Currency Pegs, Trade Deficits and Unemployment: A Reevaluation of the China Shock*

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Abstract

We study how the interaction between China's productivity growth and currency peg to the US dollar affected manufacturing decline, unemployment, trade deficit, and welfare in the United States. Empirically, we document that in response to similar surges in Chinese exports, countries pegging to the US dollar experienced larger unemployment and trade deficits compared to floating countries. Theoretically, we develop a dynamic model of trade featuring endogenous imbalances and nominal rigidity that is consistent with the findings. We show that Foreign growth may hurt Home welfare and characterize optimal trade and monetary policy in this environment. Quantitatively, we find that China's currency peg is responsible for 447 thousand manufacturing jobs lost in the US over 2000-2012, 1.3% out of 3.4% (% GDP), the average annual US trade deficit in the same period, and reduced US lifetime welfare gains from Chinese growth by 32% compared to an economy where an otherwise identically growing China had its currency floating. However, the welfare impact of the China shock remains positive. We find that a short-run safeguard tariff may have effectively accommodated China's currency peg and ameliorated the labor market distortions.

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1 Introduction

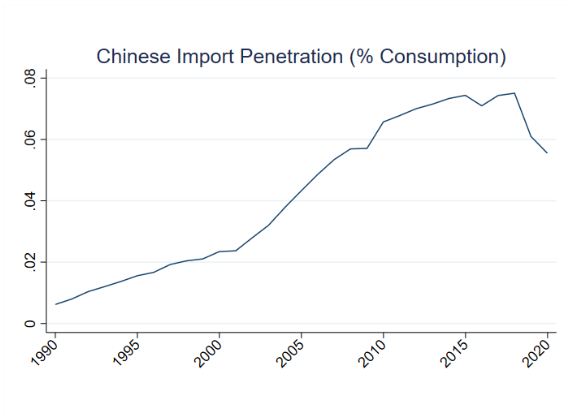
Four facts of the past two decades have drawn significant attention in both academic research and public discourse. First, China's exports to the US have grown significantly, driven by spectacular productivity growth and falling trade costs – henceforth the *China shock* (Figure 1a). Second, US manufacturing has undergone a significant decline, coupled with a rise in unemployment in manufacturing-heavy regions (Figure 1b). Third, the US has incurred a substantial trade deficit, while China ran a trade surplus (Figure 1c). Fourth, China has pegged its currency against the US dollar via an explicit peg (until 2004) or a managed band (after 2005) (Figure 1d).

An often-heard narrative in policy circles emphasizes how the last fact may have caused or magnified the first three. According to that narrative, *currency manipulation* by China might have been responsible for its sudden export surge to the US, large trade imbalances between the two countries, and, in turn, depressed the US labor market.[1] Although much has been said about the China shock in the trade and labor literature (Caliendo et al., 2019; Rodríguez-Clare et al., 2022; Dix-Carneiro et al., 2023), as well as the global savings glut in the international macro literature (Caballero et al., 2008; Mendoza et al., 2009; Kehoe et al., 2018), there has been no attempt at connecting the four facts collectively. This paper proposes to fill this gap by developing a theory in which, under an exchange rate peg, exogenous productivity shocks in China simultaneously cause import surges, trade deficits, and unemployment in the United States.

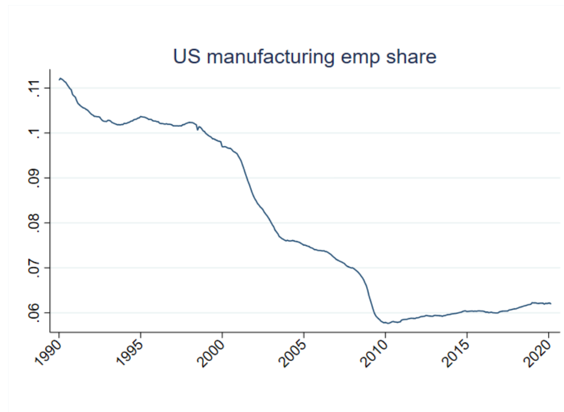
Our contribution is threefold. First, we present empirical evidence that a country's exchange rate regime affects the incidence of the China shock on labor market outcomes and trade imbalances. We show that countries using or pegging to the US dollar – whose currency was *de facto* pegged to the Chinese currency – experienced larger declines in output, higher unemployment, as well as larger trade deficits in response to higher exposure to the China shock, compared to floating countries, whose currency depreciated in response to China shock exposure. Second, we develop a simple model of intra- and intertemporal trade with wage rigidity that parsimoniously connects the four facts above by endogenizing the US trade deficit as a result of Chinese growth. We highlight the possibility that Home welfare may decrease as a result of Foreign growth and study optimal policy responses. Third, we use a richer version of the same model to reevaluate the effects of the China shock and the role of China's exchange rate peg. We find that China's exchange rate peg contributed to a substantial part of the US trade deficit, decline in US manufacturing, unemployment, and reduced the welfare gains from the China shock.

In Section 2, we present evidence of the role of China's exchange rate peg in shaping labor market outcomes and trade imbalances in response to trade shocks. We use the joint fact

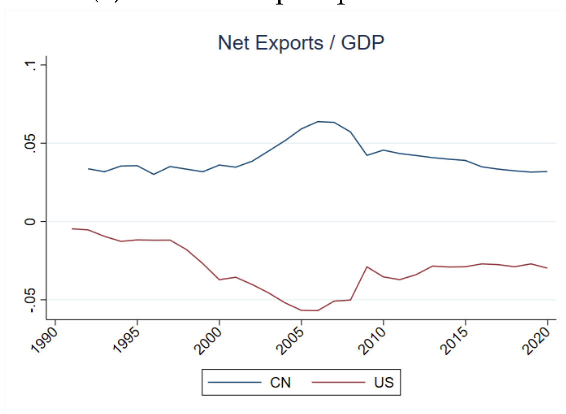
[1] Countries increase tariffs in response to unemployment (Bown and Crowley, 2013) and trade deficits (Delpeuch et al., 2021), consistent with this narrative and suggesting that it may have affected policy.



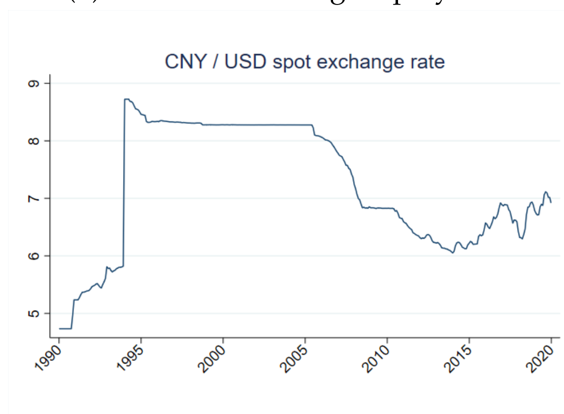
(a) Chinese import penetration



(b) US manufacturing employment



(c) Net exports (% GDP)



(d) CNY/USD exchange rate

Figure 1: Four stylized facts.

Sources: (a) Import of goods from China obtained from US Census Bureau and Bureau of Economic Analysis (BEA), US goods consumption obtained from BEA. (b) Bureau of Labor Statistics. (c) US Census and BEA. (d) Board of Governors of the Federal Reserve System (US). Retrieved from FRED.

that China's export growth post-2000 varied across sectors and that countries varied in their sectoral composition pre-2000 to construct a shift-share measure of country-specific exposure to the China shock, a cross-country analog of Autor et al. (2013, 2021). We then implement a triple-difference strategy that compares the *differential* impact of the *same* exposure between floating countries and countries pegged to the US dollar and, therefore, pegged to the Chinese currency. Our triple-difference strategy shows that a similar surge in exposure led to a lower manufacturing output, a temporary increase in unemployment, and larger trade deficits when the country's currency is pegged to the US dollar, relative to a country that floats.

In Section 3, we develop a dynamic model of trade with predictions consistent with the empirical findings and can jointly explain the four facts above. Our model is a two-period model with Armington trade in each period that allows consumption savings through an international bond market, and features short-run nominal wage rigidity. Under an exchange rate peg (Figure 1d), our model predicts that an increase in Foreign productivity (Figure 1a) causes a trade deficit at Home (Figure 1c) and Home workers face involuntary unemployment (Figure 1b).[2] This holds provided that the trade elasticity σ is higher than the intertemporal elasticity γ, as documented empirically. The intuition is as follows: after Foreign growth, the Home relative wage should adjust through nominal wage or exchange rate. With both channels muted, the trade balance is determined by expenditure switching and relative inflation. When $\sigma > \gamma$, the expenditure switching channel dominates, Home runs a trade deficit, and shrinking global demand for Home goods causes unemployment at Home. This framework allows us to jointly explain the trade deficit and unemployment in manufacturing-heavy regions of the US as an endogenous outcome of Chinese growth under an exchange rate peg, parsimoniously explaining the stylized facts of the 2000s.[3]

Turning to welfare and policy analysis, we show that Home welfare may even decrease as a result of Foreign growth when the trade elasticity is sufficiently high. Despite an improvement in terms-of-trade today, Foreign growth under a peg creates involuntary unemployment and future terms-of-trade deterioration due to required future trade surpluses. The higher the trade elasticity, the more expenditure is switched towards foreign goods, and the more severe the negative effects are. We show that the optimal short-run tariff in response to the shock is positive. Here, dynamic terms-of-trade considerations reinforce the standard motive for *safeguard* tariffs allowed by the WTO. We also highlight that Home's optimal monetary policy, barring constraints such as the Zero Lower Bound, would want to overshoot the output gap because it is borrowing and can set the global interest rate under a peg.

To explore the quantitative significance of the mechanism, Section 4 introduces a multi-country, multi-sector, infinite-horizon model consisting of two blocks. The first block is a workhorse trade model with input-output linkages and labor migration frictions (Caliendo et al., 2019), both of which shape how trade shocks affect the labor market. This trade block allows us to quantify the general equilibrium effects of the China shock using observed sector-level trade and worker reallocation data. The second block is a macroeconomic block comprising wage rigidity generating a New Keynesian Phillips Curve (Erceg et al., 2000), intertemporal balances from consumption-savings (Obstfeld and Rogoff, 2005), and exchange rate determination from long-run balances (Itskhoki and Mukhin, 2021a). This macro block allows us to incorporate involuntary unemployment, endogenous trade imbalances, and compare exchange rate pegs with floating exchange rates.

We calibrate the model to exactly match the sectoral trade flow data from the World Input Output Database (WIOD) and labor adjustment data from the Current Population Survey (CPS). Our solution algorithm allows us to solve for the full sequence of wages, prices, labor

[2]In principle, monetary policy can sufficiently react to undo this. We discuss this possibility in the main text.

[3]In related work, for which we explain in more detail below, Dix-Carneiro et al. (2023) study an environment with endogenous trade imbalances and unemployment due to search friction. As we show in the Online Supplement, in such an environment with quantity friction, we get opposite predictions on the direction of trade imbalance, highlighting the role of nominal rigidity and exchange rate pegs in connecting these facts.

allocation, and trade imbalances for any realized or counterfactual fundamentals and policies, including the exchange rate regime. We bring frontier computational methods from macroeconomics, leveraging the sequence-space Jacobian method introduced by Auclert et al. (2021a) and using advances in machine learning frameworks to efficiently solve for the equilibrium in minutes.

Section 5 conducts counterfactual and welfare analysis. We first quantify the effect of the China shock by comparing the realized economy with the counterfactual economy without Chinese productivity growth and trade liberalization. We find that the China shock can explain 2.25 percentage points of the US trade deficit between 2000 and 2012, 991 thousand manufacturing jobs lost, and may be responsible for a surge in unemployment of 3.04% over the same period, concentrated in the affected manufacturing sectors, estimates that are approximately double those in the previous literature. Turning to welfare analysis, we find that the China shock still increased the welfare of the US by 0.183%, an estimate lower than previous literature but still positive, showing that the surge in Chinese exports, even after accounting for involuntary unemployment and dynamic terms-of-trade effects due to the exchange rate peg, increases the welfare of the US.

We also consider an additional counterfactual economy without Chinese growth and trade liberalization, and also without China's *savings glut* – residual demand for savings by China, which we calibrate to match the trade imbalances of each country. We use this counterfactual to assess the contributions of China's savings glut to the outcomes of the US and find that the decline in manufacturing is nearly identical with or without China's savings glut. This reinforces the findings of Kehoe et al. (2018), which show that the global savings glut is responsible for only a small portion of the decline in US goods-sector employment (15.1%). We show that once we incorporate the exchange rate peg, China's residual savings glut had a negligible effect on the US manufacturing decline or the trade deficit. This finding underlines the centrality of the exchange rate peg in how the growth and savings of China affected the US.

Next, we isolate the effect of China's exchange rate peg on the same aggregate outcomes. The question we ask is: How different would the effects of the China shock have been without the peg? Comparing the realized economy with the counterfactual economy where an otherwise identically growing China floats its exchange rate, we find that China's peg to the US dollar is responsible for 1.3 percentage points of the US trade deficit (% GDP), 447 thousand manufacturing jobs lost. These equilibrium responses largely match those observed in the empirical findings (Section 2) and support the quantitative significance of the relevant channels in our theoretical model (Section 3). Balancing these factors, China's exchange rate peg lowered US lifetime welfare by 0.083% relative to an economy where the China shock occurred, but China floated its currency with respect to the US dollar.

Finally, we explore the consequences of counterfactual policies on labor market outcomes and US welfare. We ask the following questions: What would have been the impact on US welfare if different policy measures were implemented? What are the effects of a targeted tariff designed to reduce trade deficits? And finally, what is the role of monetary policy in shaping these outcomes? We find that a tariff of 15-20% on Chinese goods could have ameliorated the short-run labor market distortions, this positive effect remains even under retaliatory tariffs, and monetary policy could have been effective in reducing the distortion from the China shock, conditional on not being subject to the Zero Lower Bound.

The paper is accompanied by an Appendix containing a description of the data, proofs of the main propositions, and derivations of key equations, and a longer Online Supplement, that contains robustness tests, model extensions, further derivations, calibration details, and the solution algorithm.

Related Literature

Our paper contributes to a large trade and labor literature that studies the labor market consequences of globalization. On the empirical side, Autor et al. (2013, 2021), Acemoglu et al. (2016) have shown that US labor markets competing more with Chinese imports are hurt relatively more.[4] On the structural side, the seminal work by Caliendo et al. (2019) (henceforth CDP) quantifies the effect of the China shock across labor markets. We contribute to the structural trade literature by embedding a full New Keynesian macro block into CDP. This allows us to address involuntary unemployment, discuss the implications of endogenous imbalances, and study counterfactual policies.

Two closely related papers, Rodríguez-Clare et al. (2022) and Dix-Carneiro et al. (2023), also study unemployment in response to the China shock by augmenting CDP with labor market frictions. Rodríguez-Clare et al. (2022) (henceforth RUV) is most similar to ours in that they introduce wage rigidity. Our approach is different in two dimensions. First, we feature endogenous imbalances through consumption-savings and nominal rigidity generating a Phillips Curve. This complements their approach, which uses exogenous imbalances and demand anchors with a reduced-form downward nominal wage rigidity (DNWR). Second, our model underscores the central role of exchange rate pegs, allowing us to evaluate the welfare effect of China's USD peg on the United States. These differences allow our framework to highlight the effect of counterfactual monetary policies and exchange rate pegs.[5]

Dix-Carneiro et al. (2023) introduce endogenous consumption-savings to study the effect of the China shock and trade imbalances on the labor market and uses search frictions à la

[4] Recent empirical papers that connect trade shocks with the labor market include Pierce and Schott (2016), Dix-Carneiro and Kovak (2017), Handley and Limão (2017), Carrère et al. (2020), Costinot et al. (2022). Autor et al. (2016) and Redding (2022) provide excellent review of the literature.

[5] In related work, Fadinger et al. (2023) study the effect of German growth on the Eurozone through a model of DNWR and consumption-savings, with an exogenous demand anchor. In such models, a floating exchange rate moves to clear all nominal frictions; on the other hand, a floating exchange rate in our model is financially driven and may not immediately adjust to clear the labor market across all sectors.

Mortensen and Pissarides (1994) to generate unemployment.[6] However, the response to trade shocks qualitatively differs under nominal frictions (wage rigidity) and quantity friction (search) in two important ways. First, quantity friction amplifies terms-of-trade shocks and leads to a reduction in unemployment in response to Foreign trade shocks, in conflict with increased unemployment in regions more exposed to the China shock (Autor et al., 2013, 2021). Second, quantity friction generates a force for the US, not China, to run trade surpluses in response to Chinese productivity growth, necessitating an even larger exogenous *savings shock* to align with the observed trade imbalance. Under our model of wage rigidity, short-run unemployment and trade deficit in the US are endogenous outcomes of the Chinese productivity growth. Our framework can also investigate the effect of the exchange rate peg and study counterfactual tariffs or monetary policies, elements absent from their study.

We highlight how an exchange rate peg under nominal rigidity can generate trade imbalances. This contributes to the international finance literature that studies the "global savings glut" of the 2000s, a term first coined by Bernanke (2005). Recent work attributes the US current account deficit to financial frictions (e.g. Caballero et al. (2008, 2021), Mendoza et al. (2009)), business cycle dynamics (e.g. Backus et al. (2009), Jin (2012)) or demographics (e.g., Auclert et al. (2021b), Bárány et al. (2023)).[7] Our work highlights a goods-market explanation of the observed trade imbalances under exchange rate pegs that can exist concurrently with the financial origins. Through the lens of our quantitative model, we attribute 37.1% of the US deficit to China's exchange rate peg, with the remaining deficit attributable to other countries and potential financial mechanisms that we have abstracted from.

We contribute to the open economy macroeconomics literature by bridging it with structural trade models to study sector-level shocks, such as the China shock.[8] From Galí and Monacelli (2005, 2008) to more recent work such as Schmitt-Grohé and Uribe (2016) and Auclert et al. (2021c), the literature has studied the role of trade, exchange rates and monetary policy in the macroeconomy. We build on these papers along two dimensions. First, we consider the effects of the exchange rate peg for an economy facing a peg, necessitating a departure from the small open economy model, which a majority of the literature focuses on, and consider Home monetary policy that directly affects savings decisions abroad. Second, we incorporate a multisector trade model that allows us to investigate the macroeconomic effect of shocks such as the China shock that are very asymmetric across sectors.

Our work on tariffs and monetary policy in response to the China shock is closely related to the literature studying the macroeconomic consequences of trade policy and monetary pol-

[6] Kehoe et al. (2018) also study the effect of imbalances in the labor market, but do not study unemployment. Dix-Carneiro (2014), Kim and Vogel (2020, 2021), Galle et al. (2023) also embed search-and-matching into trade, without imbalances.

[7] See Gourinchas and Rey (2014) for a review of this literature.

[8] In doing so, we follow the recommendations of Rodríguez-Clare et al. (2022) by "*adding a Taylor Rule [..] allow agents to make savings and investment decisions, and incorporate international financial flows affecting exchange rates.*"

icy in the open economy. The closest to our analysis are Jeanne (2020), Auray et al. (2023), and Bergin and Corsetti (2023), each of which studies the interaction of tariffs and monetary policy in an Open Economy New Keynesian model.[9] While our insights resonate well with theirs, these papers focus on steady-state and business-cycle optimal policy, whereas we study policies in a transition path in response to a permanent shock. As such, their government is focused on steady-state welfare maximization, while the government in our model seeks to affect dynamics, including endogenous imbalances.

We underscore the role of China's exchange rate peg in generating unemployment and a steeper decline for US manufacturing by worsening its competitiveness. This is closely related to the idea that flexible exchange rates are a shock absorber. Previous empirical evidence of such an absorber role has been documented in the goods market (Broda, 2001, 2004; Edwards and Levy Yeyati, 2005; Carrière-Swallow et al., 2021), labor market (Schmitt-Grohé and Uribe, 2016; Campbell, 2020; Ahn et al., 2022), and financial market (Ben Zeev, 2019). Our analysis in Section 2 provides additional support that flexible exchange rates operate as an adjustment margin for the China shock. Our model explicitly incorporates exchange rate regimes into a structural trade model, allowing us to quantify the welfare effects of a large emerging market economy's currency peg on the US.[10]

2 Empirics: Exchange Rate Regimes and the China Shock

This section presents motivating evidence for the relevance of China's exchange rate peg in how the China shock affected the US labor market and trade deficit. Public discourse puts trade deficits and the peg at the center of how China affected the US labor market: with Chinese productivity growth and a peg, cheap Chinese goods flood the US market, shifting demand, exacerbating trade deficits, and harming US manufacturing. Would a floating exchange rate have functioned as a margin of adjustment? Establishing the sign and magnitude of the relationship between China's exchange rate peg and the labor market outcomes and trade balances is important in understanding the role the exchange rate plays in international trade.

To empirically answer this question, our focus must extend beyond the US and China, given the absence of a counterfactual scenario of Chinese export surge under a fully flexible exchange rate between the two countries. We overcome this challenge by comparing countries with different currency regimes vis-à-vis China's regime – peg to the US dollar – and similar exposure to Chinese exports. We construct a measure of each country's exposure to Chinese export

[9] See also Barbiero et al. (2019); Lindé and Pescatori (2019); Barattieri et al. (2021); Auray et al. (2022) for tariffs, Ghironi (2000); Benigno and Benigno (2003); Devereux and Engel (2003); Faia and Monacelli (2008); Corsetti et al. (2010); Lombardo and Ravenna (2014) for monetary policy, and Erceg et al. (2018), Barattieri et al. (2021), Cacciatore and Ghironi (2021) for empirical analysis of tariffs, monetary policy and exchange rates.

[10] This also relates us to the exchange rate determination literature, such as Gabaix and Maggiori (2015), Itskhoki and Mukhin (2021a), Hagedorn (2021). Our model is a limit case of these setups.

growth, and conditional on the same exposure to the China shock, test (1) whether the nominal exchange rate responds to the China shock for floating countries, and if so, in which direction, and (2) whether countries pegged to the US dollar (including the US) experience a drop in output and employment, and larger trade deficits relative to countries that do not peg to the US dollar. Our findings are consistent with these two hypotheses and motivate our modeling framework and quantitative analysis in Sections 3 onwards.

2.1 Background: the China shock and exchange rate peg

A large literature investigates the role of Chinese productivity growth and decreased trade costs in disrupting the US labor market. Empirical evidence and quantitative estimations consistently find that the surge in Chinese exports is a key factor in the economic decline and potential welfare losses of regions and sectors with greater exposure. This *China shock* is primarily attributed to productivity growth (Hsieh and Ossa, 2016) and falling trade costs due to China's 2001 accession to the WTO (Handley and Limão, 2017), and plateaued after the early 2010s (Autor et al., 2021).

Concurrently to the export growth, China maintained an exchange rate peg to the US dollar. The renminbi (China's official currency) was pegged at a rate of 8.28:1 in June 1994 and sustained a hard peg until July 2005, which "contributed to the exploding exports and ballooning trade surpluses of the early 2000s" (Kroeber, 2014). Subsequently, the People's Bank of China (PBOC) implemented a managed *band*, allowing the currency to fluctuate within a narrow band. This band gradually widened from 0.3% in July 2005 to 1% in April 2012, with a hard peg during the Great Recession. The renminbi appreciated through a slow and controlled process, and Ilzetzki et al. (2019) classify China's exchange rate policy as a *de facto peg* from January 1994 to 2019.

2.2 Data and Measure of the China Shock

In this subsection, we outline the sources of our data and the construction of shocks. Additional details are provided in Appendix A.

Exposure to the China shock. To measure the exposure of a country i to the surge in Chinese exports, we follow Acemoglu et al. (2016) and Autor et al. (2021) to construct a shift-share measure of exposure that combines (1) a weight of each sector s for each country i and (2) global growth in Chinese exports for each sector s

$$S_i = \sum_s \underbrace{\lambda_i^s}_{\text{share}} \times \underbrace{g_C^s}_{\text{China shock in sector } s} \tag{1}$$

Here $g_C^s = \log(E_{CT}^s) - \log(E_{Ct}^s)$ is the global increase in Chinese export value for each sector s from the pre-shock period t to post-shock T ($t = 2000$ to $T = 2012$, following Autor et al. (2021)), and λ_i^s is a weight of each country i's exposure to Chinese export growth in sector s. Sectoral export data is obtained from the UN Comtrade database at the 4-digit SITC level, and we closely follow the cleaning procedures in Feenstra et al. (2005) and Atkin et al. (2022).

S_i is a shift-share measure (Bartik, 1991) of each country's exposure to the surge in Chinese exports and is akin to the local labor market exposure measure in Autor et al. (2013). From Equation 1, any variation in S_i across countries comes entirely from variations in sector share λ_i^s: countries with higher S_i face more competition from Chinese exports precisely because those countries had a larger share of sectors where Chinese exports increased. A sufficient condition for S_i identifying country i's exposure to the sectoral shocks is for the shocks g_C^s to be exogenous to demand-side confounders (Borusyak et al., 2022). We discuss this further in Section 2.5 find supporting evidence for shock exogeneity in Appendix A.[11]

We define the weights λ_i^s of each sector s in country i. Gathering accurate data on 4-digit sector sizes across countries is difficult, and we proxy for the sector size using export value data, which is readily available. Thus, our baseline measure of each sector s's weight in each country i is given by

$$\lambda_i^s = \frac{E_{it}^s}{GDP_{it}}$$

where E_{it}^s is country i's total value of exports at the pre-period t; a higher share λ_i^s means country i is exporting relatively more to sector s. Thus, our measure of *exposure to China shock* for country i becomes

$$S_i = \sum_s \frac{E_{it}^s}{GDP_{it}} \Delta \log(E_C^s)$$

which has the following interpretation: a higher S_i means that country i is exporting more in sectors where Chinese exports globally increased. Thus, S_i measures how much country i's exports to third countries are substituted to China, which complements the China shock literature, which often studies domestic competition with imports from China. In the Online Supplement, we consider alternative weights λ_i and shocks g_C^s, showing that the results are robust to alternative choices.

Exchange rate regime. Because China's currency is pegged to the US dollar, we want to compare countries that use or peg to the US dollar to countries floating relative to the US dollar. We classify each country-year observation's de facto exchange rate regime using the Ilzetzki et al. (2019) (henceforth IRR) exchange rate classification. IRR categorizes every country's *de facto* exchange rate policy from 1946 to 2019 into a six-category classification, with the categories

[11] The assumption of exogenous shocks (or 'shifts') in the China shock context is standard and is used in Autor et al. (2013, 2021); Acemoglu et al. (2016).

being: (1) peg; (2) a narrow band; (3) a broad band and managed float; (4) freely floating; (5) freely falling; (6) dual market with missing market data, with an anchor currency to each observation.[12]

We define the dummy variable Peg_{it} to be 1 if the country is the United States, or the country is classified as coarse category 1 or 2 according to IRR and their anchor currency is the US dollar. We define Peg_{it} to be 0 if the country's currency is floating or is classified as coarse category 1 or 2 and their anchor currency is not the US dollar. Observations in categories 3 (intermediate categories), 5 and 6 (freely falling or missing data) are dropped, and we also exclude countries whose Peg_{it} changes during our period of interest, as currency regime changes are highly endogenous and indicate turbulent economic conditions. In the remainder of this section, we say the country *pegs* if $\text{Peg}_{it} = 1$ and *floats* if $\text{Peg}_{it} = 0$, with the implication that pegs and floats are with respect to the US dollar.

Outcome variables of interest. We consider the following outcome variables for each country: (1) nominal exchange rate; (2) real GDP; (3) manufacturing output; (4) unemployment; and (5) net exports. If the nominal exchange rate responds to higher S_i for floating countries but not for the pegged countries, this is evidence that the exchange rate is operating as an adjustment margin. Then, we investigate the effects of the margin through the dependent variables (2) to (5). For the nominal exchange rate, we use the nominal exchange rate with respect to the US dollar. Real GDP, manufacturing export, and trade balance are computed from the World Bank's World Development Indicators (WDI) database; the unemployment rate is from the International Labour Organization (ILO); the nominal exchange rate of a country is the effective exchange rate and obtained from Darvas (2012, 2021).

2.3 Empirical Design

Our goal is to test across different countries whether higher exposure to the China shock had differential effects depending on each country's exchange rate regime. Thus, we wish to test for countries i:

$$\mathbb{E}[\Delta Y_i | \Delta S_i, \text{Peg}_i = 1] \neq \mathbb{E}[\Delta Y_i | \Delta S_i, \text{Peg}_i = 0] \tag{2}$$

where Y_i denotes a dependent variable of interest (trade deficit, labor market, and goods market outcomes), S_i denotes exposure to the China shock, and Peg_i is a dummy variable for whether country i uses or pegs to the US dollar. This approach circumvents the heterogeneous exposure confounder – each country's differential exposure to the China shock – that may plague a simple binary test on the exchange rate regime.[13]

[12] IRR also provides a fine 15-category classification. Details and the fine classification are given in Appendix A.

[13] As such, confounders such as different industry composition or development levels should not affect our analysis, as they are captured by conditioning on S_i.

Triple-Difference Regression. Our novel analysis is to explore how the interaction between a country i's exposure to the China shock (S_i) and its currency regime (Peg_i) affects output, employment, and trade balances. We estimate first-difference models using successively longer time differences. For each year h, we implement Equation 2 through the following regression:

$$\Delta_h Y_{i,t+h} = \alpha_h + \beta_{1h} S_i + \beta_{2h}\text{Peg}_i + \beta_{3h}(S_i \times \text{Peg}_i) + X_i'\gamma + \epsilon_{ih}, \tag{3}$$

where $\Delta_h Y_{i,t+h} = Y_{i,t+h} - Y_{i,t}$ is the change in the outcome for country i between later year $t+h$ and initial year t. X_i includes controls for country i's pre-period characteristics that might be correlated with the exchange rate regime and affect outcome variables of interest. The strategy, a triple-difference design (over time, exposure, and exchange rate regime), aims to compare how variations in outcomes between countries with similar exposure levels are influenced by the exchange rate regime. Rejecting the null $\beta_{3h} = 0$ supports the hypothesis in Equation 2: similar exposure to the China shock affects peggers and floaters differently.

Following Autor et al. (2021), we focus on the period 2000 to 2019, comprising China's intense growth in the first decade and the plateauing in the second. Our definition of the China shock is growth in exports between $t = 2000$ and $t = 2012$. Hence, for $h < 12$, the estimate captures the effect of the partial shock from 2000 to $2000 + h$ on the outcome variables. For $h \geq 12$, the estimate is an event study of how the China shock impacts the outcome variable over a longer horizon.

Controls. Through the control vector X_i', we control for log population and log GDP per capita in each country at the starting period $t = 2000$. This is to control for the possibility that the effect of the China shock may interact with the size and development of this country. Since our construct of the shift-share exposure S_i implies $\sum_s \lambda_i^s \neq 1$ in general, we purge for the bias generated by 'incomplete shares,' highlighted in (Borusyak et al., 2022) by including $\sum_s \lambda_i^s$ in our set of controls.[14] We control for the interaction of those controls with the Peg_i, to account for the possibility that the exchange rate peg is correlated with the shares, these variables, and affects the outcome variable differently. We also control for one lag of the outcome variable – if $Y_{i,t+h}$ is the outcome variable, we control for $Y_{i,t-1}$ for $h \geq 0$ and $Y_{i,t+h-1}$ for $h < 0$. The controls, with the exception of $\sum_s \lambda_i^s$, are obtained from the WDI database.

Balanced Panel. Our empirical strategy rests on the identifying assumption that there are no omitted variables that are correlated with the exchange rate regime and affect the outcome variables differentially. Table A.2 reports summary statistics in various observable characteris-

[14] We chose these weights because the alternative – divide by total exports – would mean that relatively closed countries are more exposed to the China shock, which is unrealistic. In the Online Supplement, we conduct the same empirical specification with alternative weights λ_i^s that sum to 1.

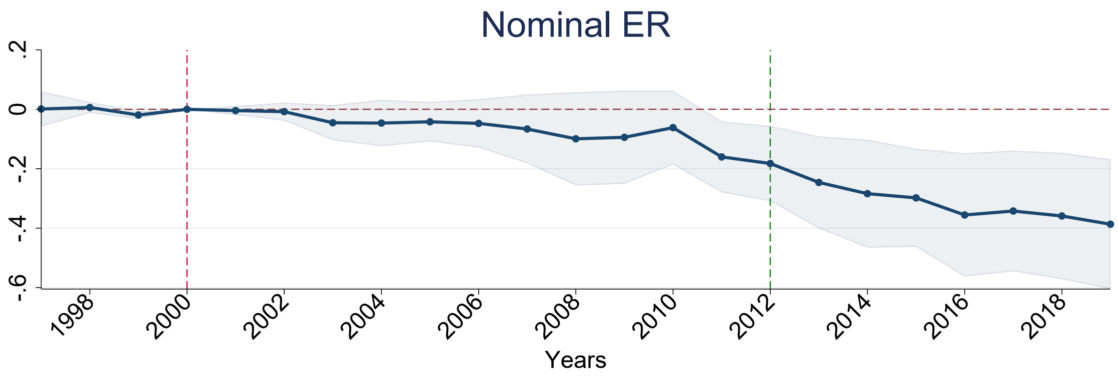


Figure 2: Exchange rate response to the China shock.

Note. The figure plots β_{3h} of the model 3 with the nominal exchange rate as the dependent variable across time. It shows the differential response of the nominal exchange rate among peggers and floaters to the China shock. In the Appendix, we plot the coefficient for the subset of countries where the currency is pegged versus floated against the US dollar respectively. A higher value of the nominal exchange rate implies depreciation of the currency. The shaded area is the 95% confidence band for each regression. The red dashed line indicates the beginning of the China shock (2000) and the green the end of the China shock (2012). The plotted coefficients have standard error of S_i normalized to 1.

tics between the countries pegging and floating with respect to the USD, and their differences. Pegging countries are smaller (Hassan et al., 2022), have a lower manufacturing share and moderately lower unemployment in 2000. However, peggers and floaters show broad similarity in other observable factors, including exposure to the China shock.

2.4 Results

Nominal exchange rate. We first ask whether the nominal exchange rate responds to the China shock. If exchange rates indeed serve as an adjustment margin, we would expect currencies of countries more exposed to the China shock to *depreciate more* under a floating regime. In contrast, we would not anticipate currency responses to the China shock for countries pegged to the US dollar. If true, this supports the hypothesis that competition with Chinese goods leads to depreciation in the currencies of floating economies, while the lack of such a response in pegged economies could lead to distortions.

We report the estimated response of the nominal exchange rate to the interaction of the China shock and exchange rate regime using our triple difference strategy. Figure 2 displays the coefficients β_{3h} of the differential response between pegged and floating countries, together with the 95% confidence intervals. Conditional on similar China shock exposure S_i, floating countries have their currency *depreciate* compared to pegged countries.

The significance of this effect suggests that the exchange rate operates as an important margin of adjustment in global export competition. This perspective is often overlooked in the China shock literature, either empirically or structurally. We underscore that the role of the exchange rate may be relatively uncharted territory, and the absence of exchange rate adjustments may have real consequences, which we explore next.

Output, Unemployment, and Net Exports. Next, we assess how the China shock affects pegged and floating economies *differently* for our variables of interest: real GDP, manufacturing output, unemployment rate, and net exports. If the pegging of China's exchange rate to the dollar indeed influences the impact of the China shock on goods market outcomes and trade balances, we should observe a non-zero β_{3t}, with the interpretation that countries more exposed to Chinese exports will experience a stronger decline in output, higher unemployment, and larger trade deficits, if their currency is pegged to the US dollar.

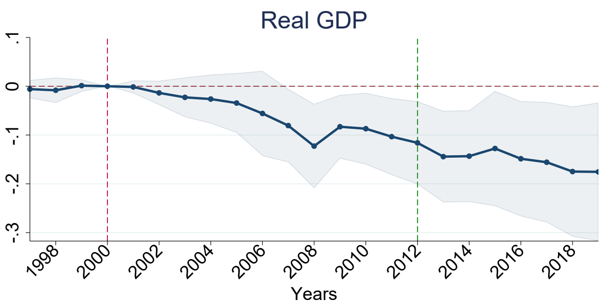
Figure 3 plots our estimates of β_{3h} for those outcome variables. For real GDP and manufacturing output, the outcome variable is $\log(Y_{i,t+h}) - \log(Y_{i,t-1})$ and is intended to measure percentage change. For the unemployment rate, the outcome variable is the simple difference $Y_{i,t+h} - Y_{i,t-1}$. For net exports, the outcome variable is $\frac{NX_{i,t+h}}{Y_{i,t+h}} - \frac{NX_{i,t-1}}{Y_{i,t-1}}$. We report the double-difference results for the full sample and the pegged and floating countries separately in Appendix A.

The top two panels of Figure 3 show that the real GDP and manufacturing output were more adversely affected by the China shock for pegging countries, even conditional on the same increase in exposure S_i. The negative effects on real GDP and manufacturing output for pegging countries build up during the trade exposure period and extend persistently for years after the shock.[15] Notably, the decline in manufacturing output is *larger* than the decline in output: the coefficient on manufacturing output is double the coefficient on real GDP, suggesting that the manufacturing sectors are hurt more by higher exposure.

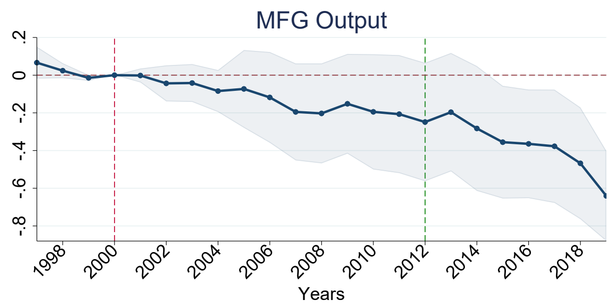
The bottom left panel (Figure 3c) shows that unemployment increases during the duration of the shock and reverts after the culmination of the shock. This finding suggests the existence of short-run friction in the labor market that is affected by higher exposure to the China shock when the currency is pegged, consistent with the notion that the friction in the labor market may be a *nominal* friction. The bottom right panel (Figure 3d) shows that the trade balances of pegged countries deteriorate more for pegged countries, and this decline persists.

In Figure A.4, we show how peggers and floaters respond differently to higher S_i separately, by running regressions for each subsample and plotting β_1. We see that within the peggers, greater exposure to Chinese exports led to lower manufacturing output, a temporary increase in unemployment, and larger trade deficits. In sharp contrast, within the floaters, we find that nominal exchange rates adjust in a way that there is no material association between the

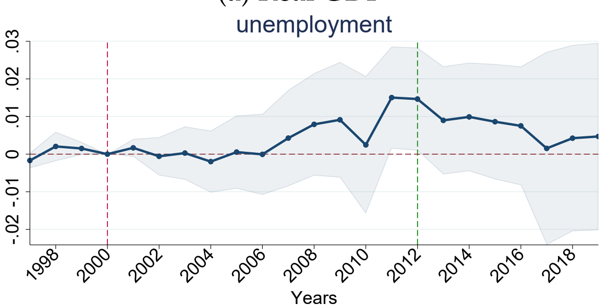
[15] Autor et al. (2021) suggest two reasons for why trade-exposed labor markets suffer long-lasting hardship; the first is that such regions are poorly positioned to recover because of a dearth of college-educated workers, and the second is that specialization in industries with Chinese competition left these regions exposed to industry-specific shocks that self-reinforce during decline (Dix-Carneiro and Kovak, 2017). We note that both are plausible.



(a) Real GDP



(b) Manufacturing Output



(c) Unemployment rate

(d) Net Exports (% GDP)

Figure 3: Responses of peggers to USD vs floaters to USD to the China shock.

Note. The plotted coefficient β_{3h} is the differential response among peggers and floaters to the China shock. A positive coefficient implies that conditional on the same exposure to the China shock S_i, pegged countries' output variable response is higher than floating countries' response for the same variable. The shaded area is the 95% confidence band for each regression. The red dashed line indicates $t = 2000$, the start of the China shock, and the green line $t = 2012$, the end of the China shock. A comparison plot of the separate double-difference regressions for pegged and floating countries is provided in Appendix A, in Figures A.3 and A.4 respectively. The plotted coefficients have standard error of S_i normalized to 1.

exposure to Chinese exports and macroeconomic outcomes.

The difference of real outcomes in pegging countries suggests that those countries' peg to the US dollar – which pegs them to China – affects the incidence of the China shock on those countries because the exchange rate cannot adjust to the China shock. These empirical findings can be viewed as supporting evidence to the strand of literature that finds the costs of exchange rate pegs through the loss of a nominal adjustment margin (see e.g., Broda (2004) and Ahn et al. (2022)).

2.5 Discussion

2.5.1 Sensitivity analysis

Robustness. The results in Figures 2 and 3 are robust to alternative specifications. In the Online Supplement, we progressively add and remove the controls, incorporate potential additional controls, and change the time horizon of the China shock to be 2000-2010 and 2000-2007 (removing the financial crisis). In addition, we conduct a parallel analysis using an alternative shift-share instrument where the shares are now exports as a share of total exports from i (summing to 1) or where the shifts are increases in nominal export volumes. Our results are consistent across these alternative specifications.

Shift-share instruments. As Borusyak et al. (2022) show, a sufficient condition for identification is for the industry-specific growth shocks g_C^s to be exogenous, clarifying the identifying assumptions in our analysis and the construction of the standard errors. In Appendix A, we draw on recent literature (Borusyak et al., 2022; Borusyak and Hull, 2023) to test the validity of the shock exogeneity assumption and find supporting evidence for the shift-share measure S_i as leveraging quasi-random variation in the shocks g_C^s.[16]

Instruments and Bias. A potential issue arises if Chinese exports and sector shares are correlated with sector-level demand shocks, which can potentially create bias in the shift-share strategy. In studying the differential effect of the China shock across US regions, Autor et al. (2013) overcome this by instrumenting the shock with exposure of other developed countries. Unfortunately, we cannot use this instrument, as a global preference shifter (our concern) would affect all countries. However, if such a shock existed, this global shock would also violate the exogeneity of the "other developed countries" instrument in Autor et al. (2013). We proceed with the OLS estimates due to the absence of a superior alternative.

2.5.2 Relation with exchange rate puzzles

Our empirical results raise the following question: how do we reconcile the fact that exchange rate regimes affect differential responses of macroeconomic aggregates to shocks to the fact that the unconditional correlation between exchange rates and output is close to zero? It is known that the exchange rate is disconnected from macroeconomic aggregates (Meese and Rogoff (1983), Itskhoki and Mukhin (2021a)), and while the nominal and real exchange rate volatility are highly correlated, (Mussa, 1986), such movements are orthogonal to behavior of other macro variables (Itskhoki and Mukhin, 2021b).

We argue that the *conditional* exchange rate response to exogenous shocks can be consistent with *unconditional* exchange rate disconnect.[17] Our empirical findings suggest that exchange rate movements *counteract* underlying shocks to fundamentals: a productivity growth leads to an increase in demand for that country's goods in partial equilibrium, and the general equilibrium response of the exchange rate moves in the opposite direction through an appreciation of that country's currency (Figure 2) – and the lack of this force has real consequences (Figure 3).

[16] Goldsmith-Pinkham et al. (2020) develop an alternative approach to identification of shift-share exposure based on the exogeneity of the initial-period shares λ_i^s; this is less suitable for our analysis.

[17] The conditional relation and unconditional disconnect can be microfounded through noisy expectation about future productivity (Chahrour et al., 2023) or through multiple financial shocks (Fukui et al., 2023).

This role of exchange rates as an insulator is documented in Broda (2004) using a VAR analysis of terms-of-trade shocks. Our analysis highlights that China's exchange rate peg to the US dollar can mute this insulator role for countries using the US dollar, leading to real consequences.

3 A two-period trade model with nominal rigidity

In this section, we develop a tractable model that rationalizes the unemployment in manufacturing and trade deficits as an outcome of Foreign productivity growth and an exchange rate peg, explaining concurrently the four facts (Figure 1) and corroborating the findings in Section 2. Our one-sector, two-period, two-country model highlights the role of exchange rate pegs and nominal wage rigidity. Using this model, we study the positive and normative implications of a trade shock and policy implications.[18] We keep the ingredients minimal for analytical tractability and extend the model in Section 4.

3.1 Model setup

Our environment has two countries, Home (H) and Foreign (F). In our application, Home will be the United States and Foreign will be China. There are two periods: $t = 0$ (short-run) and $t = 1$ (long-run). A representative household in each country consumes goods from both countries and supplies labor to firms that produce goods. Each country has its own nominal account; the price of country j's currency in units of country i's currency at time t is e_{jit}, with $e_{HHt} = e_{FFt} = 1$ and $e_{FHt} = \frac{1}{e_{HFt}}$. We denote $e_t = e_{FHt}$. Hence an increase in e_t is a depreciation of the Home currency.

Household preferences. In each country j, there is a representative agent who consumes goods C_{ijt} across origins i aggregated into a final good C_{jt}, supplies labor L_{jt}. The household has preferences represented by

$$\mathcal{U}_j = [u(C_{j0}) - v(L_{j0})] + \beta[u(C_{j1}) - v(L_{j1})], \tag{4}$$

$$\text{where } u(C) = \frac{C^{1-\gamma^{-1}} - 1}{1-\gamma^{-1}}, \text{ and } C_{jt} = (C_{Hjt}^{\frac{\sigma-1}{\sigma}} + C_{Fjt}^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}}.$$

Here σ is the elasticity of substitution between domestic and foreign goods (the Armington elasticity), and γ is the elasticity of intertemporal substitution. We assume that the Armington elasticity is larger than unity, and the intertemporal elasticity is small: formally, $\sigma > 1$ and

[18] In the Online Supplement, we analyze a two-sector tradable-nontradable model to study the *decline* in manufacturing, and how trade shocks may propagate to nontradable sectors through aggregate demand.

$\sigma > \gamma$.[19] $v(\cdot)$ is the disutility of supplying labor, which we assume is increasing and convex with $v(0) = 0$.

Technology. A representative firm in country i uses labor as input and has a constant returns to scale production function that requires $\frac{1}{A_{ij}}$ labor to supply a unit of good to market j. Thus for a firm in country i selling Y_{ij} goods to country j at time t using L_{ijt} labor, we have

$$Y_{ijt} = A_{ij} L_{ijt}.$$

A_{ij} implicitly incorporates trade frictions. Throughout we assume $A_{HF} \leq A_{HH}$ and $A_{FH} \leq A_{FF}$, implicitly assuming home bias in consumption.

Savings. Each country issues a domestic bond with zero net supply. In period 0, households in each country j have access to a claim of a unit of currency i in period 1, with the price of a claim being $\frac{1}{1+i_{i1}}$ in country i currency. We let B_{ij1} denote the amount of claims for i currency that households in country j own. We assume there is no risk, and bonds from Home and Foreign are perfect substitutes.

Labor Market and Nominal Rigidity. We consider the simplest form of short-run nominal wage rigidity. We assume that nominal wages in both countries are completely fixed in period $t = 0$ to an exogenous level $\{w_{j0}\}$, while wages $\{w_{j1}\}$ are flexible for $t = 1$. Since wages are rigid in period 0, we assume that the labor market is demand-determined in both countries, and workers supply whatever labor is demanded. In period 1, we assume that wages equalize labor supply and labor demand.[20]

Monetary policy and exchange rates. The monetary authority at Home sets the nominal interest rate according to a CPI-based Taylor rule with a coefficient of 1 on inflation:

$$\log(1 + i_{H1}) = -\log(\beta) + \log(\frac{P_{H1}}{P_{H0}}) + \epsilon_{H0}, \tag{5}$$

where ϵ_{H0} is the discretionary monetary policy.[21] This rule implicitly sets the real rate $R_{H1} =$

[19]Empirical estimates of σ range from 3-10 (Anderson and van Wincoop, 2003; Imbs and Mejean, 2017) to 1.5-3 (Boehm et al., 2023), but is consistently greater than 1. Estimates of γ are almost always less than 1 and sometimes indistinguishable from 0. Section 3.5 draws on the literature to discuss this assumption. If we instead had $\sigma = \gamma = 1$, we are in the Cole and Obstfeld (1991) case, where the equilibrium always features trade balance. Thus our assumption is essential in predicting the direction of trade imbalance.

[20]The assumption that wages are completely fixed is to highlight the intuition; any short-run friction in wage adjustment will yield qualitatively identical results.

[21]This follows McKay et al. (2016), Auclert et al. (2021c), and allows our analysis to be orthogonal to the effects of monetary policy *rules*.

$(1+i_{H1})\frac{P_{H0}}{P_{H1}}$ at

$$R_{H1} = \frac{1}{\beta}\exp(\epsilon_{H0}).$$

We say a monetary policy *does not respond to shocks* if it sets $\epsilon_{H0} = 0$, or equivalently $R_{H1} = \frac{1}{\beta}$. In Sections 4 onwards, we consider a more standard Taylor rule, which delivers similar results.

Turning to Foreign monetary policy, we are interested in the equilibrium dynamics when Foreign pegs the nominal exchange rate to Home. We assume that Foreign monetary policy directly chooses the exchange rate

$$e_0 = e_1 = \bar{e}, \tag{6}$$

at an exogenous level $\bar{e}$.[22]

Trade taxes and subsidies. Besides monetary policy, the government can also levy taxes on imports and subsidize exports. We assume that the Home government unilaterally chooses the short-run import tariff t_{FHt} and export subsidy s_{HFt} If we denote the pre-tariff price of i goods to j at time t by P_{ijt}, Home government revenue is

$$T_{Ht} = t_{FHt}P_{FHt}C_{FHt} - s_{HFt}e_{FHt}P_{HFt}C_{HFt}. \tag{7}$$

We assume that the revenue T_{Ht} is rebated lump-sum to the representative household in each period.

3.2 Competitive Equilibrium

In a competitive equilibrium, households maximize their utility, firms maximize their profit, and markets clear. We briefly derive each condition and relegate the details to the Online Supplement.

Utility maximization. The household at country j chooses consumption $\{C_{ijt}\}, \{L_{it}\}_{t=1}, \{B_{ijt}\}$ to maximize utility $\mathcal{U}_H$ as described in Equation 4 subject to the sequential budget constraints,

$$\sum_i (1+t_{ij0})P_{ij0}C_{ij0} + \sum_i \frac{B_{ij1}}{1+i_{ijt}}e_{ij0} \le W_{j0}L_{j0} + \Pi_{j0} + T_{j0}, \tag{8}$$

$$\sum_i (1+t_{ij1})P_{ij1}C_{ij1} \le W_{j1}L_{jt} + \sum_i B_{ij1}e_{ij1} + \Pi_{j1} + T_{j1}, \tag{9}$$

where P_{ijt} is the (pre-tariff) prices for goods from country i to j in units of j currency, B_{j1} is a tradable claim to one nominal unit of account in period 1 with price $\frac{1}{1+i_{jt}}$, W_{jt} is the nominal wage, Π_{jt} is the profit of country j firms and T_{jt} is the government revenue rebated lump-sum.

[22] An explicit monetary rule setting i_{Ft} that leads to the exchange rate peg can be found in Benigno et al. (2007).

The first-order conditions to this utility maximization problem are standard and imply:

$$P_{jt} = (\sum_i ((1+t_{ijt})P_{ijt})^{1-\sigma})^{1/(1-\sigma)}, \tag{10}$$

$$\lambda_{ijt} = \frac{((1+t_{ijt})P_{ijt})^{1-\sigma}}{\sum_l P_{ljt}^{1-\sigma}}, \tag{11}$$

$$v'(L_{j1}) = \frac{u'(C_{j1})w_{j1}}{P_{j1}}, \tag{12}$$

$$u'(C_{jt}) = \beta(1+i_{jt})\frac{P_{jt}}{P_{jt+1}}u'(C_{jt+1}) = \beta R_{jt} u'(C_{jt+1}), \tag{13}$$

$$\frac{1+i_{F1}}{1+i_{H1}} = \frac{e_1}{e_0}, \tag{14}$$

where P_{jt} denotes the consumer price index (CPI) in country j and λ_{ijt} the expenditure share. With the peg $e_1 = e_0 = \bar{e}$, the last condition becomes $i_{F1} = i_{H1}$ (trilemma).

Since wages $\{w_{j0}\}$ are rigid at $t = 0$ and the labor market is demand determined, we may have $v'(L_{j0}) \neq \frac{u'(C_{j0})w_{j0}}{P_{j0}}$. We define the *labor wedge* in period 0 as

$$\mu_{j0} = v'(L_{j0}) - \frac{u'(C_{j0})w_{j0}}{P_{j0}}, \tag{15}$$

how much the marginal value of working for households is away from the marginal return from working in utility terms. If $\mu_{j0} < 0$, households would like to supply more labor but cannot, so there is *involuntary unemployment*. If $\mu_{j0} > 0$, households are supplying more labor than they would want to, so the economy is *overheated*.

Firm optimization. The profits of a representative firm from j selling Y_{ijt} goods to market i is given by

$$\Pi_{it} = \sum_j \left[(1+s_{ijt})\frac{1}{e_{ijt}}P_{ijt} - \frac{W_{it}}{A_{ij}} \right] Y_{ijt}$$

where s_{ijt} is an ad-valorem sales subsidy to i. Since firms are competitive, profits Π_{jt} are equal to 0, and the unit price is equal to marginal cost:

$$P_{ijt} = \frac{1}{1+s_{ijt}} e_{ijt} \frac{w_{it}}{A_{ij}}. \tag{16}$$

Market clearing. For each (i,t), the goods market clearing conditions are given by

$$L_{it} = \sum_j \frac{C_{ijt}}{A_{ij}}, \tag{17}$$

and the bonds market clearing condition is given by

$$B_{H1} + e_1 B_{F1} = 0. \tag{18}$$

Equilibrium. We are ready to define an equilibrium in the model as follows:

Definition 1. *Given fundamentals $\{A_{ij}\}$, rigid short-run wage w_{H0}, w_{F0}, policy $\{R_{H1}, t_{ijt}, s_{ijt}\}$ and pegged exchange rate $\bar{e} = e_0 = e_1$, a pegged equilibrium consists of prices $\{w_{it}, P_{it}, P_{ijt}\}$, household's choice variables $\{C_{ijt}\}$,$\{B_{it}\}$,$\{L_{it}\}_{t\geq 1}$ and demand-determined short-run labor $\{L_{i0}\}$ such that Equations 8 to 18 hold.*

3.3 Consequences of a trade shock

In this subsection, we highlight the equilibrium response to trade shocks in this model. As a benchmark, we consider the laissez-faire equilibrium where $t_{FHt} = s_{HFt} = 0$.

The timing of the model and the shock is as follows. Before the start of our setup ($t = -1$), productivities were at a level $\{A_{ij,-1}\}$, and nominal wages $w_{i,-1}$ and exchange rate e_{-1} were such that trade is balanced and labor wedge is zero. Right before $t = 0$, a shock permanently increases Foreign export productivity A_{FH}; we call this the *trade shock*. We assume that wages $\{w_{i0}\}$ are rigid at the pre-shock level $\{w_{i,-1}\}$, and the Foreign policymaker pegs the exchange rate $e_0 = e_1$ at the pre-shock level e_{-1}.

Equilibrium responses. To investigate the effects of the trade shock on trade balance and employment levels, we first observe how the terms-of-trade responds to a trade shock under a peg. We denote by $S_{HFt} = \frac{P_{HFt}\bar{e}}{P_{FHt}}$ the Home terms-of-trade at time t, where a higher terms-of-trade means a higher price of exports relative to imports. S_{HFt} is given by:

$$S_{HFt} = \frac{(\frac{w_{Ht}}{\bar{e}A_{HF}})\bar{e}}{\frac{w_{Ft}\bar{e}}{A_{FH}}} = \underbrace{(\frac{w_{Ht}}{w_{Ft}\bar{e}})}_{\text{relative wage}} \underbrace{(\frac{A_{FH}}{A_{HF}})}_{\text{productivity}} \tag{19}$$

In a model where wages are flexible, there are two effects of an increase of A_{FH} on S_{HF}. The *direct effect* increases S_{HF} by an equal proportion, improving Home terms-of-trade. The *general equilibrium effect* is that relative wage $\omega_t = \frac{w_{Ht}}{w_{Ft}\bar{e}}$ adjusts. Under the assumption that $\sigma > 1$, an increase in A_{FH} decreases Home's relative wage ω_t, so the general equilibrium effect reduces ω_t. If wages are flexible or the exchange rate is floating, the general equilibrium effect would take place immediately, and the equilibrium after the trade shock will be a new steady-state equilibrium with $\omega_0 = \omega_1$, without any dynamics between $t = 0$ and $t = 1$.[23]

[23] The fact that a floating exchange rate can adjust for the general equilibrium effects under nominal rigidity is closely reltaed to the Dornbusch (1976) overshooting model.

However, when wages are rigid and the exchange rate is pegged, the general equilibrium effect is muted in the short-run. As such, we have $\omega_0 > \omega_1$ and $S_{HF0} > S_{HF1}$: Home's relative wage is higher in the short-run than the long-run. These dynamics of ω_t generate several equilibrium properties, summarized in the following proposition:

Proposition 1. *In the pegged equilibrium, in response to a trade shock ($A_{FH} \uparrow$), Home runs a trade deficit ($B_{H1} < 0$). Moreover, if Home monetary policy does not respond ($R_{H1} = \frac{1}{\beta}$), then there is involuntary unemployment at Home ($\mu_{H0} < 0$).*

Proof. See Appendix B. □

The logic for the first part ($B_{H1} < 0$) is as follows. Home borrows if and only if:

$$\underbrace{\frac{\bar{e}\lambda_{HF0}P_{F0}C_{F0}}{\lambda_{FH0}P_{H0}C_{H0}}}_{t=0 \text{ exports/imports}} < \underbrace{\frac{\bar{e}\lambda_{HF1}P_{F1}C_{F1}}{\lambda_{FH1}P_{H1}C_{H1}}}_{t=1 \text{ exports/imports}} \Leftrightarrow \underbrace{\frac{\lambda_{HF0}/\lambda_{HF1}}{\lambda_{FH0}/\lambda_{FH1}}}_{\text{expenditure switching}} < \frac{\pi_F}{\pi_H}\frac{C_{H0}/C_{H1}}{C_{F0}/C_{F1}} = \underbrace{(\frac{\pi_F}{\pi_H})^{1-\gamma}}_{\text{relative inflation}} \tag{20}$$

Inequality 20 highlights the two forces that determine the sign of trade balance. The first force is *expenditure switching*. When $\sigma > 1$, we have $\omega_0 > \omega_1$, so both countries want to buy more Foreign goods today than tomorrow, implying $\lambda_{FH0} > \lambda_{FH1}$ and $\lambda_{HF1} < \lambda_{HF1}$, resulting in a force towards Home deficit. The second force is *relative inflation*. With $\omega_0 > \omega_1$, Home's future prices increase *less* because of home bias in consumption. This becomes a force towards Home surplus if and only if $\gamma > 1$.[24] When $\sigma > \gamma$, expenditure switching (governed by σ) outweighs relative inflation (governed by γ), resulting in Home trade deficit.[25]

Home's monetary policy cannot affect the sign of the trade imbalance. Home borrows regardless of R_{H1}, because R_{H1} affects the consumption-savings decision of both Home and Foreign under the peg. In fact, when $\gamma = 1$, R_{H1} cannot affect the magnitude of the deficit, as the effect of interest rates on consumption is exactly proportionate in both countries. We discuss this further in the next subsection (Section 3.4).

The intuition for Home unemployment is as follows. The short-run Home consumption C_{H0} is determined from the Euler equation. At C_{H0} and real wage $\frac{w_{H0}}{P_{H0}}$, Home workers would want to supply labor $L^S_{H0} = v'^{-1}(u'(C_{H0})\frac{w_{H0}}{P_{H0}})$. However, workers supply whatever is demanded, and the demand L_{H0} is pinned down by relative wage ω_0:

$$L_{H0} = \frac{1}{A_{HH}}\frac{\lambda_{HH0}(\omega_0)P_{H0}}{P_{HH0}}C_{H0} + \frac{1}{A_{HF}}\frac{\lambda_{HF0}(\omega_0)P_{F0}}{P_{HF0}}C_{F0}.$$

If ω_0 is higher, the desired supply L^S_{H0} increases but actual demand L_{H0} falls; this generates

[24] In fact, estimates of γ are often 1 or less, whence relative inflation also leads to Home borrowing.

[25] An intuitive example is when $\sigma \to \infty$. Home wouldn't produce at all at $t = 0$, but it can compete against Foreign at $t = 1$. So Home wants to borrow to smooth consumption unless $\gamma = \infty$.

involuntary unemployment, with the unemployment rate given by $u_{H0} = 1 - \frac{L_{H0}}{L^s_{H0}}$.[26]

In contrast, under a floating exchange rate, we would observe neither deficits nor unemployment: as $\omega_0 = \omega_1$, the equilibrium is observationally equivalent to the new steady-state after the trade shock, with trade balance and full employment.

Proposition 1 parsimoniously connects the four facts in the introduction: the US trade deficit (Figure 1c) and surge in manufacturing unemployment (Figure 1b) can be endogenously explained by Chinese productivity growth (Figure 1a) and its exchange rate peg (Figure 1d). This contrasts with prior studies of the China shock, which typically perceive China's concurrent saving and growth as a puzzle. We show that China's exchange rate peg with wage rigidity promotes a stronger short-term comparative advantage during its growth, driving its endogenous decision to save.[27]

Proposition 1 supports nominal rigidity as a key factor in the labor market's slow response to trade shocks, differing from frameworks that use quantity friction such as search friction (Dix-Carneiro et al., 2023; Galle et al., 2023), which predict the opposite outcome – Home saving in response to Foreign growth. This is because relative wages across time is *reversed* under quantity friction: short-run Home relative wage is depressed, leading to Home saving and less unemployment. Further details and proof are provided in the Online Supplement.

Welfare effects. Next, we turn to the welfare implications of the trade shock. We first highlight that trade balances affect the future terms-of-trade: specifically, a deterioration in balances B_{H1} leads to a decrease in future relative wage ω_1. The intuition is closely related to the transfer problem: debt accumulated today becomes a future *transfer* for Foreign, which, combined with a home bias for demand, increases global demand for Foreign goods, improving their terms-of-trade and worsening Home's.

Using this, we study the welfare implications of the trade shock. The next proposition highlights the possibility that Home welfare may decrease as a result of Foreign growth:

Proposition 2. *In the pegged equilibrium where monetary policy does not respond ($R_{H1} = \frac{1}{\beta}$), a small increase in A_{FH} reduces Home welfare when σ is sufficiently high and improves Home welfare when σ is small (i.e. close to 1).*

Proof. See Appendix B. □

An intuitive explanation is as follows. There are three channels through which productivity

[26] In this economy, Foreign (China) is overheated and has employment rate greater than 1. We leave this open as a possibility and discuss potential microfoundations and implications in Section 6.

[27] Here we assumed that productivity A_{FH} increases from $t = -1$ but is the same between $t = 0$ and 1. If productivity were increasing between the two periods, there would be competition between our expenditure switching channel and the standard force for China to borrow. International finance papers such as Caballero et al. (2008) offer a financial solution.

growth A_{FH} affects Home welfare:

$$\frac{d\mathcal{U}_H}{dA_{FH}} = \underbrace{-\frac{u'(C_{H0})}{P_{H0}} C_{FH0} \frac{dP_{FH0}}{dA_{FH}}}_{\text{terms-of-trade at } t=0} - \underbrace{\mu_0 \frac{dL_0}{dA_{FH}}}_{\text{labor wedge}} + \underbrace{\frac{\beta u'(C_{H1})}{P_{H1}} \left[C_{HF1} \frac{dP_{HF1}}{dA_{FH}} - C_{FH1} \frac{dP_{FH1}}{dA_{FH}} \right]}_{\text{terms of trade at } t=1} \tag{21}$$

The terms correspond to (1) the short-run effect of cheaper import goods (2) labor market friction caused by wage rigidity (3) change in long-run terms-of-trade, including direct productivity effects and general equilibrium effects on future terms-of-trade. If $\sigma \to 1$, preference becomes Cobb-Douglas, the pegged equilibrium coincides with the flexible-wage equilibrium, and trade is balanced as in Cole and Obstfeld (1991). Thus, the effects (2) and the general equilibrium component of (3) go to zero, leaving cheaper goods as the primary welfare benefit. In the opposite case, when $\sigma \to \infty$, short-run demand for Home goods becomes 0. Then, a small change in A_{FH} can cause a discrete loss of utility from the labor wedge and the trade deficit worsening future terms-of-trade, dwarfing welfare gains from cheaper goods.

This possibility of Foreign productivity growth harming Home welfare echoes immiserizing growth, characterized by Home productivity growth worsening Home terms-of-trade, potentially outweighing the gains from the expansion of the production possibilities frontier (PPF) (Bhagwati, 1958). Here, Foreign productivity growth improves Home terms-of-trade. The exchange rate peg magnifies this gain in the short-run, but it moves Home production into the interior of the PPF because of unemployment and hampers future terms-of-trade through the trade deficit, offsetting the gains.

Proposition 2 emphasizes the need to be cautious in using trade balance as a welfare indicator. Public discourse often views trade deficits as inherently undesirable. However, whenever σ exceeds 1 and surpasses γ, a trade deficit is the predicted outcome for Home under a trade shock under a peg. This may benefit Home welfare if σ is not excessively high but suggests welfare losses if σ is very high. Conversely, if γ is very large and $\sigma \to 1$, Home runs a trade surplus and has welfare gains, whereas if both σ and γ are sufficiently large with $\gamma > \sigma$, Home runs a trade surplus but incur welfare losses. In the next sections, we undertake a quantitative analysis of the substitution, rigidity, and productivity growth to reassess whether the China shock improved or harmed aggregate US welfare.[28]

3.4 Policy response

In this subsection, we consider the unilateral problem of the Home government facing a growth in A_{FH} and an exchange rate peg. We assume the Home government can choose its short-run

[28] This is a different question to whether capital controls are beneficial. The next subsection shows that capital controls unambiguously hurt Home welfare.

tariff level t_{FH0}, domestic subsidy s_{HF0} and monetary policy R_{H1}.[29] We assume the government cannot choose long-run tariff t_{FH1}, as the motivation for long-run tariffs as terms-of-trade manipulation is well understood since Graaff (1949).

Formally, the policy problem that the Home government faces is:

$$\max_{t_{FH0}, s_{HF0}, R_{H1}} \mathcal{U}_{\mathcal{H}} = \max_{t_{FH0}, s_{HF0}, R_{H1}} \sum_{t=0}^{1} \beta^t [u(C_{Ht}) - v(L_{Ht})] \tag{22}$$

subject to the same equilibrium conditions.

We first note that the planner can replicate the flexible price outcome. Indeed, if $\omega_{peg} = \frac{w_{H0}}{w_{F0}\bar{e}}$ is the short-run relative wage under peg, and $\omega_f = \frac{w^f_{H0}}{w^f_{F0} e^f}$ is the relative wage under flexible price (after the trade shock), the planner can set $R_{H1} = \frac{1}{\beta}$ and $t_{FH0} = s_{FH0} = \frac{\omega_f}{\omega_{peg}} - 1$. This tax and subsidy level sets the relative prices equal to the flexible price level, and the tax revenue and cost of subsidy cancel out exactly. Thus, we know the planner can undo the wedges and the potential welfare losses in Proposition 2.[30]

However, this policy may not be optimal for the Home government. As an extreme example, if Foreign is offering goods for free, Home would be much better off taking those goods than setting high tariffs that distort consumption.

To solve for the optimal policy, we proceed in two steps. First, we solve for the optimal trade policy (t_{FH0}, s_{HF0}) given monetary policy R_{H1}, then we proceed to solve for the optimal R_{H1}. This approach makes the problem more tractable, and the inner problem may be a more reasonable benchmark of reality, where monetary policy is unable to fully respond to a sector-origin specific trade shock.[31] We give an executive summary of our results and discuss the details in the Online Supplement.

3.4.1 Optimal trade policy

Given monetary policy R_{H1}, an indirect formula for the optimal trade policy can be obtained via a first-order variation argument. Starting from the optimal policy, the marginal effect of policy change in welfare must be zero, yielding the following formula:[32]

[29] Since wages are rigid, we do not have Lerner symmetry, and subsidies and tariffs are independent.

[30] This connects with Farhi et al. (2014) that fiscal instruments can replicate currency devaluations.

[31] In the early 2000s, the government was tightening monetary policy in response to concerns over inflation and tightening of unused resources; loosening in response to the China shock was not the Federal Reserve Bank's goal (Federal Reserve Board, 2005). Following the Great Recession, the Federal Reserve Bank was subject to the Zero Lower Bound.

[32] A similar argument can be found in Costinot et al. (2022).

Lemma 1. *The optimal short-run tariff rate on imports t_{FH0} satisfies*

$$t_{FH0} = \frac{1}{P_{FH0}} \left[\underbrace{\frac{\mu_0}{\tilde{\lambda}} \frac{\partial L_{H0}}{\partial C_{FH0}}}_{\text{labor wedge}} - \frac{1}{(1+i_{H1})} \underbrace{(L_{HF1} \frac{\partial w_{H1}}{\partial C_{FH0}} - L_{FH1} \frac{\partial w_{F1}}{\partial C_{FH0}})}_{\text{future terms-of-trade}} + \underbrace{s_{HF0} P_{HF0} \frac{\partial C_{HF0}}{\partial C_{FH0}}}_{\text{subsidy externality}} \right] \tag{23}$$

The optimal short-run subsidy rate on exports s_{HF0} satisfies

$$s_{HF0} = \frac{1}{P_{HF0}} \left[- \underbrace{\frac{\mu_0}{\tilde{\lambda}} \frac{\partial L_{H0}}{\partial C_{HF0}}}_{\text{labor wedge}} + \frac{1}{(1+i_{H1})} \underbrace{(L_{HF1} \frac{\partial w_{H1}}{\partial C_{HF0}} - L_{FH1} \frac{\partial w_{F1}}{\partial C_{HF0}})}_{\text{future terms-of-trade}} - \underbrace{P_{HF0} C_{HF0} \frac{\partial s_{HF0}}{\partial C_{HF0}}}_{\text{terms-of-trade today}} \right] \tag{24}$$

where $\tilde{\lambda}$ is the Lagrange multiplier on the lifetime budget constraint.

Proof. See Appendix B. □

The first-order formula for tariffs succinctly captures the three *externalities* of imports that the Home government seeks to address via a tariff. First, tariffs and subsidies both reduce the labor wedge by stimulating demand for domestic labor. Second, tariffs and subsidies, by affecting relative prices of goods, improve current trade balance (Inequality 20), which improves the terms-of-trade in the future. Third, the fiscal externality (deadweight loss) of tariffs and subsidies interact in general equilibrium. In a competitive equilibrium, home households do not internalize any of these effects of an extra unit of import. Thus the tax level $t_{FH0}P_{FH0}$ and the subsidy level $s_{HF0}P_{HF0}$ can be considered a Pigouvian tax that corrects for the three externalities of consuming an extra unit of import or exporting an extra unit.

Using the formula, we can sign the optimal tariff and show that its magnitude *increases* with the Foreign shock A_{FH0}:

Proposition 3. *If there is unemployment at the zero-tariff economy ($\mu_{H0} < 0$ when $t_{FH0} = 0$), the optimal tariff t_{FH0} is positive and is increasing in the size of the trade shock A_{FH0}.*

Proof. See Appendix B. □

The intuition that we can and should use tariffs as second-best instruments to fix distortions is well-known. The prediction obtained in Proposition 3 is sharper. We show that in an environment where trade shocks cause unemployment and trade deficits, the tariff should be positive and increase in the magnitude of the trade shock. In this context, the short-run tariff t_{FH0} is akin to *safeguard* tariffs allowed under the WTO Agreement on Safeguards.

But this is not the only role of tariffs in our model, as highlighted in the future terms-of-trade term in Equation 23. While tariffs do not affect today's terms-of-trade (due to wage rigidity and peg), a unilateral short-run tariff reduces Home's trade deficit, improving Home's future terms-of-trade. Hence, Home would want to set tariffs beyond the globally optimal "distortion-fixing" level, at the expense of Foreign welfare. As such, short-run tariffs are *safeguard* and *beggar-thy-neighbor* at the same time, even when the short-run terms-of-trade is rigid.[33]

Our model underscores that under an exchange rate peg, the optimal short-run tariff is increasing in the magnitude of the trade shock. This contrasts with the flexible exchange rate case, where the optimal tariff is pinned down primarily by the trade elasticity (Gros, 1987) and does not depend on the shock magnitude. Our framework focuses on tariffs that correct a distortion caused by the peg and the trade shock, so the magnitude of the optimal tariff scales with the size of the distortion. We discuss this in more detail in the Online Supplement.

Proposition 3 assumes monetary policy does not clear unemployment. As aforementioned, the central bank may be unable to clear the output gap caused by sector-specific trade shocks because of multisector considerations, financial concerns, and liquidity constraints such as the Zero Lower Bound. Tariffs will be a useful tool in this second-best world.

3.4.2 Optimal monetary policy

What is the optimal monetary policy R_{H1}? An analogous first-order condition on monetary policy highlights the channels in which monetary policy affects welfare. We highlight a special case when the intertemporal elasticity is equal to 1 (consumption is log):

Proposition 4. *When $\gamma = 1$, optimal monetary policy R_{H1} satisfies the following equation:*

$$0 = \underbrace{-\mu_0 \frac{dL_0}{dR_{H1}}}_{\textit{wedge}} + \tilde{\lambda}_r [\underbrace{R_{H1} t_{FH0} \frac{P_{FH0}}{P_{H0}} \frac{dC_{FH0}}{dR_{H1}}}_{\textit{tariff fiscal externality}} + \underbrace{(NX_0)}_{\textit{intertemporal TOT}}], \tag{25}$$

where $\tilde{\lambda}_r$ is the Lagrange multiplier on the Home lifetime real budget constraint normalized by P_{H0}.

As a special case, when $t_{FH0} = 0$, the optimal monetary policy R_{H1} is such that $\mu_0 > 0$: it is optimal to loosen monetary policy beyond clearing the output gap.

Proof. See Appendix B. □

Proposition 4 highlights that in an open economy where Home is subject to a Foreign peg, optimal monetary policy may want to *overshoot* the output gap when Home borrows from Foreign. This is because Home has the power to set *global* monetary policy and can freely manipulate intertemporal terms-of-trade. When Foreign pegs its currency to Home (giving Home the power to set intertemporal terms-of-trade) and Home borrows from Foreign, Home can gain by further lowering the interest rate, beyond the output gap-clearing level. This intuition

[33] By nature of being beggar-thy-neighbor, Foreign can retaliate with its own tariffs to undo the imbalance-adjusting channel of Home tariffs.

is especially relevant to the US, which effectively sets the interest rate for many countries being the dominant currency (Gopinath et al., 2020), and runs current account deficits; the central bank may want to set a looser interest rate, with minimal risk of bond liquidation from dollar-pegging countries.

The proposition also clarifies again that tariffs are primarily second-best instruments to be used when monetary policy cannot respond – whether due to the ZLB or multisectoral considerations. In fact, under a strictly positive tariff, the additional losses from tariff fiscal externality compels Home to adopt a more contractionary monetary stance, reducing overall welfare.[34]

The assumption $\gamma = 1$ allows us to circumvent the effect of today's monetary policy on the magnitude of the trade deficit. When $\gamma = 1$, the effect of interest rate on consumption and output is proportionate in both countries: thus the real value of the deficit does not change, and monetary policy R_{H1} does not affect the intratemporal terms-of-trade in the future. On the other hand, when $\gamma \neq 1$, the optimal monetary policy equation (Equation 25) comes with an additional "future terms of trade" term: monetary policy may affect the magnitude of the deficit in real terms (but not the sign, as we discussed in Section 3.3), affecting the optimal policy.

3.4.3 Capital Controls

Lastly, we study the welfare effects of the endogenous deficits we highlighted in Proposition 1 by considering *capital controls* in addition to the tariffs and subsidies. We have established that deficits and unemployment can come from the same cause – trade shock and exchange rate peg – but are deficits inherently bad for Home welfare? While this is where some policy narratives go, the next proposition shows that this is not the case.

Proposition 5. *In the pegged equilibrium, removing international financial flows (forcing $B_{H1} = 0$) worsens Home unemployment (μ_{H0} decreases), and reduces Home welfare $\mathcal{U}_0$.*

Proof. See Appendix B. □

Removing financial flows worsens Home unemployment because of home bias in consumption. Indeed, with trade costs, under the same price levels, Home borrowing to consume will increase demand for Home goods, while Foreign saving will decrease demand for Foreign goods. Since unemployment is determined by aggregate demand, Home's trade deficit in the short-run actually ameliorates unemployment, and capital controls will only worsen unemployment. As such, while deficits may be symptoms of a friction that may harm the economy, deficits themselves are not a friction to solve, and capital controls may harm Home welfare. The fact that financial transfers are welfare-improving under an exchange rate peg is closely

[34] In the Online Supplement, we numerically solve for the joint optimal trade and monetary policy for various levels of the trade shock A_{FH0}. We find that the joint optimal policy involves no tariffs and a very loose monetary policy, highlighting the distortionary nature of tariffs. In a first-best one-sector world, Home would take advantage of the cheap goods and solve the labor wedge solely through monetary policy.

related to the idea that fiscal unions are desirable under currency unions (Farhi and Werning, 2017); we highlight that the possibility of a dynamic budget-balanced (net current value zero) transfer is welfare-improving.

3.5 Discussion

Our model shows that the welfare consequences of trade shocks under an exchange rate peg fundamentally depend on labor market frictions, and tariffs and monetary policy may work as a second-best instrument to ameliorate any potential welfare losses from the friction. Here we discuss some relevant issues with the model, including the duration of nominal rigidity and the parameter values.

Duration of nominal rigidity. A natural question is whether the duration of nominal rigidity can justify the effects of the China shock, which seem prolonged (Autor et al., 2021). Our answer is twofold. The first is that over the first decade of the 2000s, China shock itself was a persistent shock spanning over 10 years instead of a sudden productivity growth in 2000. Thus, the observed patterns of the early 2000s can be consistent with even short-lived channels. Second, the nominal rigidity that generates our channel is wage rigidity, and it is known that downward nominal wage rigidity (DNWR), which generates the unemployment effects at Home, can be highly persistent across time (Schmitt-Grohé and Uribe, 2016), and can have unemployment and trade balance implications well beyond the measured duration of price rigidity.

Assumptions on the elasticity of substitution. Our results depend on the assumption that the consumption of Home and Foreign goods in the same period is more substitutable than the consumption of goods across time. Depending on the methods, estimates vary between 1 to 10, but all estimates of the trade elasticity are above unity (Costinot and Rodríguez-Clare, 2014; Imbs and Mejean, 2017; Boehm et al., 2023), and recent literature (Teti, 2023) suggests that the estimates closer to 1 may have been biased due to misreporting in tariffs, and the corrected elasticity is much higher. Estimates of the intertemporal elasticity vary, but from Hall (1988) to Best et al. (2020), the literature's estimates are well below 1, and sometimes indistinguishable from 0. As such, it is reasonable to assume that substitution across origins has higher elasticity than substitution across time.[35] In subsequent sections, we introduce a more realistic, multisector model of high substitution within sector but lower substitution across sectors, and find that our model's predictions are quantitatively significant.

[35]The international macroeconomics literature uses a much lower macro-trade elasticity to rationalize International Real Business Cycle (IRBC) facts (Backus et al., 1994). Feenstra et al. (2018) estimate the macro- and micro-elasticities, and find that the macro-elasticity is "not as low as the value of unity sometimes found using macro time series methods," further supporting our notion that the trade elasticity is at least unity.

Multisector considerations. In this section, we used a one-sector model to highlight how trade shocks under a peg impact trade balances and unemployment. In the Online Supplement, we expand this to a two-sector model of tradable and nontradable goods, assuming a segmented labor market to examine spillovers orthogonal to labor reallocation, which is well understood (Acemoglu et al., 2016; Caliendo et al., 2019). The expanded model predicts analogous aggregate effects of a trade shock under a peg: short-term trade deficits, unemployment in tradables, and potential welfare losses.

Additionally, the tradable-nontradable model reveals the following distributional consequences. First, the output share of the tradable sector declines, even absent labor reallocation, connecting with the decline in manufacturing (Fact 1b and Section 2) under a peg. Second, if monetary policy does not respond, we have unemployment in both sectors: the recession *spills over* to the nontradable sector, through contraction of tradable demand reducing Home income and demand for nontradables. Third, the optimal monetary policy faces a trade-off between a recession in the tradable sector and overheating in the nontradable sector, explaining the US service sector boom in the 2000s. Further details and analysis are provided in the Online Supplement, and subsequent sections provide a quantification of the China shock through a general equilibrium multisector model.

4 Quantitative model

In this section, we extend the model in Section 3 so that it can be taken to sector-level trade data for a general equilibrium analysis of the effects of Chinese growth and the peg. We generalize the previous setup in two directions: (1) a multi-sector, multi-country model with Ricardian forces, input-output linkages and labor reallocation (Caliendo et al., 2019); (2) an infinite-period model with wage rigidity (Erceg et al., 2000), consumption-savings pinning down trade balances (Obstfeld and Rogoff, 1995) and exchange rate determination from financial channels (Itskhoki and Mukhin, 2021a). The first block allows us to investigate how the China shock, a sector-specific shock, affects other sectors, while the second block allows us to consider involuntary unemployment, endogenous trade imbalances, and the role of exchange rate pegs.

4.1 Model Setup and Equilibrium

In the model, time is discrete and indexed by $t = 0, 1, \cdots$. The economy consists of $i, j = 1, 2, \cdots, I$ countries, each with an exogenous labor endowment given by a continuum of workers with mass $\bar{L}_i$ (thus, we rule out migration across countries). There are $n, s = 1, 2, \cdots, S$ sectors. Unless otherwise stated, i is the producer/exporter, j is the importer/buyer, and we write exporters first in subscripts. Country 1 is the USA; country 2 is China; we are mainly interested in the interaction between these two countries. Each country has its nominal account, and nominal variables are denominated in the currency of the price-facing household. The exchange rate e_{jit} is the value of currency j with respect to currency i, so an increase in e_{jit} is a relative depreciation of i currency with respect to j currency. We present the main assumptions and relegate the derivations and details to Appendix C.

Household preferences. In each country j, there is a representative household family that comprises atomistic *members* m of measure $\bar{L}_j$ and has preferences represented by

$$\mathcal{U}_j = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \delta_{jt} \int_0^{\bar{L}_j} \mathcal{U}_{jt}(m) dm, \tag{26}$$

where $\mathcal{U}_{jt}(m)$ is the member-specific utility, β is a discount factor common across all countries, and δ_{jt} is a country-specific intertemporal preference shifter which captures financial factors exogenous to our model. We implement our model at an annual frequency, so each period t corresponds to a year.

The utility of each member m depends on final goods consumption $C_{jt}(m)$, labor supply $\ell_{jt}(m)$, current sector $s_{jt}(m)$, future sector of choice $s_{jt+1}(m)$, and an idiosyncratic preference shifter $\epsilon_{jt}(m) = \{\epsilon^s_{jt}(m)\}_s$ across different future sectors. The preferences of member m is represented by

$$\mathcal{U}_{jt}(m) = u(C_{jt}(m)) + v(\ell_{jt}(m), s_{jt}(m), s_{jt+1}(m), \epsilon_{it}), \tag{27}$$

$$\text{where } u(C) = \frac{C^{1-\gamma^{-1}} - 1}{1-\gamma^{-1}}, \text{ and } v(\ell, s, n, \epsilon_t) = -\theta^s_i \frac{1}{1+\varphi^{-1}} \ell_{it}^{1+\varphi^{-1}} + \eta^s_{it} - \chi^{sn}_{it} - \epsilon^n_{it}, \tag{28}$$

where γ is the elasticity of intertemporal substitution, φ is the Frisch elasticity of labor supply, and θ^s_i is the intensity of labor disutility in each sector s. η^s_{it} captures the non-pecuniary sector-specific benefits, and χ^{sn}_{it} captures the relocation costs of moving from sector s to sector n, measured in terms of utility. This formulation follows Artuç et al. (2010) with an additional endogenous labor supply term $\ell_{it}^{1+\frac{1}{\varphi}}$.[36]

We have perfect risk sharing across members of the family, so $C_{jt}(m) = C_{jt}$. Final goods C_{jt} is a Cobb-Douglas aggregate of consumption across each of the sectors $s = 1, 2, \cdots, S$ with shares α^s_{jt}. Consumption within each sector follows the Armington trade model, where consumption is a CES aggregate of goods from each of the I countries with an elasticity of substitution $\sigma_s > 1$ within each sector s. Consumption is given by

$$C_{jt} = \prod_s \left(\frac{C^s_{jt}}{\alpha^s_{jt}} \right)^{\alpha^s_{jt}}, \quad C^s_{jt} = \left[\sum_i (C^s_{ijt})^{\frac{\sigma_s - 1}{\sigma_s}} \right]^{\frac{\sigma_s}{\sigma_s - 1}}$$

[36] This can implicitly be interpreted as an intensive margin of labor supply; in Appendix C, we microfound this as with an *extensive* margin interpretation, more suitable to study unemployment.

Savings. Analogously to Section 3, each country issues a nominal bond of price $\frac{1}{1+i_{it}}$. There is no aggregate risk, and bonds are perfect substitutes across origins.

Firms and technology. Goods are distinguished by sector and origin. Sector s goods from country i are produced by competitive firms using Cobb-Douglas technology, with labor share ϕ_i^s and sector n input shares ϕ_i^{ns} satisfying $\phi_i^s + \sum_n \phi_i^{ns} = 1$. The total factor productivity of country i, sector s at time t is A_{it}^s, and exports from i to j face an iceberg cost τ_{ijt}^s with $\tau_{iit}^s = 1$ by normalization. Inputs from sector n across different goods are aggregated CES with elasticity σ_s, in the same way as consumption goods in sector n. Thus the production function F_{ijt}^s of a representative firm in country i, sector s at time t to destination j is

$$F_{ijt}^s(l_{ijt}^s, \{X_{ijt}^{ns}\}_n) = \frac{A_{it}^s}{\tau_{ijt}^s} \left(\frac{l_{ijt}^s}{\phi_i^s} \right)^{\phi_i^s} \prod_n \left(\frac{X_{ijt}^{ns}}{\phi_i^{ns}} \right)^{\phi_i^{ns}} \tag{29}$$

Unions and Wage Rigidity. We assume wage rigidity in each sector s through wage-setting unions facing nominal friction. A continuum of unions in sector s organizes the measure L_{it}^s of workers in sector s and employs them for an equal number of hours ℓ_{it}^s. Each union faces a labor demand curve and sets nominal wages W_{it}^s in each period to maximize the welfare of the sector s members with discount rate β.[37] We assume wage rigidity in the form of a Rotemberg friction $\Phi(W_t^s, W_{t-1}^s)$ and choose the union objective function so that the union's optimization problem leads to the wage Phillips curve,

$$\log(\pi_{it}^{sw} + 1) = \kappa_w(v'(\ell_{it}^s) - \frac{W_{it}^s}{P_{it}} u'(C_{it})) + \beta \log(\pi_{it+1}^{sw} + 1) \tag{30}$$

where $\pi_{it}^{sw} = \frac{W_{it}^s}{W_{it-1}^s} - 1$ denotes wage inflation at time t.[38]

Migration across sectors. We assume that each member m is forward-looking and faces a dynamic problem with discount factor β, labor reallocation costs χ_i^{sn} to move from sector s to n; these reallocation costs are time-invariant, additive, and measured in utility units. Each member m receives an idiosyncratic shock for each choice of sector, denoted by $\epsilon_{it} = \{\epsilon_{it}^n\}_n$. Since the per-worker labor supply ℓ_{it}^s is determined by the union, the member takes it as given. If we denote by $\mathcal{V}_{it}^s(\epsilon_{it})$ the lifetime utility of the worker in sector s with preference shock ϵ_{it},

[37] Here, we are implicitly assuming that the intertemporal preference shifters δ_{jt} are pure consumption shocks that affect consumption but not labor supply. We make this assumption for clarity of exposition, as the shifters are intended to match the realized trade imbalances and model financial shocks outside of the scope of our model.

[38] To a first order, the equation is identical to assuming Calvo rigidity, where the probability of keeping the wage fixed is θ_w, with $\kappa_w = \frac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w}$.

then we have the worker's Bellman equation,

$$\mathcal{V}_{it}^{s}(\epsilon_{it}) = \tilde{\lambda}_{it} W_{it}^{s} \ell_{it}^{s} - h(\ell_{it}^{s}) + \eta_{it}^{s} + \max_{n} [\beta \mathbb{E}[\mathcal{V}_{it+1}^{n}(\epsilon_{it+1})] + \epsilon_{it}^{n} - \chi_{it}^{sn}], \tag{31}$$

where $\tilde{\lambda}_{it} = \frac{u'(C_{it})}{P_{it}}$ is the Lagrange multiplier on the country i household family's period t budget constraint. Here $\tilde{\lambda}_{it} W_{it}^{s}$ is the marginal utility of labor by a worker in sector s. Workers internalize how their choice of sector affects the family budget. The solution to the Bellman equation above yields a transition matrix μ_{it}^{sn} and expected utility $V_{it}^{s} = \mathbb{E}[\mathcal{V}_{it}^{s}(\epsilon_{it})]$ given by

$$\mu_{it}^{sn} = \frac{\exp(\frac{1}{\nu}(\beta V_{it+1}^{n} - \chi_{it}^{sn}))}{\sum_{n'} \exp(\frac{1}{\nu}(\beta V_{it+1}^{n'} - \chi_{it}^{sn'}))}, \tag{32}$$

$$V_{it}^{s} = \tilde{\lambda}_{it} W_{it}^{s} \ell_{it}^{s} + \eta_{it}^{s} - v(\ell_{it}^{s}) + \nu \log \left(\sum_{n} \exp(\frac{1}{\nu}(\beta V_{it+1}^{n} - \chi_{it}^{sn})) \right). \tag{33}$$

Monetary policy. The monetary authority in each country i sets a nominal interest rate i_{it}. We assume that country 1 (USA) sets a Taylor rule on inflation

$$\log(1 + i_{1t}) = r_{1t} + \phi_{\pi} \log(1 + \pi_{1t}) + \epsilon_{1t}^{MP}, \tag{34}$$

where r_{1t} is the real interest rate, $\pi_{1t} = \frac{P_{it+1}}{P_{it}}$ is the CPI inflation, and interpret ϵ_{1t}^{MP} as any discretionary monetary policy the central bank of Country 1 may pursue.

The monetary policy of country 2 (China) may be a *peg* or a *float*. Under a peg, we assume that country 2 pegs the exchange rate to country 1, so i_{2t} is implicitly pinned down by $e_{12t} = \bar{e}$.[39] Under a float, country 2 pursues an independent Taylor rule of the form

$$\log(1 + i_{2t}) = r_{2t} + \phi_{\pi} \log(1 + \pi_{2t}) + \epsilon_{2t}^{MP}. \tag{35}$$

We assume that the rest of world ($i \geq 3$) floats its currency with respect to the US dollar, and assume that monetary policy in each of the countries is given by its own Taylor rule (Equation 34) responding to its CPI inflation.[40]

Exchange rate determination. Denote by $e_{it} = e_{i1t}$ the value of currency i with respect to the US dollar. We have $e_{ijt} = \frac{e_{it}}{e_{jt}}$. If country i pegs its currency, it sets e_{it} to an exogenous number $\bar{e}_i$. When country i floats its currency, the UIP condition pins down $\frac{e_{it+1}}{e_{it}}$. We assume that, if

[39] Because bonds are perfect substitutes, we rule out pegging in the form of foreign exchange intervention. In fact, in a model with UIP deviations, the first-order linear consumption responses are identical whether China pegs the currency through moving interest rates, or fixing the interest rate and buying bonds (and financing this through lump-sum taxes), because the current account of the country (fiscal authority plus household) is identical in both cases. We formally explore this in a work in progress.

[40] Alternatively we may consider a middle ground, corresponding to a Taylor rule with an exchange rate target.

country i floats its currency, e_{i0} is the unique value such that

$$\lim_{t\to\infty} B_{it} = 0. \tag{36}$$

Equation 36 operationalizes the idea that there are financial forces that move exchange rates to clear long-run balance of payments, and can be microfounded as a limit case of financial frictions pinning down the exchange rate.[41]

Tariffs and fiscal policy. Each country j can choose a set of ad valorem import tariff rates $\{t^s_{ijt}\}$ on goods from country i to country j; the tariff revenues are rebated to households lump-sum, and the government balances its budget every period. Thus if we denote the pre-tariff price of sector s goods from i to j at time t by P^s_{ijt}, government j's revenue is

$$T_{jt} = \sum_{i,s} t^s_{ijt} P^s_{ijt} (C^s_{ijt} + X^s_{ijt}) \tag{37}$$

where C^s_{ijt} is consumption of (i,s) goods in country j, and X^s_{ijt} is total input use of (i,s) goods in country j. To focus on tariffs, we assume away export subsidies.

Equilibrium. We are now ready to define the equilibrium in the quantitative model.

Definition 2. *Given parameters $\{A^s_{it}, \tau^s_{ijt}, \delta^s_i, \chi^s_{it}, \eta^s_i\}$, previous period nominal wage $\{W^s_{i-1}\}$, initial bond holdings $\{B_{i0}\}$, labor allocation $\{L^s_{i0}\}$, and policy rules $\{i_{it}\}, \{t^s_{ijt}\}$, an equilibrium in this model consists of consumption $\{C_{jt}, C^s_{ijt}\}$, bond holdings $\{B^s_{it}\}$, labor supply $\{\ell^s_{it}\}$, labor allocation $\{L^s_{it}\}$, prices $\{P_{jt}, P^s_{jt}, P^s_{ijt}\}$, wage $\{W^s_{it}\}$ and exchange rates $\{e_{ijt}\}$ that satisfy the following:*

(a) Consumption and bond holdings solve the family optimization problem,

(b) Prices, labor, and input demand solve firm profit maximization,

(c) Labor supply and wages satisfy the Phillips curve,

(d) Labor reallocation and lifetime value solves the sector choice problem,

(e) Monetary policy in the US is given by a Taylor rule,

(f) Monetary policy in other countries and exchange rates satisfy (a peg) or (zero long-run balances).

(g) Goods market, bond market clears, and the government balances its budget.

The formal equations and derivations are in Appendix C.1.

[41] This idea dates back to Meade (1951) and Friedman (1953). Equation 36 is a special case of the exchange rate determination literature with financial frictions (Kouri, 1976; Itskhoki and Mukhin, 2021a) where we take the limit of the magnitude of the friction to zero. We microfound this in Appendix C.

4.2 Data and Calibration

We provide an overview of our data and calibration process and relegate the details to the Online Supplement. Our quantitative model has six country aggregates: US, China, Europe (including UK), Asia, the Americas, and the rest of world. We consider 6 sectors: agriculture, low-, mid- and high-tech manufacturing, and low- and high-tech services, classified according to the North American Industry Classification System (NAICS).[42] The time of our data spans from $t = T_0 = 2000$ to $t = T_{data} = 2012$ annually.

Trade and production data. The primary dataset we use is the World Input-Output Database (WIOD) 2016 edition (Timmer et al., 2015). The WIOD compiles data from national accounts and bilateral trade data for 56 sectors and 44 countries. It has information on the value of trade flows X^s_{ijt} from country i to country j in sector s at year t for 56 sectors across 44 countries. It also contains data on purchases of inputs across sectors, value added of each sector in each country (which corresponds to the labor share in our model), consumption shares across sectors, and the net exports for each country. We obtain the price indices for each sector from the WIOD's Socioeconomic Accounts (WIOD SEA).

Labor and Sectoral Adjustments. We obtain the initial distribution of workers in the year 2000 by sectors using the WIOD SEA. We use data from the Current Population Survey (CPS) in the United States to construct the matrix of migration flows μ^{sn}_{it} across sectors in the US. We assume away migration flows between countries. For countries outside of the US and China, we assume that workers are immobile and fixed in that sector; for China, we assume that the cost of moving is fixed at the 2000 level.

Calibration. Table 1 provides a summary of the parameters, including the sources of parameters whose values we take from the literature or the moments that we target for the parameters we directly calibrate.

Values for parameters in Panel A of Table 1 are taken from the literature, as they are difficult to identify given available data, or our estimation strategy would be analogous to the literature. The time frequency is annual, and we use $\beta = 0.95$ to match the 5% annual interest rate. Estimating the dispersion ν of sectoral preference shocks ϵ^n_{it} requires panel data and instrumental variables; we impose this to be common across all countries and set them to be $\nu = 2.02$, following Caliendo et al. (2019). For the elasticity of intertemporal substitution, we follow standard practice in the macro and trade literature and set $\gamma = 1$, assuming log utility. The Frisch elasticity of labor supply is set to $\varphi = 2$, closer to macro estimates (Peterman, 2016). Measuring the elasticity of substitution of goods across origin often requires panel data on variation, so

[42] This follows Dix-Carneiro et al. (2023).

Panel A. Fixed according to literature			
Parameter	Value	Description	Source
β	0.95	Discount factor	5% interest rate
ν	2.02	ϵ^n_{it} dispersion	Caliendo et al. (2019)
γ	1	Intertemporal Elasticity	Standard
φ	2	Frisch elasticity	Peterman (2016)
σ_s	5	Elasticity of substitution	Head and Mayer (2014)
κ	0.05	NKPC slope	Hazell et al. (2022)
ϕ_π	1.5	Taylor rule coefficient	Taylor (1993)

Panel B. Parameters we calibrate		
Parameter	Description	Target moments
α^s_{it}	Expenditure shares	WIOD consumption share
ϕ^s_{it}	Labor share	WIOD value added
ϕ^{sn}_{it}	Input-output matrix	WIOD input-output
θ^s_i	Intensity of labor disutility	$\ell^s_{i,2000} = 1$
η^s_i	Non-pecuniary utility	WIOD SEA labor distribution
χ^{sn}_{it}	Migration cost	CPS sector change
τ^s_{ijt}	Trade cost	WIOD trade flow
A^s_{it}	Productivity	WIOD trade flow and SEA price index
δ_{it}	Intertemporal preference shifter	WIOD net exports
r_{it}	US real interest rate	Full employment without China shock

Table 1: Calibrated parameters

we set it to 5, which is standard in the literature (Head and Mayer, 2014; Rodríguez-Clare et al., 2022; Dix-Carneiro et al., 2023). We set the New Keynesian Phillips Curve slope to $\kappa = 0.05$ to match Hazell et al. (2022) which exploit variation across US states to obtain the response of inflation to the labor wedge.[43] The Taylor rule coefficient is set to 1.5, following the original paper by Taylor, as standard in the macro literature.

In Panel B of Table 1, we can directly compute the sectoral consumption expenditure share α^s_{it}, labor share ϕ^s_{it}, and input-output share ϕ^{sn}_{it} directly from the WIOD data. For the rest of the parameters, we rely on parts or all of the model to match the model-generated moments with the data. We divide our calibration into two steps: calibrating the initial period, and then calibrating how those parameters change in our model. We set the non-pecuniary utilities η^s_i such that the model-implied initial labor distribution $L^s_{i,2000}$ matches the realized labor distribution observed in the WIOD SEA, and the migration cost $\chi^{sn}_{i,2000}$ so that it matches the observed sector change flows in the CPS of the US; we assume that China faces the same sectoral migration

[43] Since their model is quarterly and the Phillips curve links price inflation with unemployment, we undergo a series of transformations to make our estimate consistent with their estimate of $\kappa' = 0.0062$. Details are given in the Online Supplement.

costs, and countries besides US and China have an immobile labor market. We normalize θ_i^s so that the initial per-worker labor supply in our model is $\ell_i^s = 1$. Turning to the trade side, we calibrate the trade costs τ_{ij0}^s and A_{i0}^s to match the trade flow in the initial period exactly up to normalization, following the exact hat algebra approach of Dekle et al. (2007) and Caliendo et al. (2019).

Next, we discuss the calibration of the *shocks* we extract. We extract three main sets of shocks from the WIOD data: changes in trade costs $\hat{\tau}_{ijt}^s = \frac{\tau_{ijt}^s}{\tau_{ij0}^s}$, changes in productivity $\hat{A}_{it}^s = \frac{A_{it}^s}{A_{i0}^s}$, and intertemporal preference shocks δ_{it}.[44] We calibrate these shocks to exactly match three realized 'shocks' in the WIOD data: changes in sectoral output price indices $\hat{P}_{it}^{s,dom} = \frac{P_{it}^{s,dom}}{P_{i0}^{s,dom}}$, changes in trade shares $\hat{\lambda}_{ijt}^s = \frac{\lambda_{ijt}^s}{\lambda_{ijt}^0}$, and net exports in each period as a share of GDP $NXGDP_{it} = \frac{NX_{it}}{GDP_{it}}$. We calibrate the trade cost shocks $\hat{\tau}_{ijt}^s$ to exactly match the gravity structure of trade flows up to normalization; we assume $\hat{\tau}_{iit}^s = 1$. On the other hand, since prices are a function of wage and productivity, and the dynamics of wage (and its rigidity) are central to our channel, we cannot back out the productivity without solving for the full model. Thus, we employ a Simulated Method of Moments (SMM) approach, targeting the changes in output price and net exports as moments we exactly match. We also calibrate the sector change costs χ_{it}^{sn} in the US so that the model-implied migration μ_{it}^{sn} exactly match the sector reallocation data in the CPS. The details of this calibration procedure can be found in the Online Supplement.

4.3 Solution algorithm

We aim to study the employment, trade balance, and welfare effects of China's peg against the US dollar and revisit the effects of the China shock under this framework. We bring frontier computational methods from macroeconomics (Auclert et al., 2021a) and apply them to answer trade questions. We sketch our solution algorithm here and provide the details and discussions in the Online Supplement.

Given the elasticities and parameters calibrated in Subsection 4.2 (Table 1), we directly solve for the equilibrium in the *sequence-space* of equilibrium objects

$$\{X_t\}_{t=T_0}^{T} = \{(B_{it}, P_{it}, C_{it}, e_{it}, W_{it}^s, \ell_{it}^s, L_{it}^s, V_{it}^s)\}_{t=T_0}^{T}$$

for $T \gg T_{data}$ such that the economy returns to a new steady-state by $t = T$. This requires solving a high-dimensional nonlinear equation.[45] The key idea is that the nonlinear system of equations that define $\{X_t\}$ is extremely sparse: each period t equilibrium condition only depends on variables of time $t, t-1, t+1$, and even those equations depend on a few parameters

[44] We also assume that the preference and technology parameters $(\alpha_{it}^s, \phi_{it}^s, \phi_{it}^{sn})$ are time-varying, but we directly observe this as shares from the data.

[45] With $I = S = 6$ and $T = 100$, the system of equations have over 20000 variables.

within each t. Then, the Jacobian of the equilibrium conditions can be efficiently constructed, and we employ nonlinear root-finding algorithms to solve for the full sequence of wages, consumptions, trade imbalances, and labor allocations. By leveraging the sequence-space Jacobian approach from Auclert et al. (2021a) and combining it with computational advances in machine learning, we can solve for the full nonlinear solution of our model in seconds to minutes depending on specification, allowing us to compute a wider dimension of counterfactual scenarios and explore policy implications.[46]

5 Effects of the China shock and the role of the peg

In this section, we use the model described in Section 4.1 and calibrated parameters from Section 4.2 to study the effect of the China shock and the China peg. In Section 5.1, we first define the "China shock", using the change in productivities, trade costs, and preference parameters observed over this period.

In Section 5.2, we revisit the effect of the China shock on the US labor market and trade deficit. We show how modeling wage rigidity, consumption-savings, and exchange rate peg affects the predictions on the effect of the China shock, compared to estimates in the literature that ignore these channels. In Section 5.3, we quantify how the exchange rate peg *magnified* the effects of the China shock on the United States by comparing the realized economy with a counterfactual economy with otherwise identical evolution of parameters, but under a floating exchange rate.

5.1 The China shock

One goal of our quantitative model is to estimate the effect of the China shock under an exchange rate peg and nominal rigidity. In this subsection, we define what the China shock is in the context of our model.

In Section 4.2, we extract the realized evolution of parameters across time. This is the baseline, *realized* economy with the China shock. We consider two notions of the China shock. The main shock, which we call the *China trade shock* only considers the changes in China that are directly associated with increasing import penetration of Chinese goods: the productivity A_{it}^{s} and the trade costs τ_{ijt}^{s}. Thus the counterfactual economy without the *China trade shock* is the equilibrium where the calibrated parameters (Table 1) are identical to the realized equilibrium, with the exception of productivity A_{it}^{s} and the trade costs τ_{ijt}^{s} in China; for China, we fix the

[46]The methods we use include parallelization, autodiff, just-in-time compiling, and Intel's PARADISO package for quickly solving large sparse systems, many of which are heavily used in machine learning contexts where the parameter space is even larger. The toolkits are available in the Python-based framework "JAX," which we use extensively. Details can be found in the Online Supplement.

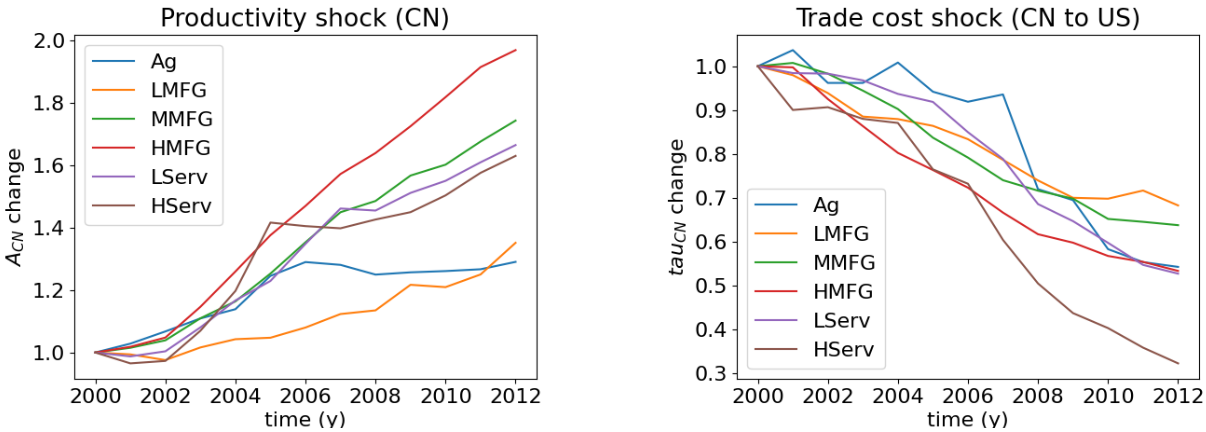


Figure 4: Calibrated values of the China trade shock.

productivity A^s_{CN} and trade costs $\tau^s_{i\mathrm{CN}t}, \tau^s_{\mathrm{CN}it}$ to be fixed at their levels in $t = T_0$.[47]

Figure 4 plots the computed China shock on the productivities A^s_{CN} and the trade cost from China to US $\tau^s_{CN,US,t}$ as a ratio between the levels at time t versus the level at the initial period $t = T_0 = 2000$ for the six sectors. China's productivity increases in all sectors, but especially in the medium-tech and high-tech manufacturing sectors. China's trade costs also decrease for all sectors; while the decline seems to be most pronounced for the service sectors, this is driven by the fact that the service sectors are close to nontradable – the implied trade costs τ^s_{ijt} in 2000 are close to 70-80 that get reduced to 30 by 2012, but is still very high. Much of the effect on the US economy is driven by the shocks in the manufacturing sectors.

We also consider another set of shocks, which includes the intertemporal preference shock $\delta_{\mathrm{CN}t}$. While the changes in productivity A and trade cost τ capture the surge in Chinese exports, this is not the only structural change in China during this period. Rich financial dynamics outside the scope of our model will affect realized trade imbalances and consumption-saving patterns. Those 'residuals' constitute the savings glut of China and are interpreted as part of the China shock in Dix-Carneiro et al. (2023). We call this shock the *China trade and savings shock*. Then, the counterfactual economy without the China trade and savings shock is the equilibrium with identical parameters as the realized equilibrium, with the exception of $A^s_{\mathrm{CN}}, \tau^s_{i\mathrm{CN}t}, \delta_{\mathrm{CN}t}$; we fix those values to be the values at $t = T_0$ in China.[48]

Comparing the realized economy with the economy without the *China trade shock* allows us to evaluate the effect of Chinese growth on US outcomes, such as the distribution of labor,

[47] In the Online Supplement, we discuss alternative notions of the *no China shock* counterfactual, such as (1) where China's global import penetration does not increase throughout the period (Caliendo et al., 2019; Rodríguez-Clare et al., 2022), or (2) Chinese productivity grows on par with the global average during this period (Dix-Carneiro et al., 2023). We find qualitatively similar results.

[48] During this period, consumption shares α^s_{it} and input-output linkages, labor shares $\phi^s_{it}, \phi^{sn}_{it}$ vary over time. We match the varying shares in both the realized and counterfactual equilibrium.

trade balances, or unemployment. Comparing the realized economy to the economy without the *China trade and savings shock* gives us the effect of China's structural change, including the savings glut, on the same US outcomes. By looking at the difference between these two outcomes, we can evaluate the extent to which the realized US trade deficit and decline in manufacturing (Figure 1) can be causally attributed to Chinese growth.

For all our counterfactual scenarios, we assume in our baseline analysis that agents have no foresight of the shocks during this period for both the realized and counterfactual equilibrium, operationalizing the notion that "every year is a China shock" during the period of spectacular productivity growth in China. We discuss the details of our implementation, the rationalization for agents' foresight, and robustness exercises where we alternatively assume perfect foresight in the Online Supplement.

5.2 Reevaluating the China shock

We start by revisiting the quantitative effects of the surge in China's imports – the *China shock* – on the US economy using our calibrated model. We are interested in asking the following question: what are the dynamic effects of the China shock on labor reallocation, unemployment, the trade balance of the US, and welfare consequences through the lens of our model? We revisit the effects of the China shock under wage rigidity and endogenous consumption-savings and compare how those ingredients lead to different implications of the China shock than three previous literature: Caliendo et al. (2019), which feature exogenous deficits and no involuntary unemployment, Rodríguez-Clare et al. (2022) which feature nominal rigidity but exogenous deficits, and Dix-Carneiro et al. (2023) which feature endogenous deficits but quantity rigidity instead.

To quantify our answer to this question, we first solve for the baseline economy with the actual evolution of fundamentals over 2000-2012. Then we solve the economy under both the *no China trade shock* counterfactual and the *no China trade and savings shock* counterfactual and treat the difference in outcomes such as the trade imbalance, labor market, and welfare outcomes between the realized and counterfactual outcomes as the effect of the shock.

Figure 5 shows the import penetration ratio of China to the US, the manufacturing share of US employment, the net exports of the US (as a percentage of contemporaneous GDP), and aggregate unemployment in the economy for the (1) realized economy, (2) the counterfactual economy without the China trade shock, and (3) the counterfactual economy without the China trade and savings shock. The first three figures replicate the four stylized facts we highlight in the introduction (Figure 1). Figure 5a clarifies that the growth in import penetration from China in this period is driven by productivity growth and trade liberalization of China. In fact, if China had not grown in this period, import penetration from China would have decreased, as other Asian countries growing in this period (most notably other parts of Asia) would have assumed the role of China.

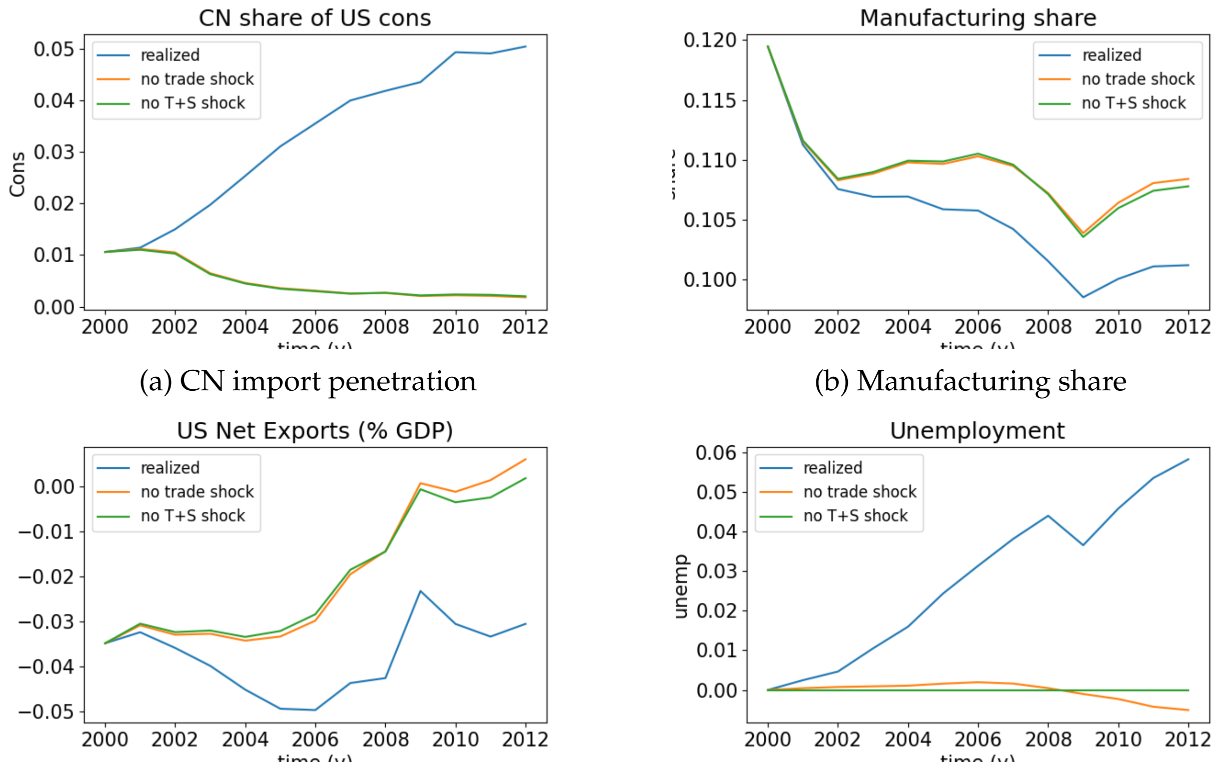
Next, we study the decline in US manufacturing. Figure 5b investigates the impact of the China shock on the manufacturing share of employment. As we see, a sizable share of the exit of workers from manufacturing can be attributed to the China shock in our framework. In numbers, 991 thousand jobs lost in manufacturing could be attributed to the China trade shock. Most notably, the decline in manufacturing is almost identical in the *no China trade shock* case and the *no China trade and savings shock* case, suggesting that the residual savings glut of China plays a negligible role in the decline of US manufacturing. This goes further than the findings of Kehoe et al. (2018), which show that the savings glut is responsible for 15.1% of the decline in US manufacturing. Our framework in Section 3 substantiates this viewpoint: Proposition 5 shows that US borrowing should mitigate the decline in manufacturing, as consuming more in the short-run would help a declining demand for Home goods.

Turning to trade deficits, Figure 5c shows that a significant proportion of realized US trade deficits can be explained by the China trade shock. In fact, taking the average from 2000 to 2012, 2.25 percentage points of the US annual deficit (% GDP) can be explained solely by the China trade shock, and if China had not grown, the US may have had balanced trade by 2012. The realized average annual trade deficit of the US during the same period was 3.4% of GDP, suggesting that two thirds of the US trade deficit over this period could be explained by the China shock. The residual savings glut δ_{it} plays little role in affecting the balances, suggesting that the theoretical channel we highlighted in Proposition 1 – permanent Foreign growth leading to Home deficits – is responsible for a majority of the US trade deficit of the 2000s.

Next, we use our general equilibrium model to obtain the implied effects of the China shock on unemployment. Figure 5d plots the aggregate US unemployment response to the China shock according to our model. Unemployment increases through the span of the shock, and on average, the excess unemployment generated from the China shock from 2000 to 2012 is 3.04%; this unemployment is necessarily short-lived, and it reaches zero after the culmination of the China shock, as nominal wages adjust to the new equilibrium level.[49]

Finally, we measure the welfare implications of the China shock. The household family's utility comprises both consumption utility and the disutility of labor. In evaluating the welfare effects, we consider the aggregate discounted utility incorporating the full path of consumption and the disutility of labor. Thus we define the *welfare effect* of the shock as the lifetime compensating variation in consumption for the US; formally, the welfare effect of the China

[49] The unemployment level is high because the shock to manufacturing can spill over to the service sector through aggregate demand (highlighted in the two-sector model in the Online Supplement), and targeting CPI inflation is not an optimal monetary policy in this setup. We consider this result as a benchmark and consider alternative monetary policy rules in the Online Supplement, and show that the decline in manufacturing share and trade deficits are robust.



(a) CN import penetration

(b) Manufacturing share

(c) Net exports (% GDP)

(d) Unemployment rate

Figure 5: Response of the economy to the China shock.

Note. The 'realized' graphs are the equilibrium outcome from the full sequence of parameters that were targeted to match realized moments. The 'no trade shock' graphs are the equilibrium outcome from the sequence of parameters identical to the realized, except we remove the productivity growth and trade cost reduction in China. The 'no T+S shock' graphs are the equilibrium outcome from the same sequence, except we remove the residual 'savings shocks' in China. The similarities between the no trade shock and the no T+S shock suggest that the residual savings glut of China played close to zero role in the manufacturing decline or the trade deficits after we account for the effect of the exchange rate peg.

shock is the scalar ζ such that

$$\mathcal{U}_0(\{C_{CS}\}_t, \{\ell_{CS}\}_{s,t})) = \mathcal{U}_0(\{(1+\zeta)C_{\text{noCS}}\}_t, \{\ell_{\text{noCS}}\}_{s,t}), \tag{38}$$

or how much more lifetime consumption (in percentages) the household needs to be indifferent between the China shock case and the no China shock case. According to this metric, the China shock contributed to a 0.183% gain in lifetime welfare, a modest but significant gain, and the distortion margins we highlighted in Proposition 2 – unemployment and future terms-of-trade deterioration – did not flip the aggregate welfare implications of the China shock.

Table 2 compares the estimated effects of the China shock from our framework to three references in the literature. The first is Caliendo et al. (2019) (CDP19), which features no intra-sector labor market friction and models imbalances through systems of transfers. The second is Rodríguez-Clare et al. (2022), which features downward nominal wage rigidity but exogenous

Effect of China shock				
	Our model	CDP19	RUV22	DPRT23
MFG jobs lost	991k	550k	498k	530k
Deficit (% GDP)	2.25	N/A	N/A	0.8
Unemployment (%)	3.04	N/A	1.4	0
Welfare gains	0.183%	0.2%	0.229%	0.183%*
Wage rigidity	O	X	O	X
Search friction	X	X	X	O
Cons-savings	O	X	X	O
ER peg	O	X	X	X

Table 2: Effects of the China shock: comparison to existing literature.

Note. *: Dix-Carneiro et al. (2023) measure welfare using consumption only, without considering the labor market effects of welfare. We take into account the disutility of labor in measuring aggregate welfare.

imbalances. The third is Dix-Carneiro et al. (2023), which models labor market friction through quantity friction (search and matching). Our model estimates close to double the number of manufacturing jobs lost through the China shock than the estimates of the previous literature, a much larger proportion of the realized US trade deficit than what Dix-Carneiro et al. (2023) attribute to the China shock and more moderate welfare gains from the China shock. Our estimate of the number of manufacturing jobs lost is close to the estimates of Autor et al. (2013) – 982,000 jobs lost as a result of the China shock after 2000 – suggesting that the *missing intercept* may not be as large as previously thought. Interestingly, despite the manufacturing jobs lost that are about twice as large and a significant level of unemployment, the welfare consequences of the China shock are still positive and close to the literature's estimates.

In the following subsection, we show that the difference between our estimates and the literature's estimates can be almost entirely attributed to China's exchange rate peg.

5.3 The effect of the exchange rate peg

The second and most novel part of our quantitative analysis focuses on how much the peg interacted with the China shock to generate the realized effects of the China shock we saw in Section 5.2. If the empirical findings in Section 2 and the propositions in Section 3 hold, we should expect that the exchange rate peg is responsible for a sizable part of the trade deficit, the decline in manufacturing, and may affect the welfare implications of the China shock.

To quantify this, we compare the outcomes of the baseline economy to a counterfactual economy with identical fundamentals, except for one change: China's monetary policy no longer pegs to the US dollar. China's alternative monetary policy could be many things – a full-discretion policy, an interest rate with an exchange rate target – but to highlight the effect of the peg, we consider the simplest counterfactual by assuming that China's monetary policy is symmetric to the US, an independent Taylor rule with the same coefficient on China's domestic CPI inflation. The difference in the outcomes of the economy with the peg and the economy without the peg, both with the China shock, is the causal effect of China's exchange rate peg on the US.

Figure 6 shows the same aggregate variables in the US – import penetration ratio of Chinese goods, manufacturing share of employment, net exports of US, and unemployment in the economy for the (1) realized economy, (2) the counterfactual economy without the China trade shock, and (3) the counterfactual economy with the same shocks as the realized economy, but China had a floating exchange rate.

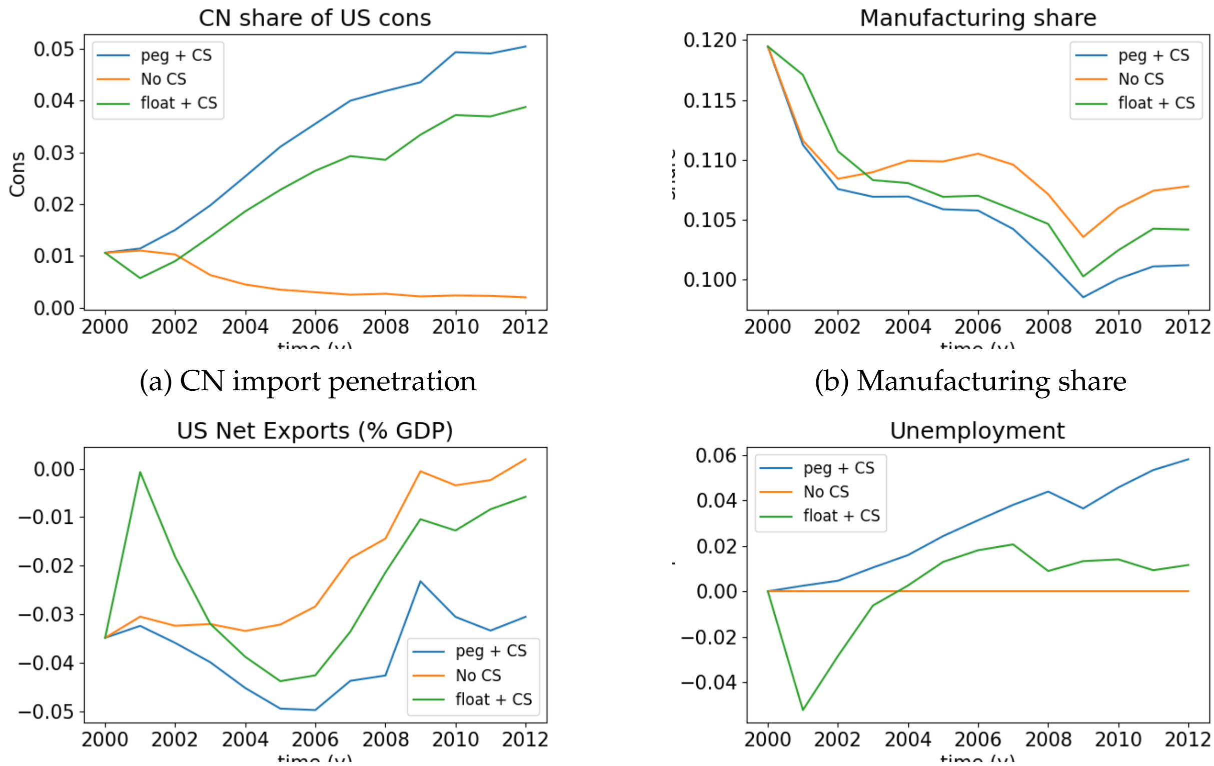
Figure 6a shows that the exchange rate peg played a role in Chinese import penetration to the US, and the actual penetration ratio would have been closer to 4% under a floating exchange rate. Under a float, Chinese currency would have appreciated during this period, and the increased price would have made Chinese goods less attractive to US consumers.

Investigating the decline in manufacturing (Figure 6b) and the US trade deficit (Figure 6c), we see that the exchange rate peg played a significant role in both. Even if China were identically growing, if China had a floating currency, close to 50% of the manufacturing decline attributable to the China shock and a significant proportion of the US trade deficit would disappear. Likewise, the level of unemployment is much closer to the 'no China shock' case (Figure 6d).[50]

Finally, we study the change in welfare. While the above results – the effect of the peg on the trade balance and the labor market – suggest that the peg may have adverse effects on the US economy, the peg comes with a clear benefit: the terms-of-trade improves, as China is selling goods at a price cheaper than in a flexible-price equilibrium. This force lowers the price index and increases consumption given the same budget. At the same time, unemployment moves the budget inwards, and this is a force that leads to a decline in consumption. Using the same compensating variations formula, we see that the China peg contributes to a welfare loss of 0.083% compared to the counterfactual economy with an identically growing but floating China.

Table 3 summarizes the quantitative effects of the interaction of the peg and the China shock. The first column summarizes the realized effects of the China shock under a peg, while the second column summarizes the counterfactual effect of the China shock when China is floating; the third and fourth columns compare the differences in relative and absolute terms. As we see, the China shock interacted with the peg significantly. In absolute terms (Column 3), we see that China's currency peg is responsible for 447 thousand manufacturing jobs lost,

[50] The 'jump' in 2001 comes from the fact that our analysis takes the realized wages and distribution of labor in 2000 as fixed initial conditions, and these values were under a peg. When we report the average trade deficit and unemployment below, we take the average from 2003 to 2012 to trim this discontinuity.



(a) CN import penetration

(b) Manufacturing share

(c) Net exports (% GDP)

(d) Unemployment rate

Figure 6: Response of economy to China's peg.

Note. The 'peg + CS' graphs are the equilibrium outcome from the full sequence of parameters targeted to match realized moments. The 'no CS' graphs are the equilibrium outcome from the *no China trade shock* assumption. The 'float + CS' graphs are the equilibrium outcome from the full sequence of parameters identical to the 'peg + CS' case (realized equilibrium), but under the counterfactual assumption that China did not peg its exchange rate and had its own independent Taylor rule.

1.34% (as a fraction of GDP) US trade deficit, and 1.84% (in percentage points) unemployment in the US, and the welfare gains are reduced by 0.083 percentage points, compared to a counterfactual economy where an otherwise identical China floats. In relative terms (Column 4), China's currency peg *magnifies* the manufacturing jobs lost from the China shock by 82%, the trade deficits caused by the China shock by 161%, unemployment by 176%, and reduces the welfare gains by 32%.

The last column takes the literature's estimates from the three papers we discussed in the previous subsection (Caliendo et al., 2019; Rodríguez-Clare et al., 2022; Dix-Carneiro et al., 2023). The effect of the China shock under a counterfactual 'floating' economy (second column) is strikingly similar to the structural estimates of the effects of the China shock in the literature. The manufacturing jobs lost are close to 550 thousand in all of the three aforementioned papers, while we estimate 543 thousand under float. The US trade deficit caused by the China shock is estimated to be 0.8% of GDP in Dix-Carneiro et al. (2023); the US trade deficit attributed to the China shock under a (counterfactual) floating economy is 0.86% of GDP. The

Decomposing China shock vs China peg					
	CS + peg	CS + float	$Y_p - Y_f$	$Y_p/Y_f - 1$	Lit estimate
MFG jobs lost	991k	543k	447k	+82%	550k
Deficit (% GDP)	2.25	0.86	1.34	+161%	0.8%
Unemployment (%)	3.04	1.10	1.84	+176%	1.4%
Welfare gains	0.183%	0.268%	-0.083p.p	−32%	0.2%

Table 3: Effects of the China peg

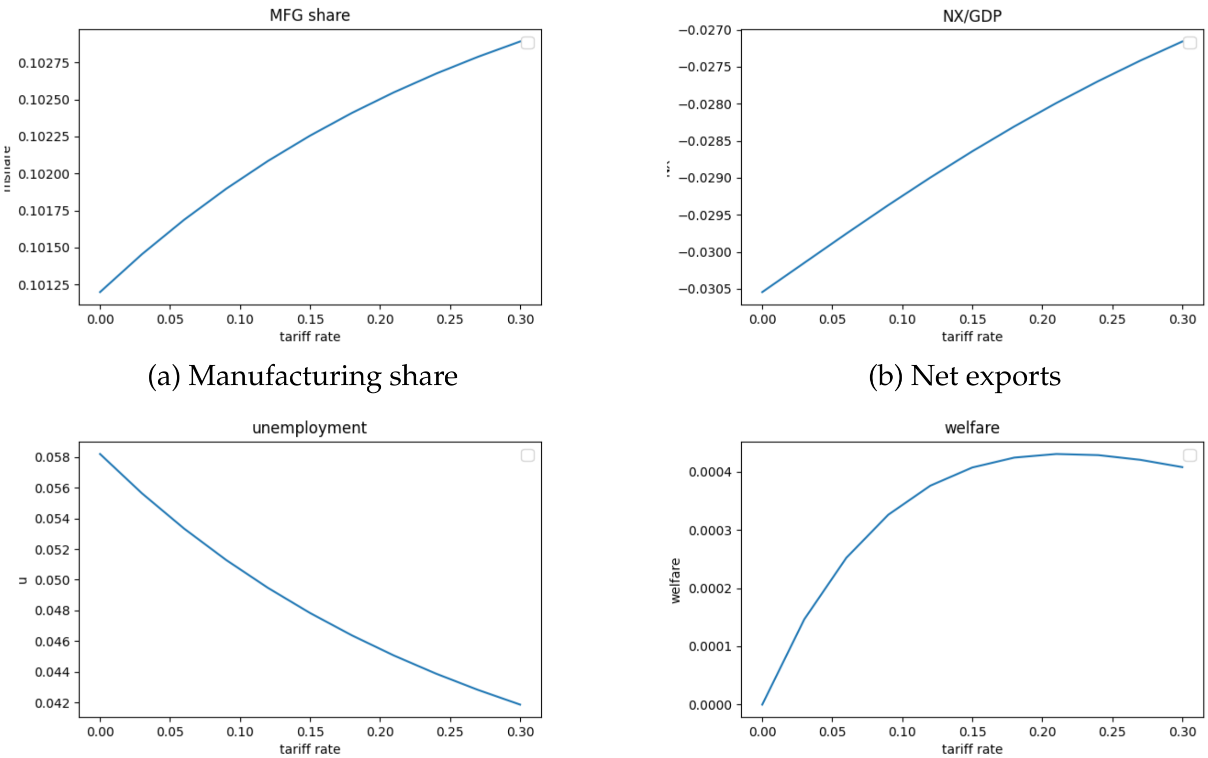
Note. The first column shows the realized effect of the China shock when the exchange rate is pegged. The second column shows the counterfactual effect of the identical China shock when China floats its currency. The third and fourth columns show the difference and ratio of the two, respectively. The fifth column shows the literature's estimates from Table 2.

unemployment effect estimated by Rodríguez-Clare et al. (2022) is 1.4%; under our modeling framework, the counterfactual effect of the China shock under a float is 1.10%. These results suggest that explicitly modeling the exchange rate peg is essential in a general equilibrium analysis of the effects of China shock on the US.

5.4 Counterfactual policies

We conclude by studying how policies such as tariffs and monetary policy may have altered the effects of the China shock. Suppose we wanted a quantitative answer to policy questions such as: (1) Could the US have mitigated the negative consequences of the China shock with a tariff on Chinese goods in the early 2000s? (2) Does the answer to this question depend on whether China retaliates? (3) Should the US have pursued a different monetary policy to counter the effects of the exchange rate peg? Our quantitative framework is especially suitable for studying the effects of alternative policies, as we can quickly compute the counterfactual equilibrium under any set of policies. We can answer such questions by comparing the realized equilibrium with a counterfactual equilibrium with different tariff rates t^s_{ijt}, or alternative monetary policies, expressed either through a discretionary monetary policy response given by ϵ^{MP}_{1t} in the US monetary policy Taylor rule (Equation 34), or alternative rules of monetary policy.

The first counterfactual exercise we consider is a unilateral tariff that the US imposes on Chinese goods. Could protective tariffs have helped ameliorate the short-run losses from China's growth and exchange rate peg? The specific policy experiment we analyze is a uniform tariff rate of x% for $x \in [0, 0.3]$ imposed by the United States on Chinese goods from 2000 to 2012. In Figure 7, we highlight the effects of the tariffs on four key variables affected by the China shock: the share of manufacturing employment, US trade deficit as a percentage of GDP, unemployment rate, and aggregate welfare in the United States. The first three indicators are measured as their level in 2012, whereas aggregate welfare is computed using compensating variations



(a) Manufacturing share

(b) Net exports

(c) Unemployment

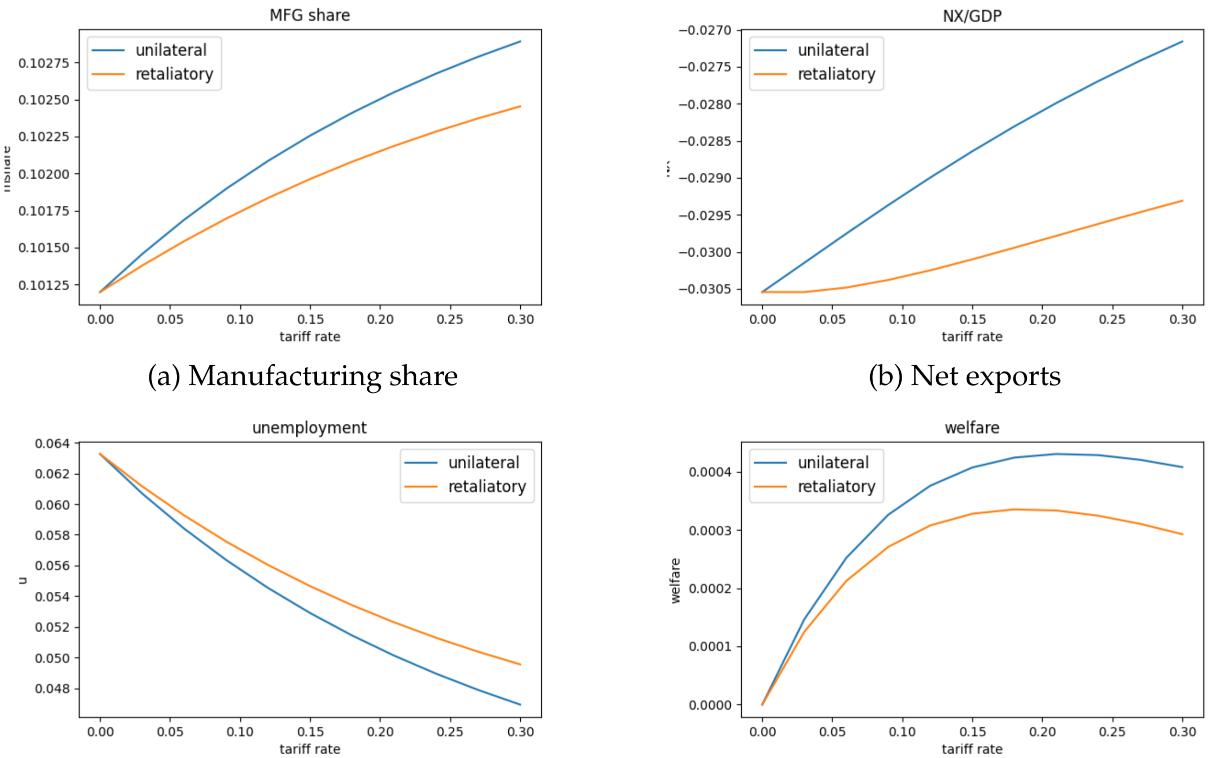
(d) Home welfare

Figure 7: Effect of unilateral tariffs.

relative to the realized equilibrium.

Figure 7 shows that a unilateral tariff reduces the decline in the share of manufacturing in the short-run, reduces the deficits, and reduces the unemployment rate. The welfare-maximizing tax rate is close to 20%, and this rate is much lower than the rate that restores full employment or restores the balance of trade. The tariff reduces 25% of the unemployment associated with the China shock and 10% of the realized trade deficit. The welfare gains from the tariff are modest, about 0.04% of lifetime welfare. This is about half of the welfare costs of the China peg (0.083%), suggesting that tariffs may help alleviate some of the welfare costs of the exchange rate peg. In this context, while a *safeguard* tariff helps alleviate the welfare losses from labor market frictions, the distortionary impact of tariffs on consumption is substantial enough so that the US government will not fully undo the distortions using tariffs. This analysis clarifies the quantitative relevance of the different welfare channels in the optimal tariff formula (Equation 23).

In the second counterfactual exercise, we consider the same tariffs on Chinese exports to the US but assume that China retaliates with a tariff of equal magnitude. The possibility of retaliatory tariffs undoing any gains from tariffs is well understood in the trade context without nominal rigidity and is often used as an argument for free trade agreements. How do the



(a) Manufacturing share

(b) Net exports

(c) Unemployment

(d) Home welfare

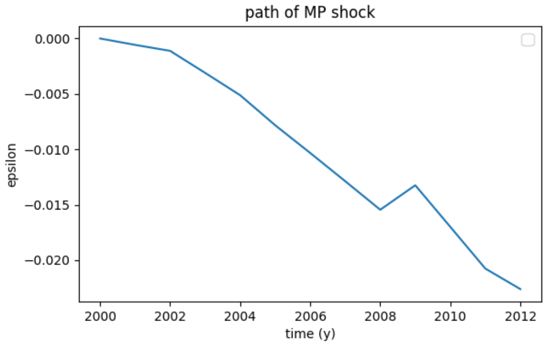
Figure 8: Effect of tariffs with retaliatory tariffs of equal magnitude

welfare effects of safeguard tariffs change when such tariffs are faced with retaliatory tariffs?

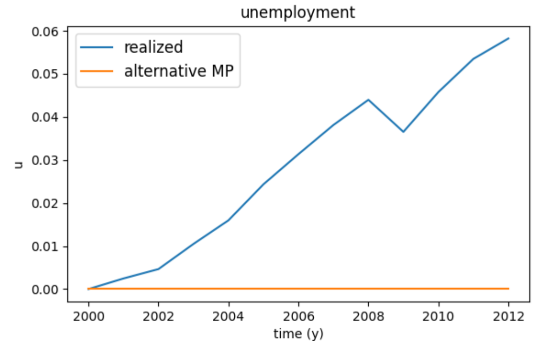
Figure 8 shows the response of the same aggregate variables for different tariff rates set by the US, with a retaliatory tariff from China of the same magnitude. Retaliatory tariffs weaken the effectiveness of tariffs on the manufacturing share, net exports, and unemployment. Still, the safeguard nature remains even with retaliatory tariffs: short-run unemployment in the US is lowered.

In the next experiment, we assess the effects of monetary policy loosening in this economy. In the baseline equilibrium (Figure 5), we saw that aggregate unemployment increased due to the China shock when the monetary policy was a Taylor rule targeting CPI inflation. How much looser should monetary policy be to undo the unemployment effects, and what are the effects of this additional discretionary monetary policy by the US? We simulate the model with different Home monetary policy shocks ϵ_{1t}^{MP} over 2000-2012 to find $\hat{\epsilon}_{1t}^{MP}$ that sets aggregate unemployment to zero from 2000 to 2012, and plot the economy's response to this monetary policy shock.

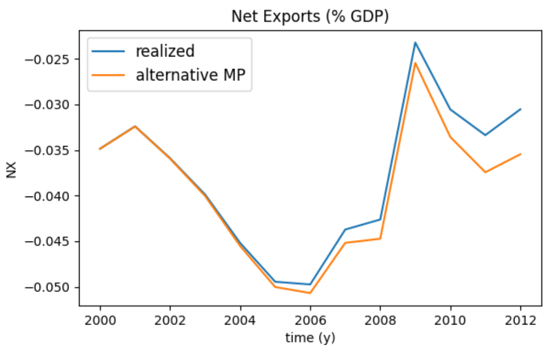
As Figure 9 shows, to clear unemployment, the nominal interest rate needs to be lower in 2000-2012 than the rate implied by the Taylor rule by up to 2%. This restores full aggregate employment but does not change the trade deficit or the decline in manufacturing share, con-



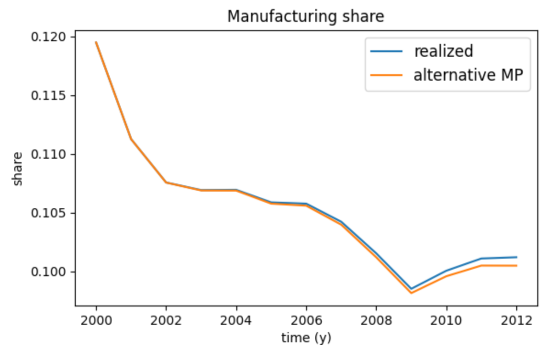
(a) Monetary policy shocks



(b) Unemployment



(c) Net exports



(d) Manufacturing share

Figure 9: Effect of alternative monetary policy

firming the role of monetary policy as an aggregate, not a distributional tool. Monetary policy loosening does not affect the trade deficit much because of the Chinese peg – if the US loosens monetary policy, the effective interest rate in China declines, too.[51]

In summary, we have found that a modest short-run tariff on Chinese goods in the early 2000s may help alleviate some of the labor market distortion caused by Chinese growth combined with the exchange rate peg.

6 Concluding remarks

What is the role of the exchange rate regime in shaping short-to-medium-run responses to trade shocks? The conventional trade literature sidesteps this question by focusing on flexible price equilibrium. We use the three different angles – empirical, theoretical, and quantitative – to revisit the effects of the China shock consistently suggest that China's currency peg against the US dollar is qualitatively and quantitatively pivotal in determining the labor market, trade

[51] In the Appendix, we study alternative monetary policy rules that are better suited to target unemployment under permanent trade shocks. In a work in progress, we study optimal monetary policy rules in this environment.

balance, and welfare response.

We have empirically documented that countries using or pegging to to the US dollar exhibit lower real GDP, a larger decline in manufacturing, and deteriorating trade balances in response to the China shock, compared to countries with similar China shock exposure that float to the US dollar. Notably, the floating countries have their currency appreciate in response to a larger exposure to the China shock, suggesting that the exchange rate operates as an adjustment margin. We develop a simple model of wage rigidity that can explain these findings, where we analytically characterize how exchange rate pegs interact with Foreign productivity growth to generate trade deficits and unemployment at Home. When we calibrate the multi-sector trade model to match the trade and sectoral reallocation data, we find that China's peg against the US dollar is quantitatively significant in shaping the effects of the China shock in the US trade deficit, unemployment, and decline in manufacturing.

While we intentionally focused our analysis on the China shock and the US dollar, the intuition of the direction of trade imbalances and labor market adjustments under exchange rate pegs apply more broadly. The post-WWII East Asian growth stories, most notably Japan and South Korea, involve having the currency follow the US dollar and running large trade surpluses in the growth path. Our framework can also give a better understanding of trade balances within the Eurozone, such as the persistent trade surplus of Germany and Ireland, and the deficit of Greece in the Eurozone.

One aspect of the model we intentionally abstracted from is China's policy goal. Why does China peg the exchange rate to the US dollar by effectively overheating its economy to supply cheap goods to the world? Potential explanations missing in our model include financial stability and an increase in investment coming from exchange rate stability, a myopic government seeking to maximize short-run output, learning-by-doing models (where more exports lead to productivity growth), and an increase in trade leading to technology diffusion (Perla et al., 2021). These are all mechanisms outside the scope of our model that can rationalize an exchange rate peg for a growing country, which we do not take a stance on.

One final direction forward is to consider heterogeneous agents in our model. In our model, since the consumption-savings decision is made at a family level, and unemployment is only at the intensive margin, our estimates of the losses from the exchange rate peg are underestimates. With a concave utility, involuntary unemployment in the extensive margin will aggravate losses for the unemployed and may have precautionary saving implications for manufacturing workers in the US. A model of heterogeneous agents and savings in incomplete markets may better highlight the distributional consequences of the China shock and the China peg. Probing this direction would further enrich our understanding of the China shock, and the role of the exchange rate as a shock absorber.

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Appendix

The Appendix contains three sections. Section A supplements Section 2, describing the data and justification for identification based on shock exogeneity of the shift-share instrument. Section B supplements Section 3, laying out the proofs for the propositions. Section C supplements Section 4, deriving key equations of the quantitative model. Robustness tests, details on the sectoral trade data, calibration procedure and solution algorithm are provided in the Online Supplement.

- Click here for the latest version of the main text and the Appendix.
- Click here for the Online supplement.

A Empirical Appendix

A.1 Description of Data

Table A.1: Ilzetzki et al. (2019)'s Exchange Rate Classification

Fine	Coarse	Description	Example
1	1	No separate legal tender	Eurozone, Cameroon
2	1	Pre-announced peg	Argentina, Malaysia
3	1	Pre-announced horizontal band $< \pm 2\%$	N/A
4	1	De facto peg	China, Egypt, Saudi Arabia
5	2	Pre-announced crawling peg; band $< \pm 1\%$	Nicaragua
6	2	Pre-announced crawling band $< \pm 2\%$	Sweden, Venezuela
7	2	De facto crawling peg	Russia, Vietnam
8	2	De facto crawling band $< \pm 2\%$	Iceland, Canada
9	3	Pre-announced crawling band $> \pm 2\%$	Hungary, Sri Lanka
10	3	De facto crawling band $< \pm 5\%$	Paraguay, Turkey
11	3	Moving band $< \pm 2\%$	Korea, Thailand
12	3	Managed floating	Brazil, Mexico, United Kingdom
13	4	Freely floating	Japan, United Stats
14	5	Freely falling	Congo, Zimbabwe
15	6	Dual market with missing data	Afghanistan, Myanmar

Note: The table lists the fine and coarse exchange rate regime classification of Ilzetzki et al. (2019). $<$ stands for 'narrower than', and $>$ stands for 'wider than', and denotes the size of the (horizontal, crawling, moving) band. The last column lists some example countries that was classified as that regime as of June 2000.

Table A.2: Summary statistics for pegs and floats

Variable	Pegs	Floats	Diff
log(population)	1.512	1.677	-0.689*
	(2.341)	(1.512)	(0.372)
log(GDP per capita)	8.421	8.562	-0.141
	(1.374)	(1.628)	(0.283)
MFG share (%)	11.414	14.213	-2.798**
	(6.428)	(7.692)	(1.394)
export (% GDP)	27.977	29.419	-1.442
	(26.995)	(22.065)	(4.561)
import (% GDP)	39.598	34.523	5.075
	(24.433)	(18.492)	(4.001)
NFA / GDP	-0.336	-0.106	-0.230
	(1.097)	(1.262)	(0.221)
CPI inflation	0.0437	0.0346	0.00910
	(0.0562)	(0.0315)	(0.00903)
unemployment rate	0.0870	0.1016	-0.0285**
	(0.0504)	(0.0871)	(0.0135)
S_i (china shock)	0.03493	0.04115	-0.00621
	(0.03022)	(0.03885)	(0.00643)
No. of obs	56	63	

Note: The first two columns report summary statistics for pegging countries and floating countries, with standard deviation in parentheses. The third column reports regression coefficients for regressions of the characteristics on a dummy variable for whether the country's currency is pegged to the US dollar, with the dependent variables on the left, with standard errors for the coefficients in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

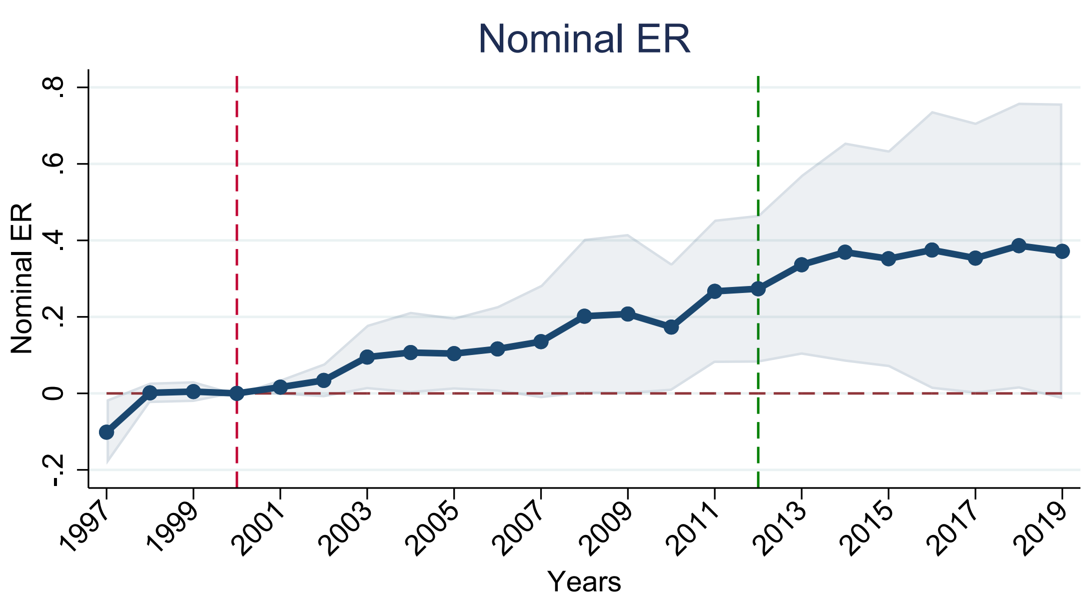


Figure A.1: Average responses to the China shock across countries.

A.2 Additional results

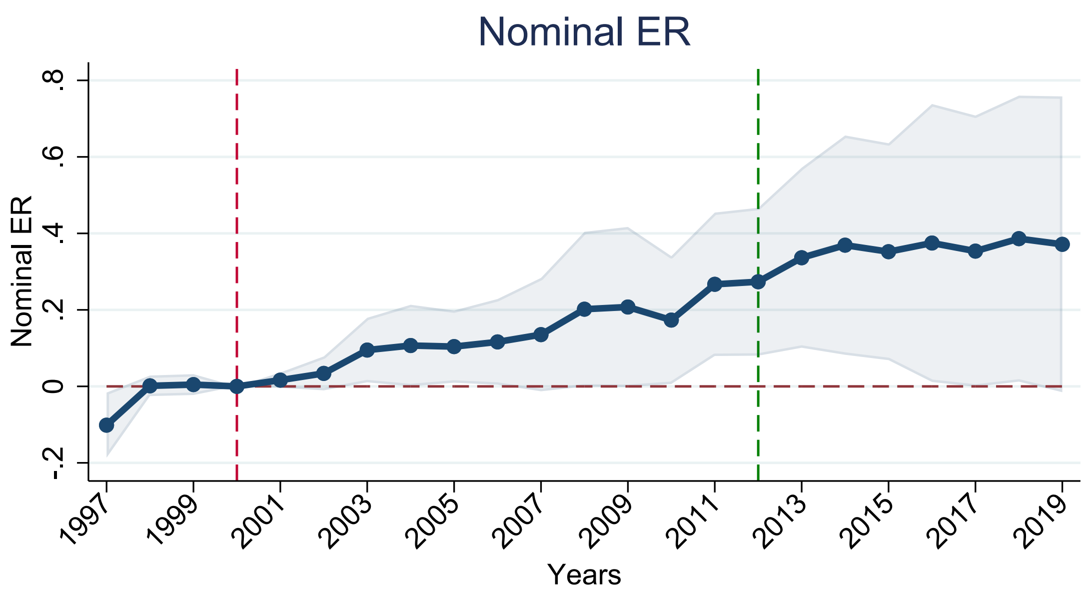
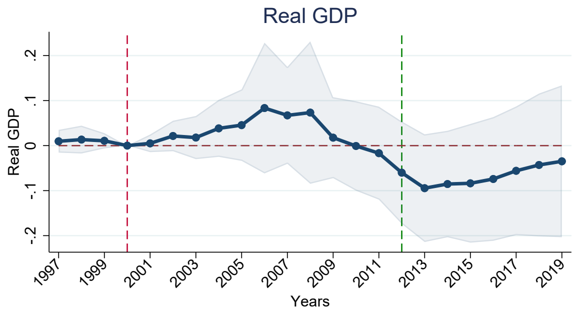
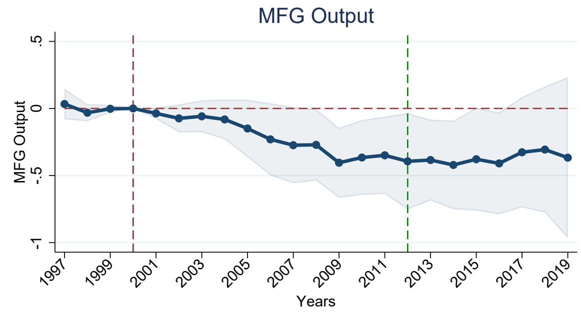


Figure A.2: Average responses to the China shock across countries.

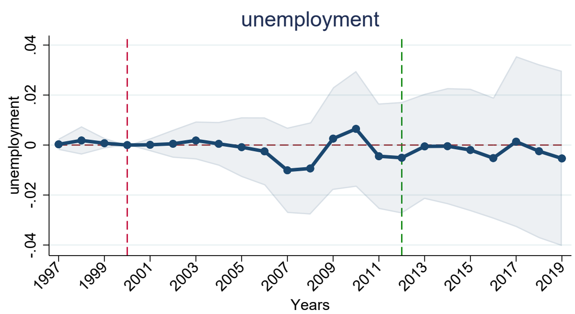
Note. The figure plots the double-difference regression result of the exchange rate against the China shock across all countries. The shaded area is the 95% confidence band for each local projection regression. The red dashed line indicates the beginning of the China shock (2000) and the green the end of the China shock (2012). On average countries' currencies depreciate in response to higher exposure to the China shock; the latter figure shows that the effect is completely driven by floaters.



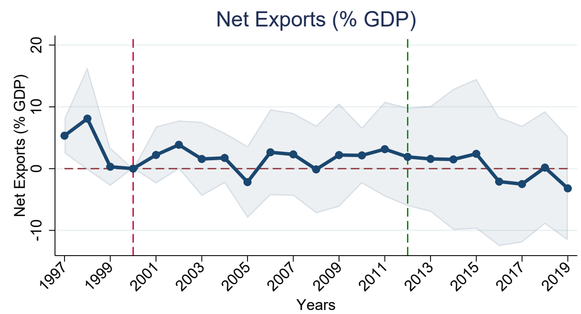
(a) Real GDP



(b) Manufacturing Output



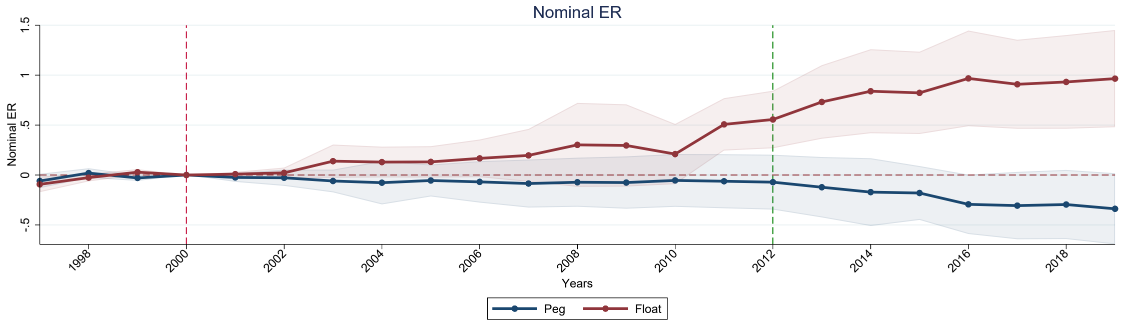
(c) Unemployment

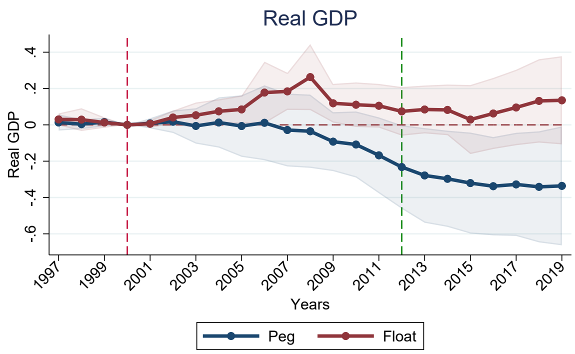


(d) Net Exports (% GDP)

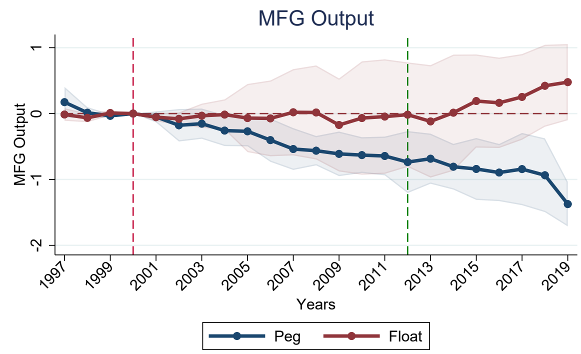
Figure A.3: Average responses to the China shock across countries.

Note. The plotted coefficient β_{1h} is the average response to the China shock, without taking into account the heterogeneity in exchange rates: this is the 'double-difference' equivalent of Figure 3. As we see, the heterogeneity in exchange rate regime masks the true effect of the China shock. The shaded area is the 95% confidence band for each local projection. The red dashed line indicates $t = 2000$, the start of the China shock and the green line $t = 2012$, the end of the China shock.

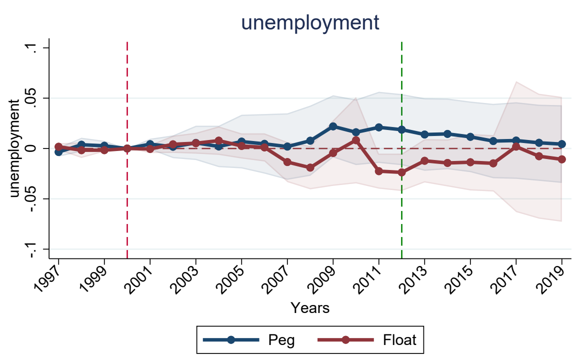




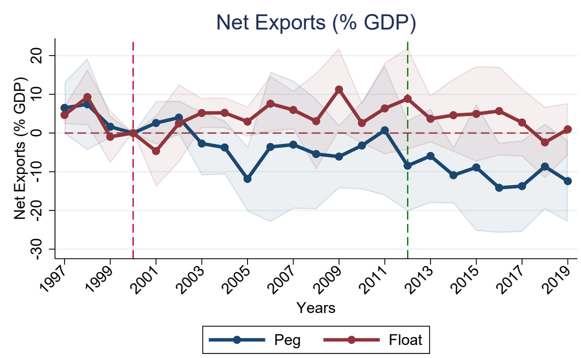
(a) Real GDP



(b) Manufacturing Output



(c) Unemployment



(d) Net Exports (% GDP)

Figure A.4: Differential response of the China shock.

Note. This regression plots the coefficient for the subset of countries where currency is pegged versus floated against the US dollar respectively. The shaded area is the 95% confidence band for each local projection regression. The red dashed line indicates $t = 2000$, the start of the China shock and the green line $t = 2012$, the end of the China shock. The figures show that the nominal exchange rate for floaters appreciated, and for floaters, higher exposure to the China hsock did not affect manufacturing output, unemployment, or net exports (red lines); in sharp contrast, greater exposure to Chinese export led to lower manufacturing output, a temporary increase in unemployment, and larger trade deficits for pegging countries (blue lines).

A.3 Causal identification and inference

In this subsection, we discuss the identification and inference properties of our shift-share instrument, in relation to recent literature on such instruments (Borusyak et al., 2022; Borusyak and Hull, 2023).

Borusyak et al. (2022) (henceforth BHJ) derive sufficient conditions for causal identification in empirical setups that measure the exposure of a shock through a 'shift-share', or an average of a set of shocks with exposure share weights. Their sufficient condition is in terms of a quasi-random assignment of the shocks: in our context, the 'shock', or the growth in global Chinese exports $\Delta \log E_C^s$ is as good as random conditional on the exposure shares s_i. This holds if the shares are exogenous (Goldsmith-Pinkham et al., 2020), or if the large-sample covariance between the export shocks g_C^s and the unobserved shocks ϵ_{ih} in the regression equation (Equation 3) is zero. Our preferred interpretation is the latter, following the China shock literature Autor et al. (2013, 2021), henceforth ADH); as highlighted in BHJ, it is *a priori* implausible that the 2000 industry shares λ_i^s are uncorrelated with the errors ϵ_{ih}, as the latter will capture unobserved industry-level shocks. As such, we interpret our empirical strategy as assuming shift exogeneity, rather than share exogeneity.

ADH studies variation within US across commuting zones, and uses Chinese export surge into other developed countries as instruments to purge US-specific demand shocks that may bias their results, adding support to their a priori justification of shift exogeneity. This is unavailable for us, as we study global surge in Chinese exports. However, if there is an unobserved global demand shock towards Chinese goods, either (1) one may interpret this as a part of the 'China shock', or (2) this demand shock violates the exogeneity condition of the ADH instrument. As such, while our analysis is reduced-form, we believe that there is a priori justification for 'global surge in Chinese exports' in each sector being as-good-as-random.

With this in mind, we follow the framework of BHJ to test for the validity and robustness of our exposure measure.

A.3.1 Industry shocks and exposure measures

For the shift-share exposure measure to be valid under the shock exogeneity assumption, it is sufficient to have that g_C^s is as good as random conditional on the shares λ_i^s (Assumption 1 of BHJ). Moreover, for the measured coefficient to be consistent, we need the effective sample size $1/E[\sum_s (\lambda_i^s)^2]$ to be large enough (Assumption 2 of BHJ). Following BHJ, we summarize the distribution of the shocks g_C^s and the industry-level weights $\lambda^s \propto \sum_i \lambda_i^s$ (normalized to add up to one).

Table A.3 reports summary statistics for the shocks and the shares.[52]. The distribution of the shock is quite regular, with the average of 1.757, a standard deviation of 1.525, and an

[52] This table is the analogue of Table 1 in BHJ.

Table A.3: Shock and share summary statistics

Mean	1.757
Standard deviation	1.525
Interquartile range	1.596
Effective sample size (1/HHI)	24.38
Largest λ^s weight	0.189
2nd largest λ^s weight	0.022
Effective sample size, SITC3	18.44
Largest λ^s, SITC3	0.214
2nd largest λ^s, SITC3	0.027
No. of shocks (SITC4 industries)	782
No. of SITC3 groups	237

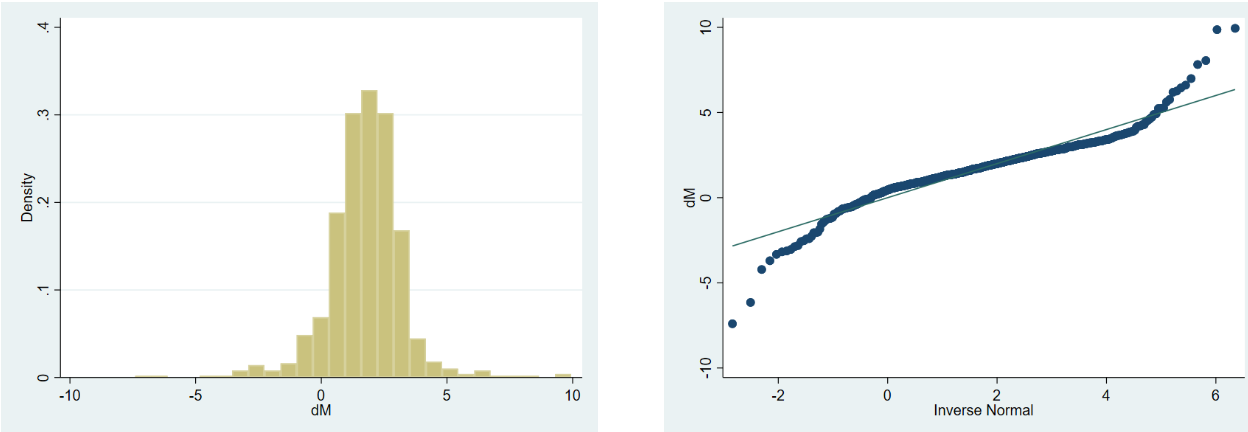
Note: The table summarizes the global China export shock g_C^s across sectors s.

interquartile range of 1.596. Figure A.5 shows the histogram of the shocks g_C^s and a Q-Q plot of the realized distribution against the quantile of the normal distribution (using the `qnorm` command of Stata) shows that the distribution is close to normal, which adds support to the shock exogeneity assumption. The inverse HHI – the "effective sample size" according to BHJ – is 24.38. This is smaller than the sample size in BHJ (191.6, 58.4 when acoross SIC3 groups), and the main cause is that some countries in our sample have high concentration in petroleum and crude oil products (code 3330, share 18.9%). Thus we have suggestive evidence that the shocks are as good as random, and the effective sample size is reasonable for causal inference.

Besides these conditions, Assumption 2 of BHJ require the shocks to be sufficiently mutually uncorrelated. BHJ recommend analyzing the correlation patterns of shocks across the industries using available industry classifications. Following their methodology, we compute intra-class correlation coefficients (ICCs) of shocks within different industry groups. We use a random effects model with nested random effects:

$$g_C^s = \mu + a_{sitc1(s)} + b_{sitc2(s)} + c_{sitc3(s)} + \epsilon_s \tag{A.1}$$

where $a_{sitc1(s)}, b_{sitc2(s)}, c_{sitc3(s)}$ respecitvely denote random effects generated by the SITC 1-digit sectors, 2-digit sectors, and 3-digit sectors respectively. We estimate Equation A.1 as a hierarchical linear model with maximum likelihood assuming Gaussian residuals. Table A.4 reports the results from this mixed linear model; there is moderate clustering of shock residuals at each level of the SITC (0.225, 0.193, 0.281), but the residual component at the 4-digit level is largest. This supports the assumption that shocks are sufficiently mutually uncorrelated.



(a) Histogram (b) Q-Q wrt normal distribution

Figure A.5: Distribution of global China export shock g_C^s

	Estimate	SE
SITC 1-digit	0.225	(0.142)
SITC 2-digit	0.193	(0.087)
SITC 3-digit	0.281	(0.089)
4-digit (residual)	1.594	(0.096)
No. of SITC1 groups	10	
No. of SITC2 groups	69	
No. of SITC3 groups	237	
No. of shocks (SITC4 industries)	782	

Table A.4: China export shock intra-class correlations

Note: This table reports intra-class correlation coefficients for the g_C^s China exprot shocks in Section 2, estimated from the hierarchical model (Equation A.1).

A.3.2 Non-random exposure

Next, we purge bias coming from non-random exposure to shocks, following Borusyak and Hull (2023). If some countries structurally have higher exposure to the quasi-random China shock because they have higher shares λ_i^s, this will create a bias in the regression coefficient; notably, in our example, if pegged countries structurally have higher (lower) shares, the estimated effect of the interaction term will be biased upwards (downwards). This is econometrically equivalent to the 'incomplete shares' issue raised in BHJ; even if the DGP for the shocks $\Delta \log E_C^s$ is truly random, if some countries have structurally high exposure shares λ_i^s, the regression coefficients will be biased.

In this subsection, we briefly explain our implied DGP, and how using $\sum_s \lambda_i^s$ is equivalent to the re-centering instrument. We assume that the shocks $g = g_C^s$ come from a distribution G with mean $E[g] = \sum_s \frac{g_C^s}{S}$. In this case, countries with higher $\sum_s \lambda_i^s$ is going to have a higher *expected* exposure $E[\lambda_i^s g_C^s]$ conditional on the DGP, and this is going to bias our regression which seeks to evaluate the effect of causal higher g_C^s on outcomes. Borusyak and Hull (2023) show that 're-centering' the exposure $S_i = \sum_s \lambda_i^s g_C^s$ by instrumenting S_i with

$$\hat{S}_i = \sum \lambda_i^s g_C^s - E[\sum_s \lambda_i^s g^s | g \in G],$$

or alternatively controlling for $E[\sum_s \lambda_i^s g^s | g^s \in G]$ in the regressions is sufficient to purge this bias. But in linear shift-share settings such as ours under conditional exogeneity of the shock, we have

$$E[\sum_s \lambda_i^s g^s | g^s \in G] = \sum_s \lambda_i^s E[g^s],$$

so this is equivalent to controlling for $\sum_s \lambda_i^s$ in the regression; this is exactly the solution for the 'incomplete shares' problem in Borusyak et al. (2022). Since we control for $\sum_s \lambda_i^s$ in our regressions, this is sufficient to purge the bias coming from non-random exposure.

B Proofs of propositions

B.1 Proofs for Subsection 3.3

In this section I prove the Propositions in Section 3.3. In the equilibrium under the exchange rate peg, I assume without loss of generality that $\bar{e} = 1$. I first highlight a number of properties of the laissez-faire equilibrium that I extensively use in the proof.

Lemma B.1. *Denote by $\omega_t = \frac{w_{Ht}}{w_{Ft}}$ the relative wage of Home at period $t \in \{0,1\}$. The following properties hold:*

(a) The real wage $\frac{w_{jt}}{P_{jt}}$ and expenditure share λ_{ijt} depend on $\{w_{Ht}, w_{Ft}\}$ only through ω_t.

(b) Home real wage $\frac{w_{Ht}}{P_{Ht}}$ increases in ω_t, while Foreign real wage decreases in ω_t.

(c) Expenditure share for Home goods λ_{Hjt} is a decreasing function of ω_t; $\lambda_{Fjt} = 1 - \lambda_{Hjt}$ is an increasing function of ω_t

(d) Home relative wage is higher in period 0: $\omega_0 > \omega_1$.

(e) The real wage of Home is higher in period 0: $\frac{w_{H0}}{P_{H0}} > \frac{w_{H1}}{w_{P1}}$.

(f) Relative inflation is higher at Foreign. If we define $\pi_j = \frac{P_{j1}}{P_{j0}}$, we have $\pi_F > \pi_H$.

Proof. (a) We have

$$\frac{w_{Ht}}{P_{Ht}} = \frac{w_{Ht}}{(P_{HHt}^{1-\sigma} + P_{FHt}^{1-\sigma})^{1/(1-\sigma)}} = \frac{w_{Ht}}{((w_{Ht}/A_{HH})^{1-\sigma} + (w_{Ft}/A_{FH})^{1-\sigma})^{1/(1-\sigma)}}$$
$$= \frac{1}{((1/A_{HH})^{1-\sigma} + (\omega_t/A_{FH})^{1-\sigma})^{1/(1-\sigma)}}$$

and analogously for w_{Ft}/P_{Ft}. Likewise, we have

$$\lambda_{Hjt} = \frac{P_{Hjt}^{1-\sigma}}{P_{Hjt}^{1-\sigma} + P_{Fjt}^{1-\sigma}} = \frac{1}{1 + (\frac{w_{Ft}/A_{Fj}}{w_{Ht}/A_{Hj}})^{1-\sigma}} = \frac{1}{1 + (\omega_t)^{\sigma-1}(\frac{A_{Hj}}{A_{Fj}})^{1-\sigma}}$$

and $\lambda_{Fjt} = 1 - \lambda_{Hjt}$. In general, the real wage and expenditure share are functions of ω_t for *any* homothetic aggregator of Home and Foreign goods $\mathcal{C}_j = \mathcal{C}_j(C_{Hjt}, C_{Fjt})$.

(b) By inspection of the previous formula, we see that when $\sigma > 1$, $\frac{w_{Ht}}{w_{Ft}}$ is increasing in ω_t.

(c) Likewise, when $\sigma > 1$, λ_{Hjt} is decreasing in ω_t.

(d) Denote by $\omega^*(\{A_{ij}\})$ the Home relative wage under a *static, flexible-price* economy under productivity $\{A_{ij}\}_{i,j\in\{H,F\}}$, which can be solved by the trade balance equation:

$$\lambda_{FH} w_H L_H = \lambda_{HF} w_F L_F \quad \Rightarrow \quad \omega^* \frac{L_H}{L_F} = \frac{\lambda_{HF}(\omega^*)}{\lambda_{FH}(\omega^*)}$$

Now since L_j is increasing in $\frac{w_j}{P_j}$, the left-hand side is increasing in ω^* while the right-hand side is decreasing in ω^*. Thus there is a unique ω^*.

Consider the trade shock that increases A_F. Since λ_{FH} is increasing in A_F, λ_{FH} is decreasing in A_F, we have that a higher A_F decreases the right-hand side. Thus to satisfy equality, an increase in A_F must be accompanied by a *decrease* in ω^*.

We assumed that Home relative wage ω_0 is rigid at $\omega_0 = \omega^*(\{A_{ij,-1}\})$. Given an increase in A_F, $\omega_0 = \omega^*(\{A_{ij,-1}\}) > \omega^*(\{A_{ij0}\})$. Now, if we assumed for sake of contradiction that $\omega_1 \geq \omega_0 > \omega^*(\{A_{ij0}\}) = \omega^f$, we would have

$$\omega_t \frac{L_H(\omega_t)}{L_F(\omega_t)} > \frac{\lambda_{HF}(\omega_t)}{\lambda_{FH}(\omega_t)} \text{ for } t = 0, 1$$

but this would break the lifetime trade balance condition – Home's relative wage is too high in both periods, so Home cannot balance the lifetime budget. Thus we have $\omega_0 > \omega_1$.

(e) This follows from 2 and 5.

(f) We have

$$\left(\frac{P_{Ht}}{P_{Ft}}\right)^{1-\sigma} = \frac{P_{HHt}^{1-\sigma} + P_{FHt}^{1-\sigma}}{P_{HFt}^{1-\sigma} + P_{FFt}^{1-\sigma}} = \frac{(\omega_t \frac{A_{FF}}{A_{HH}})^{1-\sigma} + (\frac{A_{FF}}{A_{FH}})^{1-\sigma}}{(\omega_t \frac{A_{FF}}{A_{HF}})^{1-\sigma} + 1}$$
$$= (\frac{A_{HF}}{A_{HH}})^{1-\sigma}(1 + \frac{(\frac{A_{HH}A_{FF}}{A_{HF}A_{FH}})^{1-\sigma} - 1}{(\omega_t \frac{A_{FF}}{A_{HF}})^{1-\sigma} + 1})$$

Since $\sigma > 1$ and $\frac{A_{HH}A_{FF}}{A_{HF}A_{FH}} > 1$ (Home bias, equivalently $\tau_{FH}\tau_{HF} \geq 1$), the last expression is decreasing in ω_t. Then since $\omega_0 > \omega_1$ and again $\sigma > 1$, we have $\frac{P_{H0}}{P_{F0}} > \frac{P_{H1}}{P_{F1}}$. Rearranging, we get $\pi_F > \pi_H$.

□

Using these properties, we prove the propositions.

Proposition 1. *In the pegged equilibrium, in response to a trade shock ($A_{FH} \uparrow$), Home runs a trade deficit ($B_{H1} < 0$). Moreover, if Home monetary policy does not respond ($R_{H1} = \frac{1}{\beta}$), then there is involuntary unemployment at Home ($\mu_{H0} < 0$).*

Proof. For the first part ($B_{H1} < 0$), note that Home borrows in the short-run if the following inequalities hold:

$$\underbrace{\lambda_{HF0} P_{F0} C_{F0}}_{t=0 \text{ Home exports}} < \underbrace{\lambda_{FH0} P_{H0} C_{H0}}_{t=0 \text{ Home imports}} \quad \text{and} \quad \underbrace{\lambda_{HF1} P_{F1} C_{F1}}_{t=1 \text{ Home exports}} > \underbrace{\lambda_{FH1} P_{H1} C_{H1}}_{t=1 \text{ Home imports}} \tag{B.1}$$

Invert the second inequality and multiply with the first to have

$$\frac{\lambda_{HF0}}{\lambda_{HF1}} \frac{P_{F0} C_{F0}}{P_{F1} C_{F1}} < \frac{\lambda_{FH0}}{\lambda_{FH1}} \frac{P_{H0} C_{H0}}{P_{H1} C_{H1}}$$

Rearrange to have:

$$\frac{\lambda_{HF0}/\lambda_{HF1}}{\lambda_{FH0}/\lambda_{FH1}} < \frac{\pi_F}{\pi_H} \frac{C_{H0}/C_{H1}}{C_{F0}/C_{F1}} \tag{B.2}$$

where $\pi_j = \frac{P_{j1}}{P_{j0}}$ denote inflation in country j. Note that if $B_1 > 0$, both inequalities are flipped in Inequality B.1, so we have the exact opposite inequality, so Inequality B.2 is a necessary and sufficient condition for Home borrowing. Since both countries face the same nominal interest rate under a peg, we have

$$C_{j0}^{-1/\gamma} = \beta(1+i)\frac{1}{\pi_j} C_{j1}^{-1/\gamma} \quad \Rightarrow \quad \frac{C_{j0}}{C_{j1}} = [\beta(1+i)\pi_j^{-1}]^{-\gamma}$$

Use this to rewrite Inequality B.2 as

$$\frac{\lambda_{HF0}/\lambda_{HF1}}{\lambda_{FH0}/\lambda_{FH1}} < [\frac{\pi_F}{\pi_H}]^{1-\gamma} \Leftrightarrow B_{H1} < 0$$

(Note that the left-hand-side is the first 'variation in terms-of-trade across time' governed by σ, while the right-hand-side is the second 'home bias and relative prices' governed by γ, as described in the main text.)

With the CES parametric assumption, we may rewrite the expenditure shares λ_{ij} as

$$\frac{\lambda_{HF0}}{\lambda_{HF1}} = \frac{(P_{HF0}^{1-\sigma}/P_{F0}^{1-\sigma})}{(P_{HF1}^{1-\sigma}/P_{F1}^{1-\sigma})} = \pi_F^{1-\sigma}(\frac{w_{H0}}{w_{H1}})^{1-\sigma}$$

$$\frac{\lambda_{FH0}}{\lambda_{FH1}} = \frac{(P_{FH0}^{1-\sigma}/P_{H0}^{1-\sigma})}{(P_{FH1}^{1-\sigma}/P_{H1}^{1-\sigma})} = \pi_H^{1-\sigma}(\frac{w_{F0}}{w_{F1}})^{1-\sigma}$$

Hence,

$$\frac{\lambda_{HF0}/\lambda_{HF1}}{\lambda_{FH0}/\lambda_{FH1}} = (\frac{\pi_F}{\pi_H})^{1-\sigma}(\frac{w_{H0}/w_{H1}}{w_{F0}/w_{F1}})^{1-\sigma}$$

This is smaller than $[\frac{\pi_F}{\pi_H}]^{1-\gamma}$ if and only if

$$(\frac{\pi_F}{\pi_H})^{1-\sigma}(\frac{w_{H0}/w_{H1}}{w_{F0}/w_{F1}})^{1-\sigma} < (\frac{\pi_F}{\pi_H})^{1-\gamma}$$
$$\Leftrightarrow (\frac{w_{H0}/w_{H1}}{w_{F0}/w_{F1}})^{1-\sigma} < (\frac{\pi_F}{\pi_H})^{\sigma-\gamma}$$

We have that the left-hand side is less than 1 by $\sigma > 1$ and part (d) of Lemma B.1. We have that the right-hand side is greater than 1 by $\sigma > \gamma$ and part (f) of Lemma B.1. Thus we have $RHS > 1 > LHS$.

For the second part ($\mu_{H0} < 0$ when $R_{H0} = 1/\beta$), we first have

$$v'(L_{H1}) = u'(C_{H1})\frac{w_{H1}}{P_{H1}}$$

From part (e) of Lemma B.1, we have $\frac{w_{H0}}{w_{P0}} > \frac{w_{H1}}{w_{P1}}$. At the same time, we have $u'(C_{H1}) = u'(C_{H0})$ with $R_H = \frac{1}{\beta}$. Thus, if we can show $L_{H1} > L_{H0}$, we have

$$\mu_{H0} = v'(L_{H0}) - u'(C_{H0})\frac{w_{H0}}{P_{H0}} < v'(L_{H1}) - u'(C_{H1})\frac{w_{H1}}{P_{H1}} = 0$$

We proceed to show $L_{H1} > L_{H0}$. Goods market clearing condition is $L_{Ht} = \tau_{HH}C_{HHt} + \tau_{HF}C_{HFt}$, and since $C_{H1} = C_{H0}$ and $\lambda_{HH0} < \lambda_{HH1}$ by $\frac{w_{H0}}{w_{F0}} > \frac{w_{H1}}{w_{F1}}$, we have $C_{HH0} < C_{HH1}$. Moreover, with $\sigma > 1$ and $\sigma > \gamma$, we have

$$\begin{aligned}
\frac{C_{HF0}}{C_{HF1}} &= \frac{(\frac{P_{HF0}}{P_{F0}})^{-\sigma}C_{F0}}{(\frac{P_{HF1}}{P_{F1}})^{-\sigma}C_{F1}} = \frac{(\frac{P_{HF0}}{P_{F0}})^{-\sigma}}{(\frac{P_{HF1}}{P_{F1}})^{-\sigma}} \cdot (\beta(1+i)\frac{P_{F0}}{P_{F1}})^{-\gamma} \\
&< \frac{(\frac{P_{HF0}}{P_{F0}})^{-\gamma}}{(\frac{P_{HF1}}{P_{F1}})^{-\gamma}} \cdot (\frac{P_{H1}}{P_{H0}}\frac{P_{F0}}{P_{F1}})^{-\gamma} \\
&= (\frac{P_{HF0}}{P_{HF1}}\frac{P_{H1}}{P_{H0}})^{-\gamma} = (\frac{w_{H0}}{w_{H1}}\frac{P_{H1}}{P_{H0}})^{-\gamma} < 1
\end{aligned}$$

where we have the intermediate inequality because $(\frac{P_{HF0}}{P_{F0}}/\frac{P_{HF1}}{P_{F1}}) > 1$ (which follow from $\omega_0 > \omega_1$) and $\sigma \geq \gamma$, and the last inequality from part (e) of Lemma B.1. Thus we have $C_{HH0} < C_{HH1}$ and $C_{HF0} < C_{HF1}$, so $L_{H0} < L_{H1}$, and we obtain $\mu_{H0} < 0$. □

For the next proposition, we first prove that deficits hurt future terms-of-trade.

Lemma B.2. *Suppose Home borrows more in real terms, so that $\frac{B_{H1}}{w_{H1}}$ decreases. Then $\frac{w_{H1}\bar{e}}{w_{F1}}$ falls: Home future relative wage worsens as a result of Home borrowing.*

Proof. The goods market clearing condition for Home goods at $t = 1$ can be rewritten as

$$w_{H1}L_{H1} = \lambda_{HH1}(w_{H1}L_{H1} + B_{H1}) + \lambda_{HF1}(w_{F1}L_{F1} - B_{H1})$$

Rearranging this equation and writing everything in terms of $S_{H1} = \frac{w_{H1}}{w_{F1}}$ and $b = \frac{B_{H1}}{w_{H1}}$, we may write

$$1 = \lambda_{HH1}(1 + \frac{b}{L_{H1}}) + \lambda_{HF}(\frac{1}{S}\frac{L_{F1}}{L_{H1}} - \frac{b}{L_{H1}})$$
$$b[\frac{\lambda_{HH} - \lambda_{HF}}{L_H}] = 1 - \lambda_{HH} - \lambda_{HF}(\frac{1}{S}\frac{L_F}{L_H})$$

We have $\frac{\partial \lambda_{HH1}}{\partial S}, \frac{\partial \lambda_{HF1}}{\partial S} < 0$ (Home better terms-of-trade $\iff$ Home goods more expensive), $\frac{\partial L_H}{\partial S} > 0, \frac{\partial L_F}{\partial S} < 0$ (Home better TOT $\iff$ Home workers have better real wage, want to work more). Then the RHS is increasing in S. Moreover, from home bias we have $\lambda_{HH} + \lambda_{FF} > 1 \rightarrow \lambda_{HH} > \lambda_{HF}$, so the coefficient on b is positive. Thus $\frac{\partial b}{\partial S} > 0$; then $\frac{\partial S}{\partial b} = \frac{1}{\frac{\partial b}{\partial S}} > 0$ so running more debt ($b \downarrow$) will lead to worsening terms of trade $S \downarrow$. □

Proposition 2. *In the equilibrium where policy does not respond ($R_{H1} = \frac{1}{\beta}$), the effect of a small increase of A_{FH} on Home welfare $\mathcal{U}_H$ is ambiguous, and depends on σ. For small changes in $\epsilon_A = A_{FH0} - A_{FH-1}$, we have that:*

- *When $\sigma \rightarrow 1$, we have Home welfare increases as a result of the Foreign shock: $\frac{d\mathcal{U}_H}{dA_{FH}} > 0$.*
- *When $\sigma \rightarrow \infty$, we have Home welfare decreases as a result of the Foreign shock: $\frac{d\mathcal{U}_H}{dA_{FH}} < 0$*

Proof. We first derive the first-order welfare equation 21:

$$\frac{d\mathcal{U}_H}{dA_{FH}} = \underbrace{-\frac{u'(C_{H0})}{P_{H0}}C_{FH0}\frac{dP_{FH0}}{dA_{FH}}}_{\text{cheap goods}} + \underbrace{\mu_0\frac{dL_0}{dA_{FH}}}_{\text{labor wedge}} + \underbrace{\frac{\beta u'(C_{H1})}{P_{H1}}[C_{HF1}\frac{dP_{HF1}}{dA_{FH}} - C_{FH1}\frac{dP_{FH1}}{dA_{FH}}]}_{\text{terms of trade at } t=1}$$

Home agent's lifetime utility is

$$\mathcal{U}_H = U(C_{HH0}, C_{FH0}, C_{HH1}, C_{FH1}, L_{H0}, L_{H1})$$

and is subject to the lifetime budget constraint

$$P_{HH0}C_{HH0} + P_{FH0}C_{FH0} + \frac{1}{1+i_{Ht}}(P_{HH1}C_{HH1} + P_{FH1}C_{FH1}) = w_{H0}L_{H0} + \frac{1}{1+i_{H1}}w_{H1}L_{H1}$$

Invoking the Envelope theorem, the first-order effect of A_F on $\mathcal{U}_H$ can be written as

$$\frac{d\mathcal{U}_H}{dA_{FH}} = \sum_{t=0}^{1} \sum_{i\in\{H,F\}} \frac{dU}{dC_{iHt}} \frac{dC_{iHt}}{dA_{FH}} + \sum_{t=0}^{1} \frac{dU}{dL_{Ht}} \frac{dL_{Ht}}{dA_{FH}} \tag{B.3}$$

If we denote by $\tilde{\lambda}$ the Lagrange multiplier on the lifetime budget constraint, we have:

$$\frac{dU}{dC_{iH0}} = \tilde{\lambda} P_{iH0}, \quad \frac{dU}{dC_{iH1}} = \frac{\tilde{\lambda}}{1+i_{H1}} P_{iH1}, \quad \frac{dU}{dL_{H1}} = -\frac{\tilde{\lambda}}{1+i_{H1}} w_{H1}$$

while we may have $\frac{dU}{dL_{H0}} \neq -\tilde{\lambda} w_{H0}$ because households do not choose L_{H0}: in fact, we have

$$\frac{dU}{dL_{H0}} + \tilde{\lambda} w_{H0} = -v'(L_{H0}) + \frac{u'(C_{H0})}{P_{H0}} w_{H0} = -\mu_0.$$

Plugging these into Equation B.3, we get

$$\frac{d\mathcal{U}_H}{dA_{FH}} = \tilde{\lambda} \left[\sum_{i\in\{H,F\}} (P_{iH0} \frac{dC_{iH1}}{dA_F} + \frac{P_{iH1}}{1+i_{H1}} \frac{dC_{iH0}}{dA_F}) - w_{H0} \frac{dL_{H0}}{dA_{FH}} - \frac{w_{H1}}{1+i_{H1}} \frac{dL_{H1}}{dA_{FH}} \right] - \mu_0 \frac{dL_0}{dA_{FH}} \tag{B.4}$$

Now, if we take the derivative of the budget constraint, we have

$$\begin{aligned} &\sum_{i\in\{H,F\}} \left(P_{iH0} \frac{dC_{iH0}}{dA_F} + \frac{P_{iH1}}{1+i_{H1}} \frac{dC_{iH1}}{dA_F} \right) - w_{H0} \frac{dL_{H0}}{dA_{FH}} - \frac{1}{1+i_{H1}} w_{H1} \frac{dL_{H1}}{dA_{FH}} \\ = &- \sum_{i\in\{H,F\}} \left(C_{iH0} \frac{dP_{iH0}}{dA_F} + \frac{C_{iH1}}{1+i_{H1}} \frac{dP_{iH1}}{dA_F} \right) + L_{H0} \frac{dw_{H0}}{dA_{FH}} + \frac{L_{H1}}{1+i_{H1}} \frac{dw_{H1}}{dA_{FH}} \\ = &- C_{FH0} \frac{dP_{FH0}}{dA_{FH}} - \sum_{i\in\{H,F\}} \frac{C_{iH1}}{1+i_{H1}} \frac{dP_{iH1}}{dA_F} + \frac{L_{H1}}{1+i_{H1}} \frac{dw_{H1}}{dA_{FH}} \end{aligned}$$

where the last expression follows from the fact that w_{H0} is fixed, so we have $\frac{dw_{H0}}{dA_{FH}} = \frac{dP_{HH0}}{dA_{FH}} = 0$. Now to further simplify the last term $-\sum_{i\in\{H,F\}} \frac{C_{iH1}}{1+i_{H1}} \frac{dP_{iH1}}{dA_F} + \frac{L_{H1}}{1+i_{H1}} \frac{dw_{H1}}{dA_{FH}}$, we note that the Home goods market clearing condition in period 1 is

$$L_{H1} = \frac{1}{A_H} C_{HH1} + \frac{\tau_{HF1}}{A_H} C_{HF1}$$

and $P_{HH1} = w_{H1}/A_H$ so $dP_{HH1} = \frac{1}{A_H} dw_{H1}$. From this, we can rewrite

$$
\begin{aligned}
-\sum_{i\in\{H,F\}} C_{iH1}\frac{dP_{iH1}}{dA_F} + L_{H1}\frac{dw_{H1}}{dA_{FH}} &= -C_{HH1}\frac{dP_{HH1}}{dA_F} + C_{FH1}\frac{dP_{FH1}}{dA_{FH}} + (\frac{1}{A_H}C_{HH1} + \frac{\tau_{HF1}}{A_H}C_{HF1})\frac{dw_{H1}}{dA_{FH}} \\
&= -C_{FH1}\frac{dP_{FH1}}{dA_{FH}} + \frac{\tau_{HF1}}{A_H}C_{HF1}\frac{dw_{H1}}{dA_{FH}} \\
&= -C_{FH1}\frac{dP_{FH1}}{dA_{FH}} + C_{HF1}\frac{dP_{HF1}}{dA_{FH}}
\end{aligned}
$$

Substitute everything into Equation B.4 to obtain

$$
\frac{d\mathcal{U}_H}{dA_{FH}} = -\tilde{\lambda}C_{FH0}\frac{dP_{FH0}}{dA_{FH}} - \mu_0\frac{dL_0}{dA_{FH}} + \frac{\tilde{\lambda}}{1+i_{H1}}(C_{HF1}\frac{dP_{HF1}}{dA_{FH}} - C_{FH1}\frac{dP_{FH1}}{dA_{FH}}) \tag{B.5}
$$

and we substitute in $\tilde{\lambda} = \frac{u'(C_{H0})}{P_{H0}} = \frac{\beta(1+i_{H1})u'(C_{H1})}{P_{H1}}$ to obatin Equation 21.

The terms have natural interpretations:

- The first term, $-\tilde{\lambda}C_{FH0}\frac{dP_{FH0}}{dA_{FH}}$ correspond to utility gains from cheaper consumption at $t = 0$. As A_F increases, $\frac{dP_{FH0}}{dA_{FH}}$ takes on a negative value, so the utility increases.
- The second term $-\mu_0\frac{dL_0}{dA_{FH}}$ is the *labor wedge* at $t = 0$. Labor is away from where the consumer wants to supply it. As a result of a higher A_F we have $\mu_0 < 0$ (from Proposition 1) and $dL_0 < 0$, so there is a loss in welfare.
- The third term $C_{HF1}\frac{dP_{HF1}}{dA_{FH}} - C_{FH1}\frac{dP_{FH1}}{dA_{FH}}$ can be interpreted as the terms-of-trade in $t = 1$; it pins down how much total revenue changes from an additional import versus an additional export, multiplied by the marginal utility of a dollar at $t = 1$. This is affected by both the permanent increase in A_F and the trade imbalance that is incurred that affects future terms-of-trade (Lemma B.2).

Now we can prove the proposition. Consider a small shock that increases $A_F \to A_F + \epsilon$.

When $\sigma \to 1$, we know that $\mu_0 \to 0$, and $B_{H1} \to 0$. (This is known from Cole and Obstfeld (1991), but we can directly inspect the proof of Proposition 1 and see that all the inequalities become equalities at $\sigma = 1$). So the *first-order relevant* welfare changes are the decrease in prices resulting from the productivity gains (term (1) and the productivity component of term (3)). Thus there is a welfare gain when $\sigma \to 1$.

On the other hand, as $\sigma \to \infty$, the welfare losses from term (2) are discrete. Specifically, consider the following formulation:

$$
d\mathcal{U}_H = -\tilde{\lambda}C_{FH0}dP_{FH0} - \mu_0 dL_0 + \frac{\tilde{\lambda}}{1+i_{H1}}(C_{HF1}dP_{HF1} - C_{FH1}dP_{FH1})
$$

When $0 < dA_{FH} < \epsilon$, the first and third terms are bounded by the price changes, which are also at most epsilon: so we have

$$\| - \tilde{\lambda} C_{FH0} dP_{FH0} + \frac{\tilde{\lambda}}{1+i_{H1}} (C_{HF1} dP_{HF1} - C_{FH1} dP_{FH1}) \| < \epsilon_M$$

On the other hand, as $\sigma \to \infty$, we have $L_0 \to 0$, and $\mu_0 \to \mu < 0$; there is a *discrete* loss of welfare associated with an *infinitesimal* change in A_F. As such, we have that for small ϵ and large σ, $\frac{d\mathcal{U}_H}{dA_{FH}} < 0$: there is a welfare loss associated with trade.

Remark. We conjecture that $\frac{d\mathcal{U}_H}{dA_{FH}}$ is *monotonic* in σ, so that there exists a σ^* such that there are welfare gains when $\sigma < \sigma^*$ and losses when $\sigma > \sigma^*$. This seems intuitive, as all three effects (gains from cheaper goods, labor wedge, and future terms-of-trade) should naturally be monotonic in σ. However, we are unable to prove this, and leave this as a possibility. □

B.2 Proofs for Subsection 3.4

Here we prove the propositions for the optimal policy subsection. For this, we prove the following Lemma.

Lemma B.3. *The first-order effect of a tariff and subsidy on Home welfare can be written as:*

$$d\mathcal{U}_H = - \underbrace{\mu_0 dL_0}_{\text{labor wedge}} + \frac{u'(C_{H0})}{P_{H0}} [\underbrace{t_{FH0} P_{FH0} dC_{FH0}}_{C_{H0}\text{ distortion}} - \underbrace{d(s_{HF0} P_{HF0} C_{HF0})}_{\text{cost of subsidy}}]$$
$$+ \frac{\beta u'(C_{H1})}{P_{H1}} (\underbrace{C_{HF1} dP_{HF1} - C_{FH1} dP_{FH1}}_{\text{future terms-of-trade}})$$

Proof. Re-normalize the tariffs $t_{FH0} \to t_{FH0}/P_{FH0}$, and subsidies $s_{HF0} \to s_{HF0}/P_{HF0}$ so that they have the interpretation of a 'flat addition in price', and we can renormalize them back later.

The rest of the argument is similar to the proof of Proposition 2 above. Home agent's lifetime utility is

$$\mathcal{U}_H = U(C_{HH0}, C_{FH0}, C_{HH1}, C_{FH1}, L_{H0}, L_{H1})$$

and is subject to the lifetime budget constraint

$$P_{HH0} C_{HH0} + (P_{FH0} + t_{FH0}) C_{FH0} + \frac{1}{1+i_{Ht}} (P_{HH1} C_{HH1} + P_{FH1} C_{FH1})$$
$$= w_{H0} L_{H0} + \frac{1}{1+i_{H1}} w_{H1} L_{H1} + T_{H0}$$

with $T_{H0} = t_{FH0} C_{FH0} - s_{HF0} C_{HF0}$.

Analogously to the proof of Proposition 2, the first-order effect of any policy on welfare can be written as

$$d\mathcal{U}_H = \sum_{t=0}^{1} \sum_{i \in \{H,F\}} \frac{dU}{dC_{iHt}} dC_{iHt} + \sum_{t=0}^{1} \frac{dU}{dL_{Ht}} dL_{Ht} \tag{B.6}$$

If we denote by $\tilde{\lambda}$ the Lagrange multiplier on the lifetime budget constraint, we have:

$$\begin{aligned}
\frac{dU}{dC_{HH0}} &= \tilde{\lambda} P_{HH0}, \quad \frac{dU}{dC_{FH0}} = \tilde{\lambda}(P_{FH0} + t_{FH0}) \\
\frac{dU}{dC_{HH1}} &= \frac{\tilde{\lambda}}{1+i_{H1}} P_{HH1}, \quad \frac{dU}{dC_{FH1}} = \frac{\tilde{\lambda}}{1+i_{H1}} P_{FH1} \\
\frac{dU}{dL_{H0}} &= -\mu_0 - \tilde{\lambda} w_{H0}, \quad \frac{dU}{dL_{H1}} = -\frac{\tilde{\lambda}}{1+i_{H1}} w_{H1}
\end{aligned}$$

Plugging these into Equation B.6, we get

$$\begin{aligned}
d\mathcal{U}_H =& \tilde{\lambda} \left[\sum_{i \in \{H,F\}} \left(P_{iH0} dC_{iH0} + \frac{P_{iH1}}{1+i_{H1}} dC_{iH1} \right) - w_{H0} dL_{H0} - \frac{w_{H1}}{1+i_{H1}} dL_{H1} \right] \\
&+ \tilde{\lambda} t_{FH0} dC_{FH0} - \mu_0 dL_0
\end{aligned}$$

Now the household lifetime budget constraint, with the tax revenue plugged in, is

$$\begin{aligned}
& P_{HH0} C_{HH0} + P_{FH0} C_{FH0} + \frac{1}{1+i_{Ht}} (P_{HH1} C_{HH1} + P_{FH1} C_{FH1}) \\
&= w_{H0} L_{H0} + \frac{1}{1+i_{H1}} w_{H1} L_{H1} - s_{HF0} C_{HF0}
\end{aligned}$$

Take the derivative of this, and rearrange to obtain

$$\begin{aligned}
& \sum_{i \in \{H,F\}} \left(P_{iH0} dC_{iH0} + \frac{P_{iH1}}{1+i_{H1}} dC_{iH1} \right) - w_{H0} dL_{H0} - \frac{1}{1+i_{H1}} w_{H1} dL_{H1} \\
=& \frac{1}{1+i_{H1}} (C_{HF1} dP_{HF1} - C_{FH1} dP_{FH1}) - d(s_{HF0} C_{HF0})
\end{aligned}$$

where we use the fact that $dP_{HH0} = dP_{FH0} = dw_{H0} = 0$ by rigidity, and then further simplify using the Home labor market clearing condition. Then the first-order welfare effects are given by

$$\begin{aligned}
d\mathcal{U}_H &= -\mu_0 dL_0 + \tilde{\lambda} t_{FH0} dC_{FH0} - \tilde{\lambda} d(s_{HF0} C_{HF0}) + \frac{\tilde{\lambda}}{1+i_{H1}} (C_{HF1} dP_{HF1} - C_{FH1} dP_{FH1}) \\
&= -\mu_0 dL_0 + \frac{u'(C_{H0})}{P_{H0}} [t_{FH0} dC_{FH0} - d(s_{HF0} C_{HF0})] + \frac{\beta u'(C_{H1})}{P_{H1}} (C_{HF1} dP_{HF1} - C_{FH1} dP_{FH1})
\end{aligned}$$

□

Lemma 1. *The optimal short-run tariff rate on imports t_{FH0} satisfies*

$$t_{FH0} = \frac{1}{P_{FH0}} \left[\underbrace{\frac{\mu_0}{\tilde{\lambda}} \frac{\partial L_{H0}}{\partial C_{FH0}}}_{\text{labor wedge}} - \frac{1}{(1+i_{H1})} \underbrace{(L_{HF1} \frac{\partial w_{H1}}{\partial C_{FH0}} - L_{FH1} \frac{\partial w_{F1}}{\partial C_{FH0}})}_{\text{future terms-of-trade}} + \underbrace{s_{HF0} P_{HF0} \frac{\partial C_{HF0}}{\partial C_{FH0}}}_{\text{subsidy externality}} \right] \quad \text{(B.7)}$$

The optimal short-run subsidy rate on exports s_{HF0} satisfies

$$s_{HF0} = \frac{1}{P_{HF0}} \left[- \underbrace{\frac{\mu_0}{\tilde{\lambda}} \frac{\partial L_{H0}}{\partial C_{HF0}}}_{\text{labor wedge}} + \frac{1}{(1+i_{H1})} \underbrace{(L_{HF1} \frac{\partial w_{H1}}{\partial C_{HF0}} - L_{FH1} \frac{\partial w_{F1}}{\partial C_{HF0}})}_{\text{future terms-of-trade}} - \underbrace{P_{HF0} C_{HF0} \frac{\partial s_{HF0}}{\partial C_{HF0}}}_{\text{terms-of-trade today}} \right] \quad \text{(B.8)}$$

where $\tilde{\lambda}$ is the Lagrange multiplier on the lifetime budget constraint.

Proof. Under variation in tariffs, the optimal tariff rate with $d\mathcal{U}_H = 0$ will satisfy

$$t_{FH0} = \frac{1}{P_{FH0} \frac{dC_{FH0}}{dt_{FH0}}} \left[\frac{\mu_0}{\tilde{\lambda}} \frac{dL_{H0}}{dt_{FH0}} + \frac{d(s_{HF0} P_{HF0} C_{HF0})}{dt_{HF0}} - \frac{1}{(1+i_{H1})} (L_{HF1} \frac{dw_{H1}}{dt_{FH0}} - L_{FH1} \frac{dw_{F1}}{dt_{FH0}}) \right]$$

The multiplier $\frac{1}{P_{FH0} \frac{dC_{FH0}}{dt_{FH0}}} < 0$ corresponds to the inverse elasticity of domestic demand with respect to tariffs; a lower elasticity implies a higher tariff rate. The first term is the effect of tariff on the labor wedge. Since $\frac{dL_{H0}}{dt_{FH0}} > 0$, when there is unemployment ($\mu_0 < 0$), we want a higher tariff. The second term is the effect of tariffs on subsidy revenue; a higher tariff will decrease real wage in Foreign, leading them to work/consume less, decreasing subsidy revenue. The third term is how much future terms-of-trade moves, in terms of how much marginal revenue from exports vs expenditure from imports move. A higher tariff will lead to less borrowing, leading to improving terms-of-trade, increasing the term.

In summary, when there is unemployment ($\mu_0 < 0$), the three terms inside the bracket are all negative; thus the optimal tariff t_{FH0} is *positive*.

A special case is when the Home economy is small; here today's tariffs cannot affect (1) tomorrow's terms-of-trade and (2) the subsidy revenue, so the optimal tariff is simply

$$t_{FH0} = \frac{1}{P_{FH0} \frac{dC_{FH0}}{dt_{FH0}}} \frac{\mu_0}{\tilde{\lambda}} \frac{dL_{H0}}{dt_{FH0}}$$

and this immediately shows that (1) the tariff is positive and (2) the tariff leaves some unemployment ($\mu_0 < 0$; otherwise, we have a contradiction.)

Now, considering variation in subsidies, we have

$$s_{HF0} = \frac{1}{P_{HF0}\frac{dC_{HF0}}{ds_{HF0}}}[-P_{HF0}C_{HF0} + t_{FH0}P_{FH0}\frac{dC_{FH0}}{ds_{HF0}} - \frac{\mu_0}{\tilde{\lambda}}\frac{dL_{H0}}{ds_{HF0}} + \frac{1}{(1+i_{H1})}(L_{HF1}\frac{dw_{H1}}{ds_{HF0}} - L_{FH1}\frac{dw_{F1}}{ds_{HF0}})]$$

The multiplier $\frac{1}{P_{HF0}\frac{dC_{HF0}}{s_{HF0}}} > 0$ corresponds to the inverse elasticity of foreign demand with respect to exports, and is positive. The first term is the resource cost of the subsidy; it costs to sell cheap goods. The second term is how much consumption distortion by tariffs is affected by subsidies; with a positive tariff, domestic subsidies will be a resource cost that reduces spending overall. The last two terms deliver similar intuition to the tariff case, with both forces implying a *positive* subsidy. □

Proposition 3. *If there is unemployment at the zero-tariff economy ($\mu_{H0} < 0$ when $t_{FH0} = 0$), the optimal tariff t_{FH0} is positive and is increasing in the size of the trade shock A_{FH0}.*

Proof. When $\mu_{H0} < 0$, all three terms in the optimal tariff formula (Equation 23) are positive:

- The first term is positive since an increase in imports C_{FH0} reduce demand for Home labor.
- the second is positive since an increase in C_{FH0} decrease w_{H1} relative to w_{F1} tomorrow (transfer affecting future terms-of-trade effect).
- The third term is positive since an increase in C_{FH0} is associated with an increase in exports C_{HF0}.

Likewise, all three forces increase when the magnitude of A_{FH0} increases. □

Proposition 4. *When $\gamma = 1$, optimal monetary policy R_{H1} satisfies the following equation:*

$$0 = \underbrace{-\mu_0\frac{dL_0}{dR_{H1}}}_{\text{wedge}} + \tilde{\lambda}_r[\underbrace{R_{H1}t_{FH0}\frac{P_{FH0}}{P_{H0}}\frac{dC_{FH0}}{dR_{H1}}}_{\text{tariff fiscal externality}} + \underbrace{(NX_0)}_{\text{intertemporal TOT}}], \tag{B.9}$$

where $\tilde{\lambda}_r$ is the Lagrange multiplier on the Home lifetime real budget constraint normalized by P_{H0}.

As a special case, when $t_{FH0} = 0$, the optimal monetary policy R_{H1} is such that $\mu_0 > 0$: it is optimal to loosen monetary policy beyond clearing the output gap.

Proof. Since the central bank is choosing the real rate R_{H1}, we rewrite the budget constraint to incorporate R_{H1}:

$$R_{H1}\frac{1}{P_{H0}}(P_{HH0}C_{HH0}+(P_{FH0}+t_{FH0})C_{FH0})+\frac{1}{P_{H1}}(P_{HH1}C_{HH1}+P_{FH1}C_{FH1})$$
$$=R_{H1}\frac{1}{P_{H0}}(w_{H0}L_{H0}+T_{H0})+\frac{w_{H1}}{P_{H1}}L_{H1}$$

Then the Lagrange multiplier on this *real* budget constraint is $\tilde{\lambda}_r=\frac{u'(C_{H0})}{R_{H1}}=\beta u'(C_{H1})$

Recall that the central bank's monetary policy rule sets interest rate according to Equation 5:

$$\log(1+i_{H1})=-\log(\beta)+\log(\frac{P_{H1}}{P_{H0}})+\epsilon_{H0}\ \Leftrightarrow\ R_{H1}=\frac{1}{\beta}\exp(\epsilon_{H0})$$

We consider variations in $\exp(\epsilon_{H0})$ that leave inflation constant; notably, P_{H1} does not move in this variation.

Transform the marginal change in utility in a way analogous to Lemma B.3 to write

$$d\mathcal{U}_H=\tilde{\lambda}_r\left[\sum_{i\in\{H,F\}}\left(R_{H1}\frac{P_{iH0}}{P_{H0}}dC_{iH0}+\frac{P_{iH1}}{P_{H1}}dC_{iH1}\right)-R_{H1}\frac{w_{H0}}{P_{H0}}dL_{H0}-\frac{w_{H1}}{P_{H1}}dL_{H1}\right]$$
$$+\tilde{\lambda}_rR_{H1}\frac{t_{FH0}}{P_{H0}}dC_{FH0}-\mu_0dL_0$$

Taking the derivative of the budget constraint, we get:

$$\sum_{i\in\{H,F\}}\left(R_{H1}\frac{P_{iH0}}{P_{H0}}dC_{iH0}+\frac{P_{iH1}}{P_{H1}}dC_{iH1}\right)-R_{H1}\frac{w_{H0}}{P_{H0}}dL_{H0}-\frac{w_{H1}}{P_{H1}}dL_{H1}$$
$$=\frac{1}{P_{H1}}(C_{HF1}dP_{HF1}-C_{FH1}dP_{FH1})+dR_{H1}(\frac{1}{P_{H0}}NX_{H0})$$

where $NX_{H0}=(w_{H0}L_{H0}+T_{H0})-P_{HH0}C_{HH0}-(P_{FH0}+t_{FH0})C_{FH0}=\frac{B_{H1}}{R_{H1}}$ is the net export in period 0. Plugging this in and replacing $t_{FH0}\to t_{FH0}P_{FH0}$, we get

$$d\mathcal{U}_H=-\mu_0dL_0+\tilde{\lambda}_r[R_{H1}\frac{t_{FH0}P_{FH0}}{P_{H0}}dC_{FH0}$$
$$+\frac{1}{P_{H1}}(C_{HF1}dP_{HF1}-C_{FH1}dP_{FH1})+dR_{H1}(\frac{1}{P_{H0}}NX_{H0})]$$

Now we note that when $\gamma=1$, the equilibrium level of real balances $\frac{B_{H1}}{P_{H1}}$ do not depend on R_{H1}. This is because after any change in $R_{H1}\to\zeta R_{H1}$ for some constant ζ, the equilibrium conditions exactly hold if we replace C_{ij1},C_{i1},L_{i1} with $\zeta C_{ij1},\zeta C_{i1},\zeta L_{i1}$; monetary policy affects period 0 without affecting any real variables in period 1. (We can verify by inspecting the equilibrium conditions)

Thus, the period 1 variables do not depend on R_{H1}, and under the optimal monetary policy, the above equation becomes

$$0 - \mu_0 dL_0 + \tilde{\lambda}_r [R_{H1} \frac{t_{FH0} P_{FH0}}{P_{H0}} dC_{FH0} + dR_{H1} (\frac{1}{P_{H0}} NX_{H0})] \tag{B.10}$$

which is exactly the equation in the proposition. □

C Derivations and microfoundations

In this section, we derive the equations in the main text in 4.

C.1 Equilibrium in the quantitative model

The equations characterizing the equilibrium (Definition 2) in the case when China pegs is given by the following conditions:

(a) Family optimization:

$$P_{jt} = \prod_s (P^s_{jt})^{\alpha^s_j} \tag{C.1}$$

$$P^s_{jt} = [\sum_i ((1+t^s_{ijt})P^s_{ijt})^{1-\sigma_s}]^{\frac{1}{1-\sigma_s}} \tag{C.2}$$

$$\lambda^s_{ijt} = \frac{((1+t^s_{ijt})P^s_{ijt})^{1-\sigma_s}}{\sum_k ((1+t^s_{kjt})P^s_{kjt})^{1-\sigma_s}} \tag{C.3}$$

$$\tilde{\lambda}_{it} = \frac{u'(C_{it})}{P_{it}} \tag{C.4}$$

$$u'(C_{jt}) = \beta\hat{\delta}_{jt}(1+i_{jt})\frac{P_{jt}}{P_{jt+1}}u'(C_{jt+1}) \tag{C.5}$$

$$1 + i_{it} = (1+i_{jt})\frac{e_{ijt+1}}{e_{ijt}} \tag{C.6}$$

$$P_{jt}C_{jt}\bar{L}_j + \frac{1}{1+i_{jt}}B_{jt+1} \leq B_{jt} + \sum_s W^s_{jt}\ell^s_{jt}L^s_{jt} + \Pi_{jt} + T_{jt} \tag{C.7}$$

(b) Firm optimization: if R^s_{jt} is total revenue of sector s in country j at time t, we have

$$P^s_{ijt} = e_{ijt}\tau^s_{ijt}\frac{1}{A^s_{it}}(W^s_{it})^{\phi^s_i}\prod_n (P^n_{it})^{\phi^{ns}_i} \tag{C.8}$$

$$W^s_{it}\ell^s_{it}L^s_{it} = \phi^s_i R^s_{it} \tag{C.9}$$

(c) Labor supply: given by New Keynesian Phillips curve

$$\log(\pi^{sw}_{it}+1) = \kappa_w(v'(\ell^s_{it}) - \frac{W^s_{it}}{P_{it}}u'(C_{it})) + \beta\log(\pi^{sw}_{it+1}+1) \tag{C.10}$$

(d) Labor reallocation and worker's value function:

$$\mu_{it}^{sn} = \frac{\exp(\frac{1}{\nu}(\beta V_{it+1}^{n} - \chi_{it}^{sn}))}{\sum_{n'} \exp(\frac{1}{\nu}(\beta V_{it+1}^{n'} - \chi_{it}^{sn'}))} \tag{C.11}$$

$$V_{it}^{s} = \tilde{\lambda}_{it} W_{it}^{s} \ell_{it}^{s} + \eta_{it}^{s} - v(\ell_{it}^{s}) + \nu \log\left(\sum_{n} \exp(\frac{1}{\nu}(\beta V_{it+1}^{n} - \chi_{it}^{sn}))\right) \tag{C.12}$$

$$L_{it+1}^{n} = \sum_{s} \mu_{it}^{sn} L_{it}^{s} \tag{C.13}$$

(e) Monetary policy and exchange rates:

$$\log(1 + i_{1t}) = r_{1t} + \phi_{\pi} \log(1 + \pi_{1t}) + \epsilon_{1t} \tag{C.14}$$

$$e_{2t} = \bar{e} \tag{C.15}$$

$$\log(1 + i_{jt}) = r_{it} + \phi_{\pi} \log(1 + \pi_{jt}) + \epsilon_{jt} \quad (j \geq 3) \tag{C.16}$$

$$\lim_{T \to \infty} B_{jT} = 0 \quad (j \geq 3) \tag{C.17}$$

(f) Market clearing conditions:

$$R_{it}^{s} = \sum_{j} e_{jit} \lambda_{ijt}^{s} \left[\alpha_{j}^{s} P_{jt} C_{jt} + \sum_{n} \phi_{j}^{sn} R_{jt}^{n}\right] \tag{C.18}$$

$$0 = \sum_{i} B_{it} e_{i1t} \tag{C.19}$$

The equilibrium is: given calibrated parameters and initial conditions $w_{j,-1}^{s}$, B_{j0}, L_{j0}^{s}, a sequence of variables $\{X_t\}_{t=0}^{\infty}$ where

$$X_t = (B_{jt}, C_{jt}, P_{jt}, e_{jt}, W_{jt}^{s}, P_{jt}^{s}, L_{jt}^{s}, \ell_{jt}^{s}, V_{jt}^{s})$$

that satisfy Equations (C.1) to (C.19). In the case where China floats its exchange rate, we replace $e_{2t} = \bar{e}$ with an analogous Taylor rule for China along with $\lim_{T\to\infty} B_{2T} = 0$.

In the next subsections, we derive each of the equations, especially the ones that are new in the quantitative setup.

C.1.1 New Keynesian Phillips curve

Suppress the country and sector index (i, s). In each labor market, the maximization problem of the labor packer ι at time t facing a labor demand curve with elasticity ϵ_w is

$$\max_{w_t(l)} \sum_{t \geq t'} \beta^{t'-t} [\tilde{\lambda}_{t'} w_{t'}(\iota) l_{t'}(\iota) - \int v(l_{t'}(\iota)) d\iota - \Phi(\frac{w_{t'}(\iota)}{w_{t'-1}(\iota)}) L_{t'}]$$

where $l_{t'}(\iota) = (\frac{w_{t'}(\iota)}{w_{t'}})^{-\epsilon_w} L_t$. The FOC wrt $w_t(\iota)$ is:

$$0 = \tilde{\lambda}_t(1-\epsilon_w)(\frac{w_t(\iota)}{w_t})^{-\epsilon} L_t + v'(l_t(\iota))\epsilon_w(\frac{w_t(\iota)}{w_t})^{-\epsilon_w - 1}\frac{L_t}{w_t} - \Phi'(\frac{w_t(\iota)}{w_{t-1}(\iota)})\frac{1}{w_{t-1}(\iota)} L_t + \beta\Phi'(\frac{w_{t+1}(\iota)}{w_t(\iota)})\frac{w_{t+1}(\iota)}{w_t(\iota)^2} L_{t+1}$$

Impose symmetry $w_t(\iota) = w_t$ and $l_t(\iota) = \ell_t$, if we let wage inflation $1 + \pi_t^w = \frac{w_t}{w_{t-1}} - 1$, the above equation becomes

$$0 = \tilde{\lambda}_t(1-\epsilon_w)L_t w_t + v'(\ell_t)\epsilon_w L_t - \Phi'(1+\pi_t^w)(1+\pi_t^w)L_t + \beta\Phi'(1+\pi_{t+1}^w)(1+\pi_{t+1}^w)L_{t+1}$$

If we let $\Phi(x) = \epsilon_w \frac{1}{2\kappa_w}(\log x)^2$, then $\Phi'(\pi) = \frac{\epsilon_w}{\kappa_w}\frac{1}{x}\log x$. Moreover, $\tilde{\lambda}_t = \frac{u'(C_t)}{P_t}$, and letting $\mu_w = \frac{\epsilon_w}{\epsilon_w - 1}$ be markup, we have

$$\log(1+\pi_t^w) = \kappa_w \underbrace{(v'(\ell_t) - w_t\frac{u'(C_t)}{P_t}\mu_w)}_{\text{output gap}} + \beta\log(1+\pi_{t+1}^w)\frac{L_{t+1}}{L_t}$$

Note that when cost of adjustment is zero, $\kappa_w \to \infty$ so output gap becomes zero. Since we are not interested in the markup that unions charge, we assume that every period we tax w_t so that wage markup is undone and any tax revenue is rebated to the household lump-sum, we have the desired New Keynesian Phillips Curve:

$$\log(1+\pi_t^w) = \kappa_w(v'(L_t) - w_t\frac{u'(C_t)}{P_t}) + \beta\log(1+\pi_{t+1}^w)\frac{L_{t+1}}{L_t}$$

C.1.2 Exchange rate determination

In Section 4, for each floating country i, we defined the exchange rate in period e_{i0} to be the unique value such that

$$\lim_{t\to\infty} B_{it} = 0. \tag{36}$$

Here we microfound this condition through the *segmented financial market* model, a reduced-form version of Itskhoki and Mukhin (2021a). We assume that the household family in country i cannot directly trade any assets with one another, and the international asset positions are intermediated by the financial sector. As in the main text, households in each country i demand a quantity B_{it+1} of home-currency bonds in time t, giving identical optimization conditions, minus the UIP condition (since we do not have free bond markets).

The financial sector features two additional types of agents that trade bonds internationally: arbitraguers and noise traders. We assume countries $i \geq 2$ have each type of them, and they trade domestic bonds and US dollars only.[53] Each period, arbitraguers of mass m_i in country i choose a zero-capital portfolio (d_{it+1}, d^U_{it+1}) such that $\frac{d_{it+1}}{R_{it}} + \frac{1}{e_{it}}\frac{d^U_{it+1}}{R_{1t}} = 0$, where $R_{it} = 1 + i_{it}$ is the gross return, or the inverse price of bonds of country i at time t, and $e_{it} = e_{i1t}$ is the value of currency i with respect to the US dollar. Their profits are rebated lump-sum to the household in i, and seek to maximize the CARA utility of the real return in units of country i goods:

$$\max_{d_{it}} \mathbb{E}_t \left[-\frac{1}{\omega} \exp\left(-\omega \frac{(R_{it} - R_{1t}\frac{e_{it+1}}{e_{it}})d_{it+1}}{P_{it+1}} R_{it} \right) \right] \tag{C.20}$$

where ω is the risk aversion parameter.

In addition, the financial market features a liquidity demand from a measure n_i of symmetric noise traders in each country $i \geq 2$. The total positions in US dollar bonds invested by noise trader in country i is modeled as an exogenous process

$$\frac{N^U_{it+1}}{1 + i_{it}} = n(e^{\psi_t} - 1) \quad \text{with} \quad \psi_t = \rho_\psi \psi_{t-1} + \sigma_\psi \epsilon_t^{\psi_t}. \tag{C.21}$$

and they invest in country i bonds equivalent to this.

Denoting the total position of arbitraguers as $D_{it+1} = m_i d_{it+1}$, we have the portfolio balance condition for each i:

$$B_{it+1} + N_{it+1} + D_{it+1} = 0 \quad \text{and} \quad B_{1t+1} + \sum_{i \geq 2}(N^U_{it+1} + D^U_{it+1}) = 0 \tag{C.22}$$

The fact that intermediaries are risk-averse $(\omega > 0)$ require them to take some compensation, and yields the *modified* UIP condition for each country with respect to the US dollar:

Lemma C.1. *(Lemma 1 of Itskhoki and Mukhin (2021a).) The equilibrium condition in the finnacial market, log-linearized around a symmetric steady-state with $\bar{B}_i = 0, \bar{R} = \frac{1}{\beta}$, is given by*

$$i_{it} - i_{1t} = \mathbb{E}_t \Delta e_{t+1} + \chi_1 \psi_t - \chi_2 b_{t+1} \tag{C.23}$$

where $\chi_1 = \frac{n}{\beta}\frac{\omega\sigma_e^2}{m}$ and $\chi_2 = \bar{Y}\frac{\omega\sigma_e^2}{m}$.

Consider the limit of this economy, first where $n \to 0$, sending the magnitude of the noise trader to zero, while fixing $\frac{\omega}{\sigma_e^2}m$ (with an appropriate adjusting financial shock volatility). The UIP deviation then becomes

$$i_{it} - i_{1t} = \mathbb{E}_t \Delta e_{t+1} - \chi_2 b_{t+1}. \tag{C.24}$$

Note that this condition can alternatively be microfounded through convex portfolio adjustment costs (Kouri, 1976) or debt-elastic interest rate premiums (Schmitt-Grohé and Uribe, 2003);

[53] This can be relaxed, and is mainly for clarity of exposition.

the business-cycle level equivalence of these models are explored in (Schmitt-Grohé and Uribe, 2003).

We highlight that under Equation C.24, the model is stationary, and when e_{it} is pursuing an independent monetary policy, we must have

$$\lim_{t \to \infty} b_{t+1} = 0, \tag{C.25}$$

in any steady-state. If we take the limit $\chi_2 \to 0$, the condition converges to

$$i_{it} - i_{1t} = \mathbb{E}_t \Delta e_{t+1} \tag{C.26}$$

which is the UIP condition, and a terminal condition given by Equation C.25.

Discussion on relevance. Why do we need an extra 'terminal' condition under UIP? This is closely related to the indeterminacy result by Kareken and Wallace (1981). Under frictionless bond markets with pure interest rate targets, the exchange rate at $t = 0$ after a shock is indeterminate. While this fact is a pure nominal result without real consequences in Kareken and Wallace (1981), in our model, each *level* of the nominal exchange has real implications on output and labor supply, as it connects with the *nominal wage anchor* from $t = -1$: different exchange rates correspond to different levels of output and demand in each country. The fact that the indeterminacy result could have real implications in setups of nominal rigidity and independent interest rates is also explored in Caballero et al. (2021), and the nonstationarity of a pure UIP model is also discussed in (Schmitt-Grohé and Uribe, 2003).

C.1.3 Labor and unemployment as extensive margin

In our current formulation, all supply of labor is at the intensive margin. We provide a microfoundation of the labor supply problem in terms of the extensive margin, following Gali (2008). We assume that each member m draws idiosyncratic productivity shocks $\{\epsilon_{it}^n(m)\}$ distributed Type 1 EV, and moving fromm sector s to n involves moving costs of χ_{it}^{sn}:

$$v(\{\epsilon_{it}^n(m)\}_n, s_{it}(m), s_{it-1}(m)) = \sum_{n,k} [\epsilon_{it}^n(m) - \chi_{it}^{sn}] \, \mathbb{I}(s_{it}(m) = n, s_{it-1}(m) = s),$$

Then, given sectoral choice $n = s_{it}(m)$, we pin down optimal work decisions at that sector (under full employment). Each member m has a disutility from wage inflation and work according to

$$\Phi\left(\iota_{it}(m), \{\pi_{it}^{w,s}\}\right) = -\iota_{it}(m) - \Phi_{it}^s(\pi_{it}^{w,s})$$

where $\iota_{it}(m)$ is the disutility from working. Once a member m is in sector n, we assume that the households draw idiosyncratic disutility from work after choosing a sector n:

$$\iota_{it}(m) = \tilde{\iota}^{\nu}, \quad \tilde{\iota} \sim_{iid} U[0,1].$$

Households decide to work if

$$\bar{v}\tilde{\iota}^{\nu} \leq \tilde{\lambda}_{it} w_{it}^{n},$$

where $\tilde{\lambda}_{it}$ is the Lagrangian multiplier on the budget constraint, and w_{it}^{n} is the wage. Then, conditional on choosing sector n, fraction $\ell \in [0,1]$ member will want to work where

$$\ell_{it}^{n} \in \arg\max_{\ell \in [0,1]} w_{it}^{n} \lambda_{it} - v(\ell)$$

with

$$v(\ell) = \bar{v} \int^{\ell} \tilde{\iota}^{\nu} d\tilde{\iota} = \bar{v} \frac{\ell^{1+\nu}}{1+\nu}.$$