}(\omega)^{\alpha}$$

The intermediate input $X_{i,t}^{e}$ is purchased from final goods producers from both domestic and foreign firms; thus, the demand for domestic $X_{ii,t}(\omega)$ and foreign final goods producers $X_{ji,t}(\omega)$ are

$$X_{ii,t}^{e}(\omega) = \gamma_i h\left(\frac{P_{ii,t}^{e}(\omega)D_{i,t}^{e}}{P_{i,t}^{e}}\right)X_{i,t}^{e}$$

$$X_{ji,t}^{e}(\omega) = \gamma_j h(\frac{P_{ji,t}^{e}(\omega)D_{i,t}^{e}}{P_{i,t}^{e}})X_{i,t}^{e},$$

respectively.

The cost minimization conditions for firms imply the following optimal conditions for labor and intermediate inputs:

$$(1-\alpha)\lambda_{i,t}^{e}\frac{Y_{i,t}^{e}(\omega)}{L_{i,t}^{e}(\omega)} = W_{i,t} \tag{9}$$

$$\alpha\lambda_{i,t}^{e}\frac{Y_{i,t}^{e}(\omega)}{X_{i,t}^{e}(\omega)} = P_{i,t}^{e} \tag{10}$$

where $\lambda_{i,t}^{e}$ is the marginal cost component that produces an additional unit of the intermediate products in sector e. $\lambda_{i,t}^{e}$ is also a Lagrangian multiplier in the firm optimization problem, which is given by

$$\lambda_{i,t}^{e} = \mathcal{MC}_{i,t}^{e} \equiv \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\frac{(W_{i,t})^{1-\alpha}(P_{i,t}^{e})^{\alpha}}{A_{i,t}}.$$

Firms are monopolistically competitive in each market such that they can set different prices based on the destination markets. The imported intermediate goods can be priced in different currencies. Denote $P_{ij,t}^{e^k}(\omega)$ as the price of the variety ω sold to country j with the invoiced currency k. The firms are faced nominal price rigidity during exports. We follow the Calvo (1983) and assume that each firm has an exogenous probability in each period $1-\delta_p$ to adjust price. When firm ω can adjust its price, it re-optimizes profit by selecting the price that maximizes discounted profits in currency, subject to demand constraints:

$$\max_{P_{ij,t}^{e^k}(\omega)} \quad \mathbb{E}\left[\sum_{s=0}^{\infty}\delta_p^s\mathcal{M}_{t,t+s}\left(\mathcal{E}_{ki,t+s}P_{ij,t}^{e^k}(\omega)Y_{ij,t}^{e}(\omega) - \mathcal{MC}_{i,t}^{e}Y_{ij,t}^{e}(\omega)\right)\right]$$

$$\text{s.t.} \quad Y_{ij,t}^{e}(\omega) = \gamma_i h(\frac{P_{ij,t}^{e}(\omega)D_{j,t}^{e}}{P_{j,t}^{e}})Y_{j,t}^{e}$$

where $\mathcal{E}_{ki,t+s} = 1$ when firms sell goods to the domestic market (i.e., when $i=j$) or when firms use the producer currency to export (i.e., when $k=i$). $\mathcal{M}_{t,t+s} = \beta^s(\lambda_{t+s}/\lambda_s)$ is the stochastic discount factor. Subsequently, the first-order conditions are as follows:

$$\mathbb{E}_0\sum_{s=0}^{\infty}\delta_p^s\mathcal{M}_{t,t+s}Y_{ij,t+s}^{e^k}(\omega)\left(\mathcal{E}_{ki,t+s}P_{ij,t}^{e^k}(\omega) - \frac{\sigma_{ij}(\omega)}{\sigma_{ij}(\omega)-1}\mathcal{MC}_{i,t+s}^{e}\right) = 0$$

where $\sigma_{ij,t}(\omega)$ denotes the elasticity of demand, which is defined as

$$\sigma_{ij,t}^{e}(\omega) = -\frac{\partial\log Y_{ij,t}^{e}(\omega)}{\partial\log P_{ij,t}^{e}(\omega)} \quad \text{for} \quad i,j\in\{H,F\}$$

Essentially, this model considers the invoicing currencies in international trade. Let $\theta_{ij}^{e^k}$ be the exogenous proportion of intermediate goods in sector e from country i to country j, priced in currency k, and for any i or j. We restrict the currency choice to the dominant currency (U), producer currency (i), and local currency (j) and $\sum_k\theta_{ij}^{e^k} = 1$, $k = U,H,R$. For the intermediate goods in sector e from country i to country j, we consider the following combination of invoicing currencies:

(1) Producer currency pricing (PCP): Products are fully priced in the currency of the producer country: $\theta_{ij}^{e^i} = 1$ for every $i\neq j$. (2) Local currency Pricing (LCP): Products are priced fully in the currency of the destination country, which is $\theta_{ij}^{e^j} = 1$ for every $i\neq j$. (3) Dominant currency Pricing (DCP): Products are fully priced in the dominant currency—$\theta_{ij}^{e^U} = 1$ for every $i\neq j$.

Assuming that the firms are pricing-to-market, $\hat{p}^{e^U}_{ij,t}$, $\hat{p}^{e^i}_{ij,t}$ and $\hat{p}^{e^j}_{ij,t}$ are the optimal price set by firms in the dominant currency, producer currency, and local currency, respectively. Subsequently, one can derive the weighted price index for the intermediate goods of sector e exports from country i to country j as

$$P^e_{ij,t} = \left[\theta^{e^U}_{ij}\,\mathcal{E}_{Ui,t}(\hat{p}^{e^U}_{ij,t})^{1-\sigma^e_{ij}} + \theta^{e^i}_{ij}(\hat{p}^{e^i}_{ij,t})^{1-\sigma^e_{ij}} + \theta^{e^j}_{ij}\,\mathcal{E}_{ji,t}(\hat{p}^{e^j}_{ij,t})^{1-\sigma^e_{ij}}\right]^{\frac{1}{1-\sigma^e_{ij}}}$$

3.3. Monetary policy

We assume that monetary policies are implemented using a short-term interest rate. The central bank adjusts its interest rate according to Taylor's rule:

$$\frac{R_{i,t}}{R_i} = \left(\frac{R_{i,t-1}}{R_i}\right)^{\rho_m}\left(\pi^{\phi_m}_{i,t}\left(\frac{Y_{i,t}}{Y_i}\right)^{\phi_y}\right)^{1-\rho_m}\epsilon_{i,t}$$

where R_i and Y_i are the steady-state levels of nominal interest rates and nominal gross output, respectively. On the steady state and the inflation rate $\pi_i = 0$. ρ_m controls for the inertia of the monetary policy, ϕ_m and ϕ_y govern the central bank's sensitivity to deviations in inflation and the output, respectively. $\epsilon_{i,t}$ is the shock to monetary policy following the AR(1) process: $\epsilon_{i,t} = \rho_\epsilon \epsilon_{i,t-1} + \epsilon^m_{i,t}$. ρ_ϵ is the autocorrelation coefficient used to capture the persistence of a monetary shock and $\epsilon^m_{i,t} \sim N(0, \sigma^2_m)$ is the white noise.

3.4. Goods market clearing

In each country, final goods are either sold to final consumers or back to intermediate goods production. The market clearing condition for the final goods sector is given by

$$Y^e_{i,t}(\omega) = \sum_j \left(C^e_{ij,t}(\omega) + X^e_{ij,t}(\omega)\right).$$

4. Model and parameters specifications

4.1. Kimball formula specification

Kimball aggregator is predominantly used in New Keynesian models such as Smets and Wouters (2007). It carries significant implications for firms' pricing behaviors and monetary policy. The use of the Kimball aggregator introduces additional strategic complementary in firms' pricing behaviors, lowering the price sensitivity to marginal cost for a given degree of price stickiness. To conduct numerical analysis, we use the functional form Y as per Klenow and Willis (2016).

$$Y^e_{ij,t}(\omega) = \gamma_j\left(1 + \epsilon\ln\frac{\sigma-1}{\sigma} - \epsilon\ln\left(\frac{P^e_{ij,t}(\omega)D^e_{j,t}}{P^e_{j,t}}\right)\right)^{\sigma/\epsilon}\left(C_{j,t} + X_{j,t}\right).$$

The elasticity of demand is

$$\sigma_{ij,t}(\omega) = \frac{\sigma}{\left(1 + \epsilon\ln\frac{\sigma-1}{\sigma} - \epsilon\ln\left(\frac{P_{ij,t}(\omega)D_{j,t}}{P_{j,t}}\right)\right)}.$$

The mark-up is $\mu_{ij,t}(\omega) = \frac{\sigma_{ij}(\omega)}{\sigma_{ij}(\omega)-1}$. In symmetric equilibrium, $Y^e_{ij}(\omega) = \gamma_i(C^e_{j,t} + X^e_{j,t})$, where $\sigma_{ij,t}(\omega) = \sigma$ and the elasticity variation is $\frac{\epsilon}{\sigma-1}$. When $\epsilon = 0$, the Kimball specification is reduced to the constant elasticity case.[6]

4.2. Parameter specification

Table 2 lists the calibrated parameters for the numerical analysis. The period is assumed in quarterly frequency. For the household parameters, we follow Galí (2015) to set the discount factor to 0.99, resulting in a 4% of annual return rate (*i.e.*, $1-0.99^{-4}\approx 0.04$). Following the existing literature, the inverse of Frisch elasticity is set to 2, and the scale of labor disutility is $\mu_L = 0.5$. For the Kimball demand specification, we follow Gopinath et al. (2020) to set $\sigma = 2$, which implies that the elasticity of substitution between domestic and foreign varieties is close to 1. To parameterize the strength of the strategic complementarity, we set $\epsilon = 1$. Thus the steady-state value of $\Gamma = \epsilon/(\sigma-1) = 1$ (Amiti et al., 2019). The elasticity of substitution between two renewable and conventional energy source goods is 1.8, which translates to 0.45 marginal rate substitution as in Papageorgiou et al. (2017).[7]

From the production perspective, the share of intermediate inputs in the roundabout production was set to 0.667 (Gopinath et al., 2020), aligning with the values suggested in Basu (1994). We assume that only one-fourth of the firms can adjust their prices quarterly; hence, the price stickiness is set to 0.75 (Christiano et al., 2010). We assume that the country is a net importer of energy products. Home biases toward conventional and renewable products were set to 0.7 and 0.6, respectively. This implies that the steady-state spending on imported goods for consumption and intermediate inputs is 30% and 40%, respectively, (Gopinath et al., 2020). The International Energy Agency (IEA) report indicates that renewable energy accounted for approximately one-third of energy use in recent years. Thus, we assume the share of conventional energy products as 65%.[8]

For the parameters in the $AR(1)$ process, we refer to the standard Literature. Monetary persistence and standard deviation shocks were set to 0.9 and 0.0025, respectively. The Taylor rule parameters adopted the following Galí (2015).

5. Dynamic effects of monetary shocks through exchange rate

In this section, we describe how exchange rates respond to monetary shocks and induce a domestic economic response when all internationally traded goods are invoiced in US dollars. We first simulate an expansionary domestic monetary policy (a cut in domestic interest rate) shock and explain its impact on inflation and domestic output. Subsequently, we compare the spillover effects of monetary policy originating from the dominant currency issuer and the third country (i.e., emerging markets).

5.1. Expansionary domestic monetary policy

Fig. 4 plots the dynamic monetary response expansion under DCP. Expansionary monetary policy encourages domestic households to invest in US bonds, leading to the depreciation of the currency. For goods produced by dollar-invoiced firms, price increases immediately. Thus, in an economy in which all the traded goods are invoiced in the US dollar (i.e., the full DCP), nominal depreciation would result in import inflation.

Additionally, a lower interest rate affects output by changing the domestic and foreign demand for products. Under DCP, the export price

[6] We express our gratitude for your insightful recommendations from an anonymous referee. To further underscore the significance of the Kimball aggregator in our analysis, we provide additional insights into the influence of the Kimball aggregator in Supplementary Material Section 2. To demonstrate the persistence of monetary policy, we analyze how firms' pricing behavior varies with different values of the strategic complementarity parameter ϵ.

[7] In Section 3 of the Supplementary Material, we provide additional robustness checks of the impact of different substitution elasticities.

[8] Source: https://www.iea.org/topics/global-energy-transitions-stocktake.

Table 2
Calibrated parameter values used for numerical analysis.

Calibrated Parameters	Value	Descriptions
Households		
β	0.99	Subjective discount factor
κ	1	Labor dis-utility
σ_c	2	Degree of risk aversion
ϕ	2	Frisch elasticity
Demand		
σ	2	Demand elasticity for and foreign varieties
ϵ	1	super-elasticity
ρ	1.8	elasticity of substitution between renewable and conventional products
η	0.65	shares of conventional products
Trade Shares		
γ_H^C	0.7	share of spending on conventional products
γ_U^C	0.15	share of spending on US conventional products
γ_R^C	0.15	share of spending on ROW conventional products
γ_H^R	0.6	share of spending on renewable products
γ_U^R	0.2	share of spending on US renewable products
γ_R^R	0.2	share of spending on ROW renewable products
Firms		
α	0.667	share of intermediate goods in production
δ_p	0.75	price stickiness
Monetary policy		
ρ_m	0.5	inertia in interest rates
ρ_ϵ	0.5	persistence in shock to interest rates
ϕ_m	1.5	inflation sensitivity
ϕ_y	0.5/4	output sensitivity
i^*	$(1/\beta)-1$	steady state level of interest rate
ρ_ϵ	0.9	persistence of monetary shock
σ_M	0.25%	standard deviation of monetary shock
σ_U	0.25%	standard deviation of US monetary shock

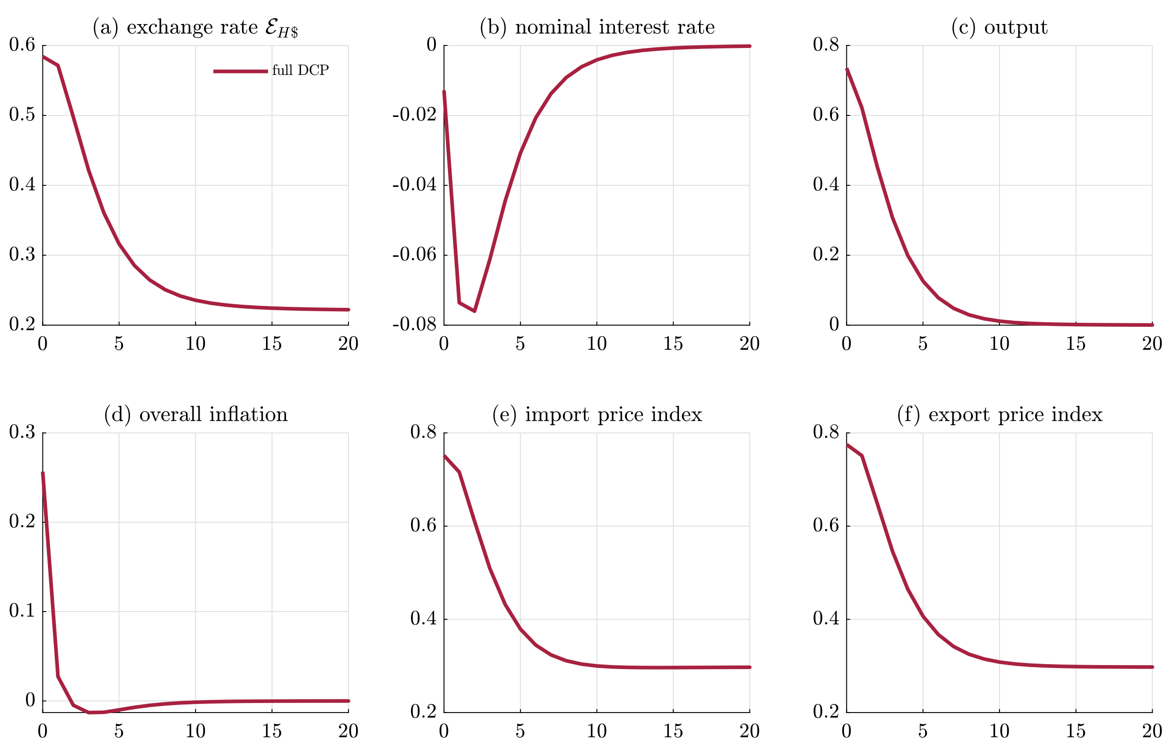


Fig. 4. Impulse response of interest rate shocks under DCP. The red solid line denotes that both renewable and conventional products are invoiced by the dominant currency. The effects are represented in percentage change.

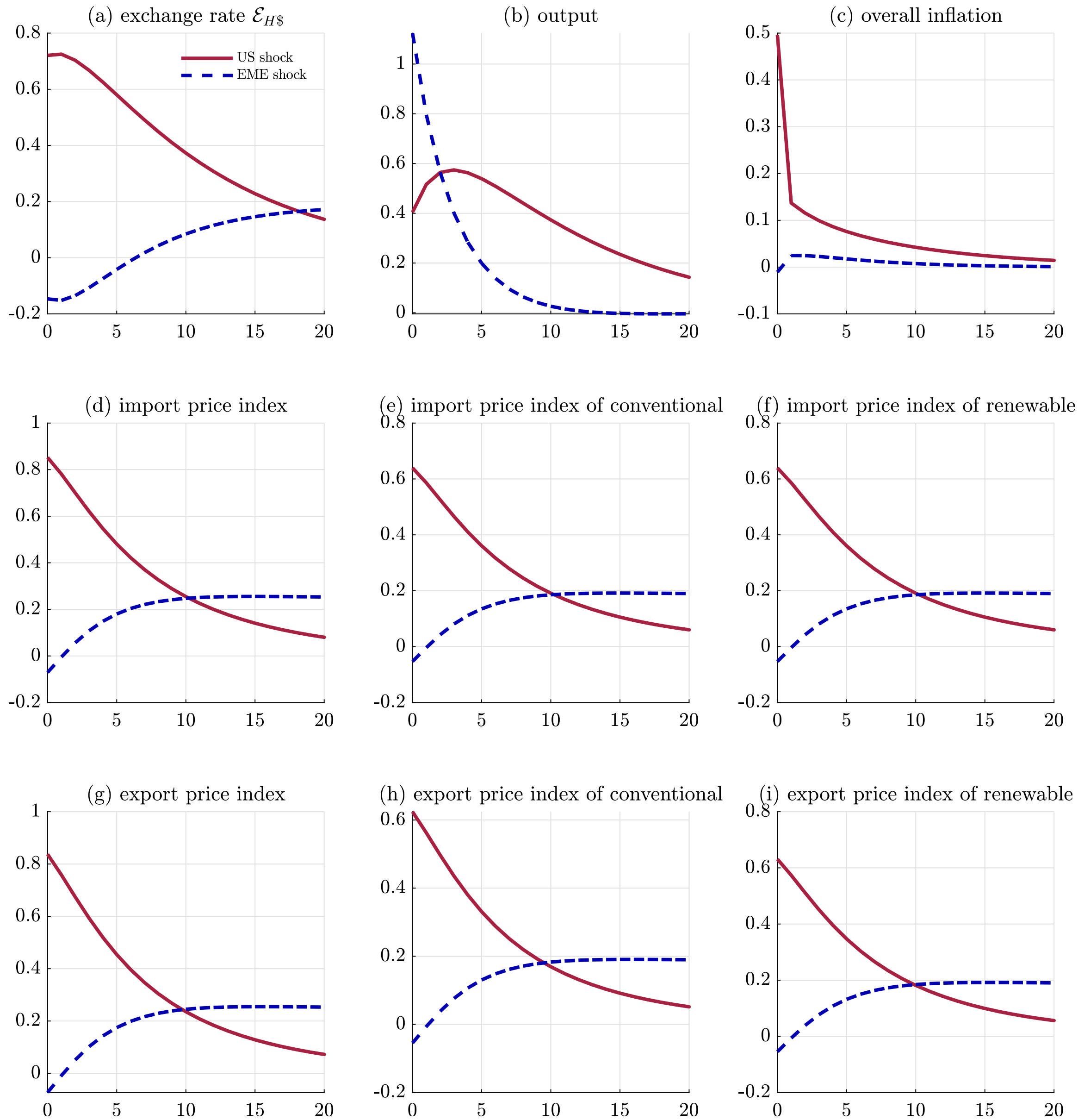


Fig. 5. Spillover effect of monetary tightening from foreign countries under DCP. The red solid line represents the US monetary shock, while the blue dashed line represents the EME monetary shock. The effects are represents in percentage change.

increases owing to the depreciated domestic currency and nominal rigidities, consequently, increasing the relative prices of the domestic products. Therefore, we observe that the expansionary effect of lower interest rates is partially offset by the reduction in foreign demand.

5.2. Tight foreign monetary policy

In the second set of results, we simulate monetary spillovers on policy tightening by foreign central banks. A country would expect a small spillover effect of foreign monetary policy. The results in Fig. 5 demonstrate that the domestic response to foreign monetary tightening differs significantly from the originating countries. Generally, monetary tightening from the US produces higher spillovers than those from other countries.

When the US central bank implements a tight monetary policy, an increase in the US interest rate raises domestic investments in US bonds, resulting in currency depreciation. Under the full DCP, US dollars are predominantly used to invoice traded goods, and the domestic imported goods price increases proportionally with the exchange rate. Therefore, rising import prices cause import inflation from the US to the domestic countries. Subsequently, the domestic authority would respond to the inflation pressure by raising interest rates following Taylor's rule. Finally, the currency depreciation effect is partially contradicted by the subsequent monetary contraction by the domestic central bank.

In comparison, the emerging economy's (EME) monetary policy has an indirect effect. Following EME currency appreciation, the domestic authority implements a contraction policy to increase interest rates, resulting in a lower domestic exchange rate against US dollar. Subsequently, the prices of the traded goods decrease. Hence, regarding magnitude, the impact of EME policy spillovers is relatively minimal.

6. Counterfactual analysis: role of alternative invoicing currencies

In recent years, the surge of trade exchange rate risk has propelled several countries to adopt diversified currencies. Notably, nontraditional currencies are witnessing an increasing utilization in international trade. Over the past two decades, the US dollar has accounted for approximately 70% of global foreign exchange reserves; nonetheless, this share has gradually declined to approximately 60% recently (Arslanalp et al., 2022). Furthermore, as foreign exchange transactions

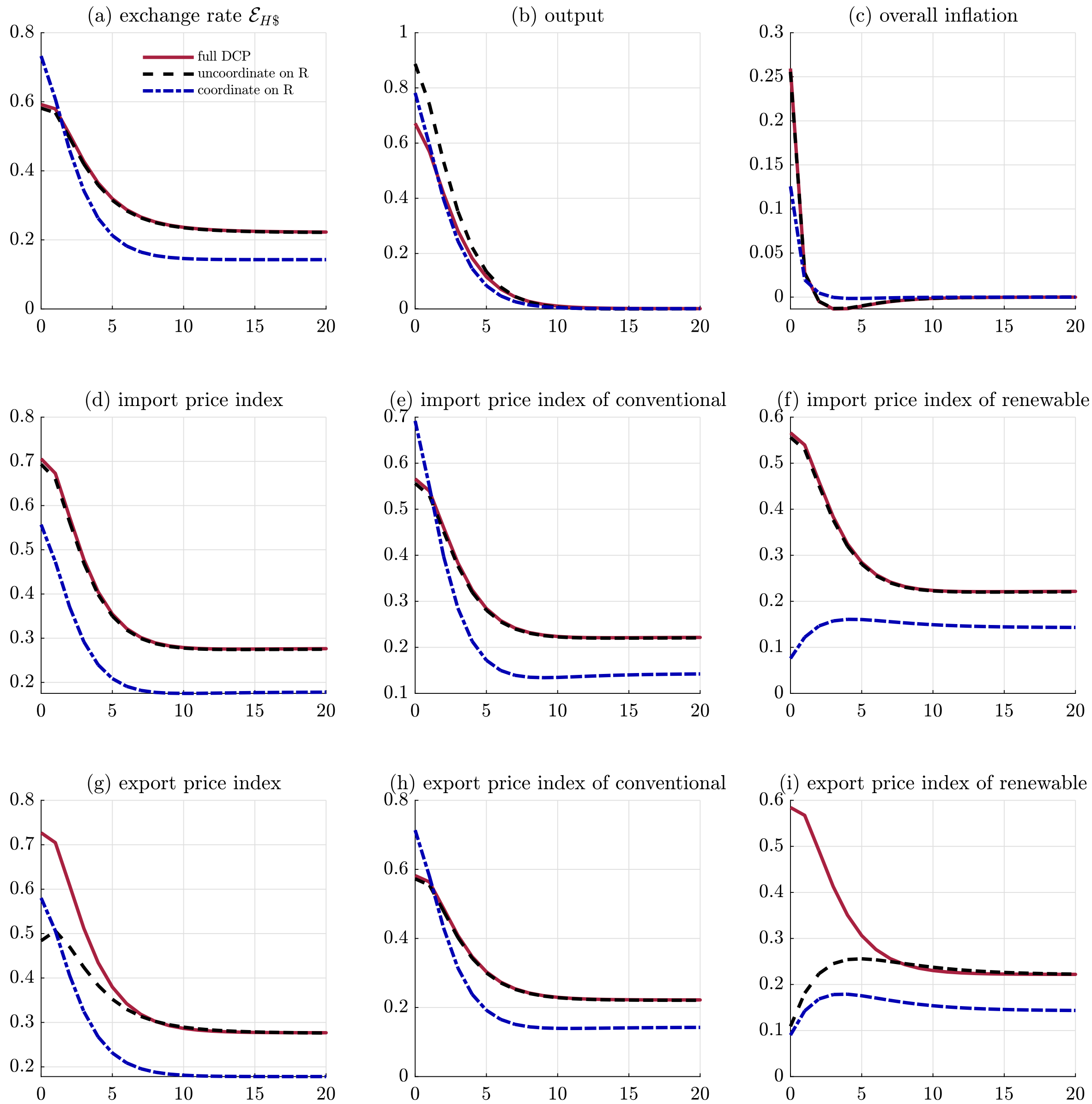


Fig. 6. Impulse response of domestic interest rate shocks. The red solid line denotes that both renewable and conventional products are invoiced by the dominant currency. The black dotted line denotes that renewable products are traded with producer currency. The blue dashed line denotes that the renewable trade was coordinated to be invoiced on the country's currency. The effects are represented in percentage change.

are costly, central banks are prone to holding coordinated currencies, which are widely used and priced (Matsuyama et al., 1993; Rey, 2001).

Given the compelling empirical evidence and underlying mechanisms outlined in the preceding sections, it is reasonable to expect that reducing the share of dollar-invoiced trade can stabilize prices and enhance the effectiveness of monetary policies. Considering that most conventional energy products are invoiced in US dollars, we conduct a simulation, assuming that renewable-energy products are traded in alternative currencies. Specifically, we considered two alternative scenarios: (1) Renewable energy products are traded in producer currency (i.e., uncoordinated in R); (2) all renewable products are coordinated with currency trade (i.e., coordinated with R). In both scenarios, the conventional products are priced in dollars.

To demonstrate the attractiveness of currency diversification, we conduct two series of analyses. First, we examine the effectiveness of domestic monetary policy being affected by currency invoicing. Specifically, we compare the inflation-output ratio (that is, the slope of short-run Phillips' curve) under the full DCP for counterfactual scenarios when a share of products (i.e., renewable energy goods) are priced in different currencies. Second, we compare how such spillovers from foreign monetary policies change when international firms trade in various invoicing currencies.

6.1. Effectiveness of domestic monetary policy

The first set of simulation results concerns the effectiveness of the domestic monetary policy. Central to the implementation of monetary policy in the New Keynesian framework is a tradeoff between inflation and output.

Fig. 6 plots the nominal variable dynamics under the expansionary monetary policy. Output-inflation ratio improved when intermediate firms used alternative currencies for export. When only the domestic

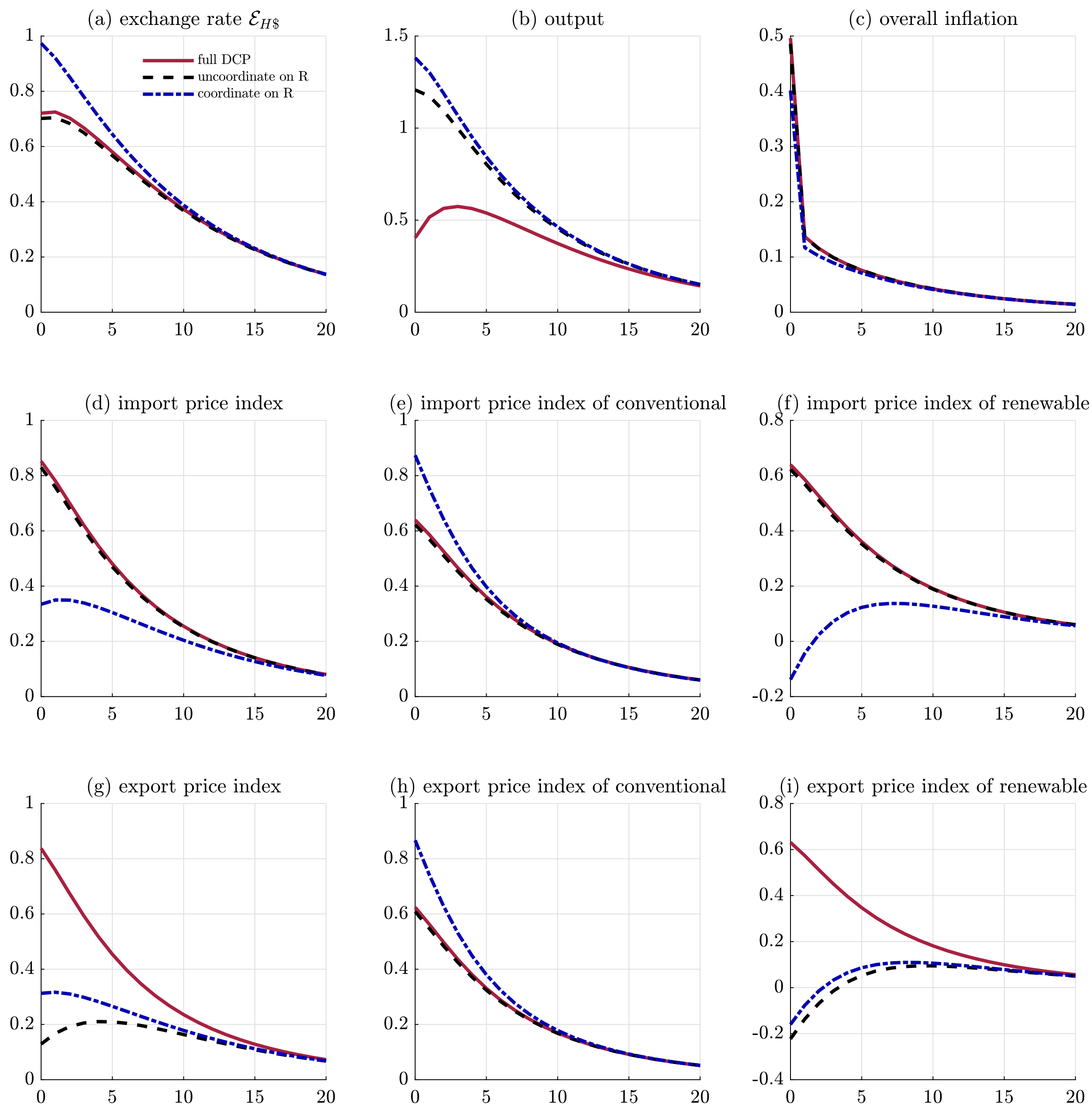


Fig. 7. Impulse response of the US monetary tightening. The red solid line denotes that both renewable and conventional products are invoiced by the dominant currency. The black dotted line denotes that renewable products are traded with producer currency. The blue dashed line denotes that the renewable trade was coordinated to be invoiced on the country's currency. The effects are represented in percentage change.

country uses domestic currency to export renewable energy products, the output increases, whereas inflation remains compared to the case in which all trades are denoted as the dominant currency. Moreover, the output inflation ratio is found to increase substantially from 3.2 to 6.5 when the three economies opted to coordinate to use domestic currency.

The differences in the changes in overall inflation are typically explained by the proportion of firms that use domestic currencies for exports. The export prices for firms invoiced in the domestic currency would not be affected by changes in the exchange rate between the domestic currency and the US dollar. Hence, while domestic currency depreciation is caused by the expansionary monetary policy, import prices increase the least when renewable energy sources imports are priced in domestic currency (countries that coordinate to use domestic currency to exports), leading to the lowest inflation.

Additionally, the export price for domestic producers is lower than foreign producers, giving rise to the real price advantages of products, increasing domestic exports. The terms of trade improved when *only* domestic producers used the domestic currency to export. Thus, total production increases significantly under an uncoordinated case.

6.2. Spillovers of US monetary policy

The results in Section 5.2 indicate that US monetary policy transmits substantial volatility to domestic economy, which is a worthwhile concern. In Fig. 7, we investigate how the magnitude of spillovers from the US monetary policy changes in the share of goods invoiced by the dominant currency.

In the uncoordinated case, when countries use producer currencies to export (i.e., in the uncoordinated case), all imported goods priced

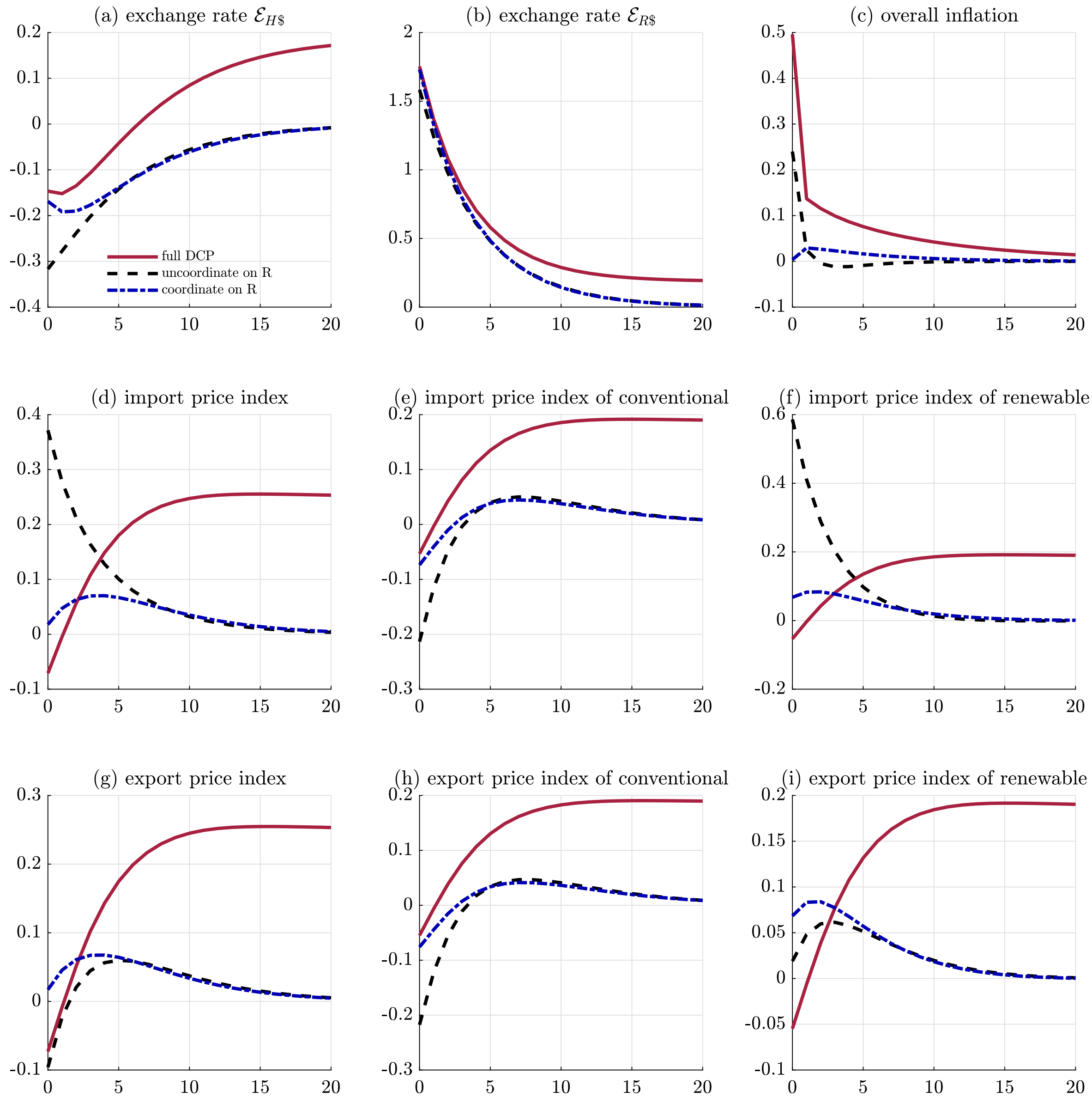


Fig. 8. Impulse response of the EME monetary tightening. The red solid line demonstrates that both renewable and conventional products are invoiced by the dominant currency. The black dotted line indicates that renewable products are traded with producer currency. The blue dashed line indicates that the renewable trade was coordinated to be invoiced in the domestic country's currency. The effects are represented in percentage change.

in the US dollar. The import price index rises for exchange-rate depreciation. Therefore, the domestic inflation response remains similar to that in the full DCP case. Moreover, using the producer currency in renewable energy products prevents export prices from exchange rate movement, leading the terms of trades varying substantially. Thus, we expect the output levels to fluctuate substantially when currency mismatches occur between imports and exports.

In the coordinated case, a decreased invoicing fraction in dollars leads to stable prices for both exports and imports of renewable products. Therefore, the US monetary policy produces fewer spillover effects on inflation and minimal impact on foreign demand for goods. This leads to alterations in relative prices and relative demand for conventional and renewable products.

The result implies that reducing the share of exports invoiced by the dominant currency from exports unilaterally is insufficient to stabilize inflation spillover from US monetary policy. Seeking for bilateral coordination of the invoice currency for renewables would reduce the proportion of imports invoiced in US dollars, thus reducing import inflation in each un-dominant country.

6.3. Spillovers of emerging economy's monetary policy

Finally, we undertake simulations and analyses to assess the benefits of using alternative currencies regarding mitigating domestic fluctuations resulting from emerging economies' monetary policies. Fig. 8 illustrates the impact of contractionary monetary shocks originating in emerging economies. for different invoicing currency scenarios.

Compared to the full DCP scenario, the extent of domestic currency appreciation decreased in the other two scenarios. Under DCP, import and export prices are affected by domestic-US bilateral exchange rates. However, some firms did not choose an alternative invoicing currency, the exchange rates between domestic country EME are relevant. Therefore, in an uncoordinated case in which firms use producer currencies for renewable energy exports, the depreciation of the domestic currency against EME currencies results in higher prices of imported renewable

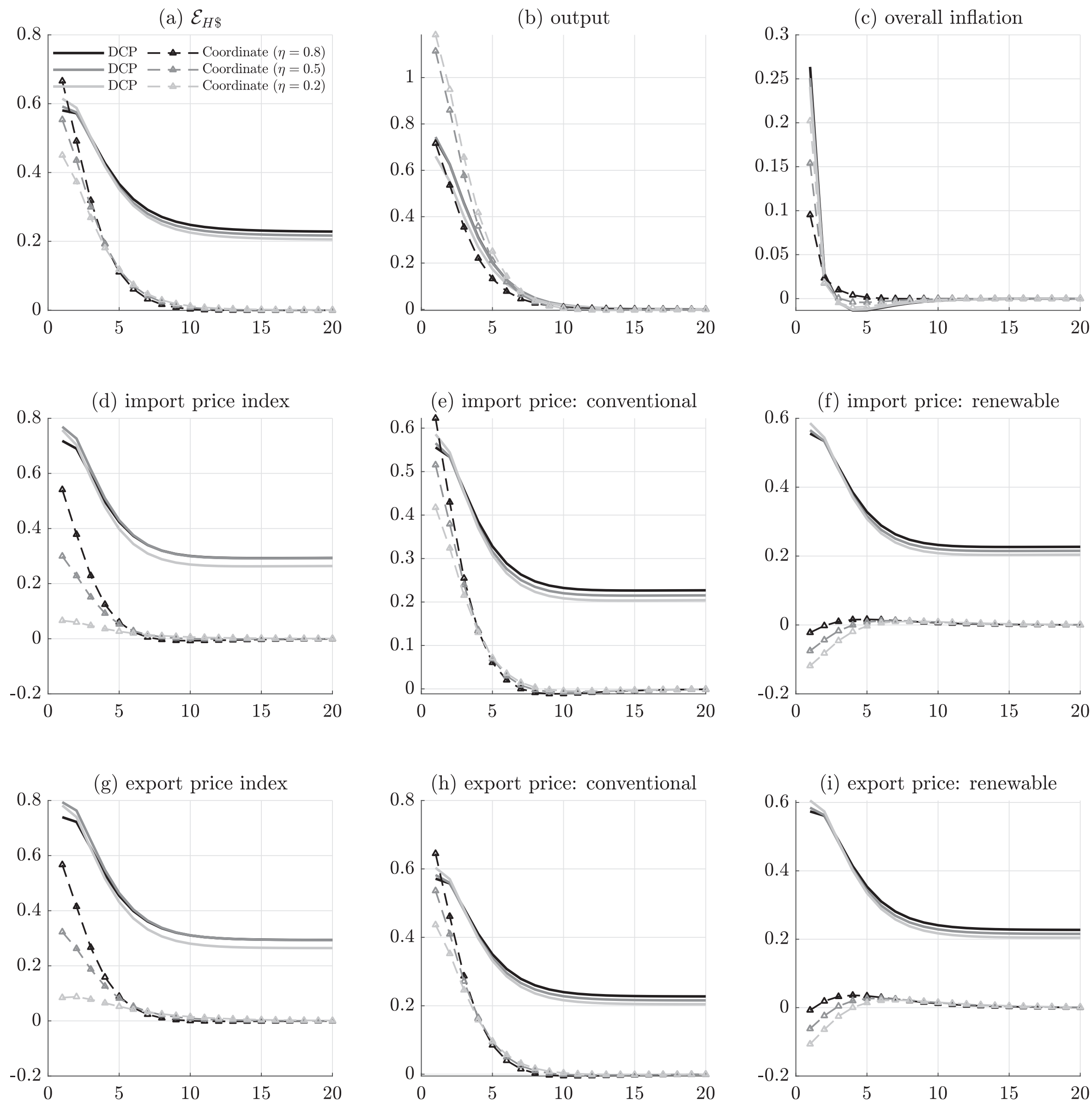


Fig. 9. Robustness when the renewable share changes. The solid line represents the impulse response of domestic monetary shock when both renewable and conventional products are invoiced by the dominant currency. The dashed line represents that the renewable trade was coordinated to be invoiced on the country's currency. The effects are represented in percentage change.

energy. goods. Nevertheless, as explained by the baseline results in Section 5.2, domestic authorities raise the domestic interest rates in response to the EME monetary policy, leading to a domestic currency appreciation against the US dollar. This appreciation has led to a decrease in import prices in the conventional energy trade. Consequently, overall, the inflation level is somewhat lower than in the full DCP case.

When all countries cooperate to use their domestic currencies for renewable energy trade, both renewable and conventional energy products are less affected by exchange-rate fluctuations. This results in smoother exchange rates and inflation movements. This outcome underscores the advantages of the coordinated adoption of alternative currencies in the renewable energy sector.

6.4. The role of invoicing currency during low carbon transitions

Concerning the continuously growing proportion of renewable energy in the energy sector, we simulate the benefits of currency coordination for several projected renewable energy shares. We compare the change in the monetary policy impact when the proportion of renewable energy increases under the different pricing regimes. According to the IEA report, renewable energy accounts for nearly 79% of the energy end-use. Maintaining clarity without losing intuition, we include the full DCP and the coordinated case. The results are then presented in Fig. 9.

Coordinated use of the domestic currency for pricing renewables in each country yields notable different outcomes compared with the full DCP, the former case results in a significant increase in output and a comparatively smaller increase in inflation. This outcome causes domestic monetary policy to stimulate output at a lower cost of inflation.

As the share of renewable products in the market expands, the overall price level becomes increasingly influenced by changes in renewable energy prices. Under the full DCP framework, both conventional and renewable product prices are subject to the influence of the exchange rate. When the share of renewable products increases, a greater depreciation of the domestic currency leads to nominal price increases for conventional and renewable products, respectively. Conversely, under the coordinated pricing case, in which all renewable products are denominated in the domestic currency, prices remain unaffected by the exchange rate fluctuations, whereas for conventional products, nominal prices rise. These differential pricing outcomes provide renewable products with a price advantage over conventional ones. With an increasing proportion of renewables in the market, the relative demand for domestically produced conventional products has significantly declined. Households display a preference for domestic production and renewable energy products. Consequently, foreign exporters in the domestic market are inclined to reduce the prices of conventional energy products. This pricing behavior leads to a substantial reduction in the import prices of conventional products in the domestic market.

7. Conclusion

This study investigates the transmission of inflation through international energy trade, focusing on the role of invoicing currencies. Empirical findings indicate a rise in inflation within the energy sector with a fraction of trade invoiced in US dollars. This positive correlation can be attributed to domestic currency depreciation against the US dollar. To explore the effect of the exchange rate, we construct a small open economy New Keynesian model and simulate exchange rate variations originating from exogenous monetary policies in various countries. Several primary findings regarding this model exist. First, when all traded goods are invoiced in the US dollar, due to nominal rigidity, firms cannot adjust their prices. Consequently, the prices of these products are changed proportionally to variations in the exchange rate, leading to imported inflation. Second, the dominant issuer's monetary policy produces more spillovers than non-dominant countries. Additionally, we compare the transmission of monetary policies when countries use alternative currencies for renewable energy products. The counterfactual analysis implies that trading renewable products with domestic currency can improve the effectiveness of the domestic monetary policy and reduce spillovers to foreign monetary policy. Finally, we also highlight the benefit to use coordinated currencies with projected shares of renewable in the near future.

This study validates the dominant currency-pricing theory in the energy sector. Furthermore, it highlights the benefits of using a diversified currency approach to mitigate the risk of monetary policy spillovers. While the feasibility of trading conventional products in alternative currencies is low, we addressed the benefits of adopting a non-dominant currency in the renewable sector. However, our paper only demonstrates the benefits of adopting a non-dominant currency in the renewable sector, the issue of how these international firms choose among several currencies remains a subject for further study in future research.

CRediT authorship contribution statement

Hui Qiao: Methodology, Visualization, Writing (part). **Ping Qin:** Supervision, Reviewing, Validation. **Yang Liu:** Conceptualization, Methodology, Writing (part). **Yugang Yang:** Data curation, Data cleaning.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.eneco.2023.107178.

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