Exchange Rates and Structural Change

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While macroeconomics tends to view exchange rate movements as transitory, this paper studies how persistent exchange rate realignments, arising from sustained capital flows or capital account policies, can impact longer run issues such as structural change and productivity growth. We provide empirical evidence that policies of reserve accumulation have had significant effects on the sectoral composition of output and also on industry structure, in terms of number of firms, product varieties, and sourcing of inputs in global production chains. We develop a dynamic two-country model with two sectors, firm dynamics, and international asset trade, to show how exchange rate realignment can impact longer run growth prospects. Novel to our approach is consideration of changes in industrial structure -- firm creation, number of varieties, and what we term "capture of global supply chains" -- as aspects of structural change in addition to the usual consideration of sectoral reallocation and learning-by-doing. The model is used to explore implications of the mechanism for optimal capital account policy.

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1. Introduction

The standard macroeconomic view of exchange rates and exchange rate policy is that implications for the real economy are transitory, relevant for the duration of price stickiness, and for business cycle frequencies at best. But the success of some Asian economies in promoting manufacturing growth, especially in contrast with the premature de-industrialization of other emerging markets, has led to a growing recognition that foreign reserves policies supporting sustained currency realignments can have long-lasting implications for the real economy, including longer-run issues like structural change and productivity growth. See for example, Rodrik (2008, 2016).[1] The most common formalization of a linkage of currency undervaluation to long-run productivity growth entails reallocating production from nontraded to traded sectors, where the latter sector exhibits a learning-by-doing externality (see Korinek and Serven (2016), Choi and Taylor (2022), Benigno et al. (2022), Ottonello et al. (2023)).[2]

This paper proposes a complementary mechanism by which sustained exchange rate realignment may affect structural change and growth, focusing on industrial complexity and redirection of supply chains. The economic development literature has long recognized that changes in industrial structure, in terms of greater varieties of more specialized inputs, are an integral aspect of structural change and growth, alongside of the accumulation of knowledge of the type captured by learning-by-doing noted above (see Ciccone and Matsuyama (1996), Matsuyama (2008), and Rodrik (2008)). As Matsuyama (2008) puts it: "Productivity growth is often associated with a greater indirectness of production, as many advanced technologies require a wide variety of highly specialized inputs."

This paper begins by providing empirical motivation for this channel, using panel data from 45 countries during the period of 1985 to 2007. We first document that the combination of capital controls with positive reserve accumulation is associated with gains in manufacturing

[1] Other prominent examples include Dooley et al. (2004), Aizenman and Lee (2007, 2010), Bacchetta et al. (2013), Jeanne (2013), McMillan et al. (2014), Michaud and Rothert (2014), Korinek and Serven (2016), Choi and Taylor (2022) and Benigno et al. (2022).

[2] Aizenmann and Lee (2010) rely on a standard learning-by-doing mechanism, in which the total factor productivity rises with the level of production in the previous period. Korinek and Serven (2016) assume the economy exhibits aggregate learning-by-investing spillover effects, where the aggregate level of productivity in the intermediate goods sectors rises in proportion to the change in the aggregate capital stock. Michaud and Rothert (2014) use a model where financial repression depressing consumption as a tool to correct learning-by-doing externality. Benigno et al. (2022) introduce a model that the government uses reserves policies to internalize the growth externality that appears only in the tradable sector and to provide liquidity to private agents during financial crises.

shares of employment and aggregate labor productivity in the manufacturing sector. A contribution is that we find empirical support for a linkage of productivity to an indicator of capital account policy, which is arguably more exogenous, and certainly easier to measure than indicators of real exchange rate undervaluation relative to some benchmark, typically employed in the literature. As appeal to a simple balance of payments condition is sufficient to make clear, reserve accumulation under capital controls directly implies a given trade surplus, the trigger to our mechanism – sidestepping contentious debates over the estimates of exchange rate undervaluation or the even more contentious debates over the relevant elasticities to use in evaluating the trade response. A further contribution is that we document this capital account policy also is associated with certain features of industry structure, such as the number of domestic firms, the extensive margin of trade, and domestic sourcing of inputs.[3] We argue on the basis of this evidence that the literature under-appreciates the impact that exchange rate policies can have on longer-term structural adjustment.

This paper next uses a two-country model to explore the linkage of exchange rates to structural change in industrial structure. In the asset market of the model, one country restricts private trade in international assets and adopts a policy of reserve accumulation implying currency undervaluation and net trade surplus. The goods market includes traded (manufacturing) and nontraded sectors. The traded sector features firm entry subject to a one-time sunk entry cost, as well as production chains in the form of roundabout production, where firms use as inputs a bundle of domestic and imported manufacturing goods. The model is calibrated and then used to generate a deterministic simulation tracing dynamics after the adoption of the reserve-accumulation policy. The central logic is that as a currency devaluation shifts global demand toward a country's manufacturing exports, it promotes investment in creation of new domestic manufacturing firms and varieties, with a corresponding decline in the number of manufacturing firms abroad. As the home country comes to represent a larger share of global manufacturing varieties, the home price index of manufacturing goods used as intermediates drops due to local sourcing. This increases measured labor productivity in the home manufacturing sector. We refer to this dynamic as

[3] Our finding that capital account policy by emerging markets such as China increases domestic shares of intermediate input is also consistent with Kee and Tang (2016), who document China's rising domestic content (in exports), particularly, in intermediate input sectors. They show that China's processing exporters substituted domestic for imported materials, which leads to a decline in the relative prices of domestic to imported input varieties. They empirically show that China's increasing FDI and declining input tariffs led to a greater variety of domestic materials becoming available at lower prices. Our results indicate that capital account and exchange rate policy also contributed to this process.

domestic capture of the global supply chain. In other words, as manufacturing firms are able to source more specialized inputs from nearby suppliers, the complexity of the domestic manufacturing sector is augmented, which promotes productivity growth.[4] The effect in the foreign country is the opposite, of course, with firm exit and a drop in domestic source of inputs and productivity. We suggest this dynamic may be a contributor to the premature deindustrialization observed in Rodrik (2016) and the rise in industrial polarization observed in Sposi et al. (2021).

More specifically, the main theoretical finding is that a policy of sustained reserve accumulation can induce a substantial rise in labor productivity in the manufacturing sector, and that the dynamics of this productivity growth track the dynamics of new firm creation. Reserve accumulation in the presence of capital controls directly implies a trade surplus through the balance of payments condition, and this trade surplus stimulates production in the traded goods sector. Initially, this implies a drop in labor productivity in this sector, as the rise in production is generated by a more than proportionate rise in labor input. But labor productivity rises over time as the number of domestic firms in this sector rises gradually, and the level of labor productivity surpasses the initial productivity level prior to the adoption of the reserves policy. In contrast with a transitory exchange rate depreciation commonly studied in the macroeconomic literature, the sustained currency undervaluation and trade surplus made possible by a sustained policy of reserve accumulation creates the expectation of future profits needed to motivate significant firm entry. In the foreign country, there is a corresponding fall in the number of manufacturing firms, hence firm delocation, and a shift in comparative advantage away from manufacturing. The calibrated model implies that the rise in labor productivity arising from this firm delocation mechanism can explain about half of the rise in productivity estimated from the empirical regressions. When the model is augmented with a simple specification of learning-by-doing, we find that firm delocation interacts positively with this feature, amplifying the size of the productivity gain, and making these gains more persistent after the end of the reserves policy. The augmented model can explain two-thirds of the empirical estimates of the rise in productivity.

[4] This reallocation of firms across countries has been termed “firm delocation” in the trade literature (see Ossa 2007); we apply this mechanism to the case of exchange rate movements rather than tariffs as in the trade literature, and we extend it to a case with roundabout production so that it affects productivity.

The model then is used for welfare analysis. When both mechanisms, firm dynamics and learning by doing are active, reserve accumulation raises home welfare. The short run cost of financing reserve accumulation is more than countered by the longer-run gains from productivity increases. We find that the addition of firm dynamics greatly amplifies the effect of learning by doing on welfare, and in the absence of firm dynamics, our model has no case where learning by doing on its own raises welfare. [5] The calibrated model indicates that the optimal accumulation of reserves is at a level of 5% of GDP per year, lasting 35 years.

This paper contributes to multiple literatures. It is, of course, closely related to the large literature on export-led growth (See Rodrik (2008), Aizenman and Lee (2010), Korinek and Serven (2016), Choi and Taylor (2022), and Benigno and Fornaro (2022)).[6] It contributes by proposing firm delocation as an alternative to the common explanation of learning-by-doing. Our theory implies that gains in aggregate productivity are less associated with learning within a given firm, but rather with the interconnected relationships among firms.

The paper also contributes to the recent literature on deindustrialization initiated by Rodrik (2016), which highlights that some East Asian economies have resisted the trend of premature de-industrialization experienced in some other emerging markets. Sposi et al. (2021) document a general pattern of rising polarization in industrialization among countries, in which the cross-country dispersion of the industry share of value-added has increased. They present a model where sector-biased productivity growth and sectoral trade integration drive this polarization.[7] Our model proposes that differences in government policies, regarding capital account restrictions and exchange rate policies, may be an additional mechanism contributing to this polarization, whereby sustained currency undervaluation promoting comparative advantage in manufacturing in some countries implies complementary premature deindustrialization in others.

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[5] This finding echoes that of Korinek and Serven (2016), which also find for their mechanism of learning-by-doing/investing that the static losses of reserve accumulation outweigh the dynamic gains, except in cases they describe as extreme, such as a very low level of goods market openness, no capital in the nontraded sector, or an unusually high intertemporal elasticity of substitution. We considered alternative values for analogous parameters in our model, but did not find a case where reserve accumulation of any size improves household welfare. This does not deny that various policies capital controls, as distinct from polices of reserve accumulation, can raise welfare in alternative environments with other distortions, such as frictions in the financial market.

[6] We note that in a similar vein, Brunnermeier et al. (2020) document the relation of net exports with sectoral productivity. They, however, argue that net export surpluses relative to domestic absorption provide a more favorable environment for R&D of the tradable sector, and this is the key for the endogenous sectoral growth.

[7] See also Huneeus and Rogerson (2020) and Fujiwara and Matsuyama (2020) for models of premature deindustrialization based on heterogeneous sectoral productivity growth.

We also contribute to the macro literature studying currency devaluations. While competitive devaluations have long been a staple of international macro theory and policy, our work shows how they can affect longer-un concerns such as structural change and growth.

We contribute similarly to the macroeconomic literature studying firm dynamics (such as Ghironi and Meltiz, 2005), by studying the effect of exchange rate policies. It previously has been argued in this literature that exchange rate fluctuations are too transitory to influence long-rerun considerations such as firm entry subject to sunk cost (see Ruhl 2008).

This paper also contributes something new to the trade literature studying firm delocation. While the trade literature has studied firm delocation in the context of tariffs that raise demand and hence firm creation, we study the use of capital account policy and exchange rate management as an alternative to tariffs. Further, while the trade literature was limited to an environment of balanced trade, we show that allowing for unbalanced trade (net exports) provides a powerful tool for generating a large amount of firm delocation. In this regard, our work is related to Epifani and Gancia (2017), which studies the interaction of the classic transfer problem with firm delocation. We differ in taking a macro perspective that explicitly models the capital account and exchange rate policy needed to generate the net trade flows, in studying the implications for productivity growth, in comparing the production delocation mechanism to learning-by-doing, and in providing empirical evidence for this mechanism.

While our empirical work is not specific to China, the paper is related to recent work on macro policy under capital controls in China. Chang et al. (2015) studies an environment of capital controls, managed exchange rates, and sterilized intervention; but while their focus is on optimal monetary policy aimed at macro stabilization of business cycle responses to external shocks, our focus is on the medium-run implications of sustained currency undervaluation. Chang et al. (2019) studies the implications of Chinese reserve requirements for aggregate productivity, and like us, this depends on implications of this policy for reallocation between two sectors; however, the reserves in their case concern bank reserve requirements in a closed economy, not the accumulation of foreign currency reserves. Liu et al. (2021) is closer in that it studies the implications of capital controls for a tradeoff between aggregate productivity and the efficiency of intertemporal consumption allocations. They even provide a case where (outflow) capital controls potentially can promote aggregate productivity, by directing private saving to finance domestic private firms, which are assumed more productive than state-owned enterprises. We differ in studying a mechanism based on firm dynamics, and also in focusing on the positive question of explaining our empirical result of rising productivity.

The paper also is distinct from related theoretical work studying firm delocation in Bergin (2022). First, this paper differs in that it has an empirical contribution, providing evidence of the production relocation mechanism in response to reserves and exchange rate policies. Second, this paper differs in studying the implications for labor productivity rather than comparative advantage. Correspondingly, the theoretical model differs in studying an environment with one traded good, rather than two traded goods where the issue of comparative advantage can arise. The paper is also distinct from related empirical work in Bergin et al. (2022), in that it is the first to provide empirical evidence of a firm delocation channel linking reserves and exchange rate policies to productivity growth, proposing metrics in terms of firm numbers, extensive margin of trade, and domestic input shares.

The next section of the paper describes the data and presents empirical evidence. Section 3 presents a theoretical model along with some analytical results. Section 4 derives theoretical implications by model simulation, along with sensitivity analysis, and a comparison of production delocation with learning-by-doing. Section 5 conducts welfare analysis [to be completed]. Section 6 concludes.

2. Empirical Motivation

2.1. Data

Our sample includes 45 countries—22 emerging market economies and 23 advanced economies for 1985-2007 before the global financial crisis. A novel feature of this paper is to construct sectoral labor productivity data. We split sectors into manufacturing and non-manufacturing, where the latter includes all other sectors but manufacturing. We use the manufacturing sector as the tradable goods sector, and all other sectors are to be the non-tradable goods sector. For the labor productivity measure for country j, we use the following,

$$LP_{j,t}^{s} = \left(\frac{VA_t^{s}}{PVA^{s}{}_t}\right)/L^{s}{}_t \tag{1}$$

where s stands for the sector; $VA\ \ ^{s}, PVA^{s}, L^{s}$ stand for values added, price deflator, and the employment of sectors s, respectively. Sectoral value added is first deflated by the sectoral price index. Then we further divide real value added by employment to construct average labor productivity. Our sectoral data come from several different sources, including World Input-Output Database (WIOD), EU KLEMS and WKLEMS, OECD, STAN, and GGDC 10 sector database. See Appendix A.1 for more detailed productivity measure construction.

Our main variables of interest include the firm dynamics channels of capital account policy on productivity growth. We first construct a variable that captures firms' new entry and exit in the export market using the extensive margins of trade (e.g., Bergin and Lin, 2012). We employ panel data which cover product exports from 1985 to 2007. The trade data of 1985–2000 come from the NBER-UN World Trade Data set, developed by Feenstra et al. (2005). The trade data after 2000 come from the UN Comtrade dataset (https://comtrade.un.org/). We use annual bilateral trade flows at the four-digit Standard International Trade Classification with some adjustments for UN trade data.[8]

The extensive margin of exports is measured following Hummels and Klenow (2005), which is based on the consumer price theory in Feenstra (1994). The extensive margin of exports from country *j* to country *m* in year *t*, denoted by EXM_{jt}^{m}, is defined as

$$EXM_{jt}^{m} = \frac{\sum_{i \in I_{m,t}^{j}} X_{m,i,t}^{W}}{X_{m,t}^{W}} \tag{2}$$

where $X_{m,i,t}^{W}$ is the export value from the world to country *m* of product category *i* in year *t*. $I_{m,t}^{j}$ is the set of observable product categories in which country *j* has positive exports to country *m* in year *t*, and $X_{m,t}^{W}$ is the aggregate value of world exports to country *m at t*. The extensive margin is a weighted count of *j*'s categories relative to all categories exported to *m*, where the categories are weighted by their importance in the world's exports to country *m*. Then, we calculated an average of EXM_{jt}^{m} over countries *m* and derive EXM_{jt}.

The intensive margin of exports from country *j* to *m*, denoted as INM_{jt}^{m} is defined as

$$INM_{jt}^{m} = \frac{X_{m,t}^{j}}{\sum_{i \in I_{m,t}^{j}} X_{m,i,t}^{W}} \tag{3}$$

where $X_{m,t}^{j}$ is the total export value from country *j* to country *m* at t. The intensive margin is measured as *j*'s export value relative to the weighted product categories in which country *j* exports

[8] The data for 1984–2000 only had values in excess of \$100,000, for each bilateral flow. Thus, for the data since 2001, we set the cutoff of exports as \$100,000, which implies that goods are considered nontradable if an export value of the product category is less than \$100,000. See also Bergin and Lin (2012).

to country m.[9] We also calculate an average of INM_{jt}^{m} over countries m and derive INM_{jt}. With the same level of share of world exports to country *m* at time *t*, the measurement implies that country *j* has a higher extensive margin measure if it exports many different categories of products to country m, whereas it has a higher intensive margin if country *j* only export a few categories to country m.

While the extensive margins capture a firm's entry and exit in the export market, we also introduce the number of domestic firms listed on the country's stock exchanges to explicitly count changes in the number of firms in the domestic market. Note that this variable is reported per million people at the end of each year and does not include investment companies, mutual funds, or other collective investment vehicles. The data is collected from the Global Financial Development Database, World Bank. We convert it by multiplying by population.

Another important variable for firm dynamics is domestic intermediate input share (DIS), which is defined as a ratio of domestic intermediate input to total intermediate input (the sum of domestic intermediate input and imported intermediate input). To construct this measure, we utilize two data sources. First, we obtain the total intermediate input value from KLEMS.[10] The World KLEMS project provides gross output, labor, capital, and intermediates in current local currency by industry, which are available for 27 countries in our sample (see Table 1 for the list of countries). Second, we collect imported intermediate input value in the current US dollars from WITS, World Bank.[11] Since the total intermediates from the KLEMS are in the local currency unit, we convert it to the current price US dollars using the nominal exchange rate. Then, we compute domestic intermediate input by subtracting imported intermediate input from total intermediates in the manufacturing industry. For robustness check, we use intermediate in total industries, but the results are consistent.

[Insert Table 1 about here]

For capital account policy (CAP), we utilize capital controls and reserve accumulation. For capital control measures, we modify Chinn and Ito (2008)'s capital control index, which they

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[9] Therefore, multiplying the intensive margin by the extensive margin can get country *j*'s share of world exports to country *m*.

[10] World KLEMS (https://www.worldklems.net/wkanalytical). Also see EU(https://euklems.eu) and Latin America KLEMS(http://laklems.net/)

[11]Please check (https://wits.worldbank.org/CountryProfile/en/Country/WLD/Year/1988/TradeFlow/Import/Partner/all/Product/UNCTAD-SoP2)

construct using the Annual Report on Exchange Arrangements and Exchange Restrictions at IMF, as follows,

$$CC = 1 - KAOPEN, \tag{4}$$

where *KAOPEN* is a standardized measure of *de jure* financial openness, which is ranged from 0 (closed) to 1 (open). Note that we will interchangeably use the index of capital control with financial closedness. For productivity growth regression, we compute reserves growth, $\Delta RSRV_{it}$ is 5 year average of annual difference in reserves to GDP in the period t. Having the government's policy behavior of reserve accumulation combined with capital controls (say Pigouvian tax), private agents will decide international asset transactions endogenously (see Bergin et al. (2022) for more discussion).

We collect foreign reserves, terms of trade, trade openness from standard data sources from the World Development Indicator (WDI). Private credit is collected from the Global Financial Development Database, World Bank. For the quality of institutions, we use proprietary data, namely investment profiles from the International Country Risk Guide (ICRG). Human capital index is a percentage of complete tertiary schooling attained in the population from Barro and Lee (2013). A crisis variable contains historical banking, currency, and debt crisis events recorded by Laeven and Valencia (2020). Please also check Appendix Table A.2. for the descriptive statistics.

Following the standard cross-country growth literature, we construct annual data, then take the average of 1985-1990, 1990-1995, 1995-2000, 2000-2005, and 2005-2007 (see Bergin et al. 2022). Owing to the global financial crisis, we use only three years of information within the last period. Before moving to systematic analysis on the effect of capital account policy on productivity growth via firm dynamics. Appendix Figure 1, selecting China, plots its capital account policy and the three variables related to our firm dynamics mechanism. Here, the degree of capital account policy (CAP) can be measured as capital controls (CC) times reserves growth ($\Delta RSRV_{it}$). Since capital controls range between 0 (full capital mobility) and 1 (full capital control) and annual reserves growth is also between -0.03 to 0.1 in our data, the higher positive value of CAP (its maximum is 0.1) means the more aggressive CAP. First, China's CAP (solid blue line with circle marks) had been above the average of other countries' CAP, particularly, in the late 1990s and the early 2000s, China seemed to use reserve accumulation combined with capital controls more actively. With this trend of aggressive China's CAP, we find that China's number of listed domestic firms and extensive margins of exports also increased and were above the average of other countries. Also, while domestic intermediate shares of all countries show a decreasing trend since 1985 (e.g., Kee and Tang, 2016), a decline in China's domestic intermediate share has been much slower than the average, consistent with China's CAP pattern.

2.2. Empirical Specifications

Our baseline analysis for sectoral productivity is a cross-country panel regression, using 5-year averaged data as shown in Bergin et al. (2022). We analyze within-country variation over time to identify the effect of the capital account policy on sectoral productivity and its channels. First, we identify the effect of the capital account policy on manufacturing and non-manufacturing labor productivity growth. We have the following specification:

$$\Delta \ln(LP_{it}) = \alpha_0 + \alpha_1 \ln\big(LP_{it,0}\big) + \alpha_2 CC_{it} + \alpha_3 \Delta RSRV_{it} + \alpha_4 (CC_{it} \times \Delta RSRV_{it}) + X_{it}'\gamma + \eta_i + \rho_t + \varepsilon_{it}, \quad (5)$$

where the subscripts i and t represent specific countries and time periods. $\Delta \ln(LP_{it}) = \ln\big(LP_{it,T}\big) - \ln\big(LP_{it,0}\big)$ is the labor productivity growth in tradable and non-tradable goods sectors in period t. $\ln\big(LP_{it,T}\big)$ is a log productivity at last year, T , in the period t. $\ln\big(LP_{it,0}\big)$ is the initial level of productivity at the beginning of each period t. CC_{it} is our measure for capital controls in the period t, and we incorporate the capital control measure and its interaction with reserves. $\Delta RSRV_{it}$ is a 5 year average of annual differences in reserves to GDP in the period t. X_{it} represents a vector of explanatory variables (as described in the previous section). In particular, all controls are averaged during each period. η_i captures unobserved and time-invariant country-specific effects. This regression equation also includes a time dummy, ρ_t, to control for the common effect of a specific period. ε_{it} is the error term.

We first implement not only country fixed effect estimations but also a system GMM approach to address dynamic panel data. Arellano and Bond (1991) assert that it is crucial to allow for dynamics (i.e., including a lagged dependent variable among the regressors) in the panel estimation, and suggest a correction method that uses instruments to control for endogeneity. Particularly, we use the system generalized method of moments (GMM) estimator proposed by Arellano and Bover (1995) and Blundell and Bond (1998).[12] As the validity of the GMM estimator

[12] They pointed out that difference GMM estimator proposed by Arellano and Bond (1991) cannot account for cross-country variations and that the regressors' lagged levels might be weak instruments for the first-differences if the

depends on whether the explanatory variables' lagged values are valid instruments, we conduct a weak instrument test (Sanderson and Windmeijer, 2016), and an over-identification restriction test where failure to reject the null hypothesis gives support for the valid instruments. Lastly, we implement the specification test to check whether the error term, ε_{it}, is serially correlated; if it is not, then the first order differenced error terms $(\varepsilon_{it} - \varepsilon_{it-1})$ are expected to have a serial correlation, and the second-order differenced error terms $(\varepsilon_{it} - \varepsilon_{it-2})$ will have no serial autocorrelation.

Second, we discuss how the combined reserves and capital controls affect firm dynamics (e.g., firm delocation). We stick to 5 year averaged data and the following specification analyzes the effect of the policy mix on the entry of new firms in domestic and export markets (extensive margins), and their domestic intermediate shares. Note that we provide possible empirical evidence that a country's capital account policy significantly influences the latter three variables in Appendix Figure 1.

$$FD_{it}^{S} = \beta_0 + \beta_1 CC_{it} + \beta_2 \Delta RSRV_{it} + \beta_3 (CC_{it} \times \Delta RSRV_{it}) + H_{it}'\gamma + \eta_i + \rho_t + e_{it}, \quad (6)$$

where dependent variables, FD^S refers to firm dynamics variables such as the number of firms in a sector s, the extensive (or intensive) margins of exports, and domestic intermediate shares. CC_{it} is the measure for capital controls in the period t. $\Delta RSRV_{it}$ is a 5 year average of annual differences in reserves to GDP in the period t. Since we are focusing on the "level" dependent variables, we slightly modify our reserve variable for robustness check: $\Delta \overline{RSRV}_{it}$ is a difference in 5 year average of reserves to GDP from period *t-1* to period *t*. We also include the interaction terms of the two policies. H_{it} includes a log of real GDP per capita, a log of real GDP per capita squared, terms of trade and crisis variable. The specification follows Rodrik (2016) in that the share of the manufacturing sector follows a hump-shaped pattern along with the development path. The share increases initially as the economy takes off and starts to industrialize. However, as the development proceeds, the service sector starts to expand, and the relative size of the manufacturing sector starts to dwindle. The initial effect is controlled by the log of real GDP, and the latter by the log of real GDP squared. Additionally, we include the terms of trade to capture external factor and crisis to address sudden and unexpected shocks on firm dynamics. Our model provides the testable hypothesis that a policy mix of reserves and capital controls would prop up

regressors are persistent over time (close to a random walk process).Thus, the difference-GMM performs poorly because the past levels convey little information about future changes.

the manufacturing sector's share by increasing the firm's extensive margins and its domestic intermediate input shares (for differentiated goods). Thus, we would expect the coefficients of the combined CC and $\Delta RSRV_{it}$ to be positive.

2.3. Empirical Results: Capital Account Policy Effects on Growth and Sectoral Productivity via firm dynamics

Columns (1)-(3) of Table 2 show the results with the manufacturing (tradable) sector labor productivity, and columns (4)-(6) display the results with non-manufacturing (non-tradable) sector productivity. We first show a benchmark panel regression and then two-step GMM to control for dynamic panel structure. In the dynamic panel, we consider the initial productivity level at the beginning of each period as only the endogenous variable because expanding multiple endogenous regressors causes serious weak instrument problems.

[Insert Table 2 about here]

Interestingly, the results on capital control plus reserve accumulation are starkly different between tradable sector productivity and nontradable sector productivity. While the coefficients on the interaction terms of capital control and reserves growth are positive and significant in columns (1)-(3), those on the interaction terms turn out to be insignificant in columns (4)-(6). This means that capital account policy stimulates productivity growth in the tradable sector, but not in the nontradable sector. Our results also echo those of Bergin et al. (2022) regarding real GDP and TFP growth by analyzing at a disaggregate level. Column (1) shows that if an economy that fully restricts its capital account increases reserves to the GDP by one percentage point (0.01) in the period (5 years), it has higher labor productivity growth by 1.37 percentage points or 0.0137 [=(1.82-0.45)×0.01] during 5 years. However, those statistically strong coefficients cannot be found in the non-manufacturing sector. Note that AR(1) and AR(2) tests and the over-identification test in all columns support not only the validity of specification, but also that of instruments. A weak IV test rejects the null of weak instruments at the 10% level in columns (2), (3) and (6), except for the results with non-manufacturing labor productivity in column (5). See also Appendix Table A.2, which addresses endogeneity of reserves.

Then, we study the effect of capital account policy on three variables that reflect firm dynamics—the extensive margins of trade, the number of listed domestic firms and domestic intermediate input shares. We again use 5-year averaged data and report the results in Table 3. Column (1) of Table 3 shows the result with manufacturing labor shares. The coefficient of interaction term of capital controls and reserves growth is significantly positive, suggesting that capital account policy leads to an expansion of manufacturing labor shares. Columns (2) and (3) of Table 3 indicate that the capital account policy interaction term has a large and significant effect on the extensive margin of trade, but there is not a significant effect on the intensive margin. This partly echoes results in Freund and Pierola (2012), who found that export surges in emerging markets tend to be associated with the expansion of the extensive margin of trade, and often are preceded by currency devaluations reversing previously overvalued currencies. Our results show that this set of results also occurs for currency undervaluations associated specifically with capital account policies of capital controls and reserve accumulation. While it has been conjectured (Ruhl, 2008) that currency movements should not have an effect on extensive margins because real currency depreciations are too short-lived to affect firm decisions subject to sunk costs, the currency undervaluations we describe are not dependent on price stickiness, and hence can be much more long-lasting, sustained by capital account policies and reserve accumulation. They last long enough to affect firms' decisions about paying up-front sunk costs regarding export entry.

[Insert Table 3 about here]

Table 3 also studies the effects on another extensive margin, domestic firm creation. To our knowledge, no one has studied firm dynamics in this context previously, even though extensive recent literature on firm dynamics has shown that firm creation can be an important margin of output dynamics and growth. Estimates in column (4) indicate that firm creation rises significantly with the capital account policy with reserve accumulation. An increase in capital account policy by one standard deviation (=0.008, capital controls are more restrictive and reserves growth is higher) increases domestic firm creation by 0.097% from the mean (about 80 listed domestic firms can be created). The findings that capital account policy affects the extensive margins of exporting and firm creation will motivate our theoretical work below regarding channels by which capital account policy promotes growth.

Column (5) also introduces a new channel, the share of intermediates that are of domestic origin. Rodrik (2008) notes that one reason traded goods benefit from undervaluation is greater complexity in production, such as the prevalence of complex production chains and the use of inputs and the outputs of other firms. Our theory in the next section will predict that the share of intermediates of domestic origin will be an important predictor of gains from undervaluation. To preview, the claim is that when the devaluation raises exports and lowers imports, it also shifts domestic firms to reduce imports of intermediate inputs. The estimated coefficient on capital controls (CC) is significantly positive and that on the interaction term is also significantly positive at the 10% level, suggesting that capital account policy increases the share of domestic intermediate input.

Bergin et al. (2022) also shed light on the part of the (previous) mechanism by which capital controls affect labor and real value-added in the traded goods sector. First, Bergin et al. (2022) find a hump-shaped pattern of manufacturing share in a country's economic development, implied by the negative coefficients of the squared real log GDP terms (See their Figure 1 for a graphical representation.) This reflects the finding in Rodrik (2016) that the share of labor and real value-added in manufacturing sector initially rises with real GDP, but then decreases as the economy expands. Rodrik (2016) further notes that while this hump-shaped relationship between labor share and incomes has shifted downward in Latin American countries, Asian countries have retained a high degree of manufacturing labor share despite their rise in income. In our sample, Asian countries represent the group of countries with high reserves and relatively severe financial account restrictions. Our work suggests that the different experiences of deindustrialization by Asian countries might be related to the capital account policies adopted by these countries, fostering trade surpluses that sustain a manufacturing sector.

3. Theoretical Model

We develop a dynamic theoretical model of two-countries useful for studying the effect of capital market and exchange rate policies on firm dynamics and productivity growth. The model includes capital controls on home country residents, which allow the home government to peg the real exchange rate at a desired level through reserve accumulation. Given the pegging of exchange rates in real terms, the model dispenses with sticky prices or other nominal rigidities. The goods market features two sectors, where the traded sector is characterized by firm entry.

3.1. Goods market structure

The goods market consists of two sectors, one consisting of differentiated goods which can be internationally traded, and the other non-traded non-differentiated goods. The differentiated goods come in many varieties, produced by a time-varying number of monopolistically competitive firms in the home and foreign country, n_t and n_t* respectively, each producing a single variety. Each variety is an imperfect substitute for any other variety in this sector, either of home or foreign origin, with elasticity ϕ. We will denote the traded sector with T; we will denote the nontraded sector with N.

The overall consumption index is specified as, $C_t \equiv \left(\nu^{\frac{1}{\eta}} C_{T,t}^{\frac{\eta-1}{\eta}} + (1-\nu)^{\frac{1}{\eta}} C_{N,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$, where $C_{T,t} \equiv \left(\int_0^{n_t} c_t(h)^{\frac{\phi-1}{\phi}} dh + \int_0^{n_t^*} c_t(f)^{\frac{\phi-1}{\phi}} df \right)^{\frac{\phi}{\phi-1}}$ is the index over the endogenous number of home and foreign varieties of the differentiated manufacturing good, $c_t(h)$ and $c_t(f)$, and where ν is the weight on differentiated goods in the overall index. The corresponding welfare-based consumption price index is

$$P_t = \left(\nu P_{T,t}{}^{1-\eta} + (1-\nu) P_{N,t}{}^{1-\eta} \right)^{\frac{1}{1-\eta}}, \tag{7}$$

where

$$P_{T,t} = \left(n_t p_t(h)^{1-\phi} + n_t^* p_t(f)^{1-\phi} \right)^{\frac{1}{1-\phi}} \tag{8}$$

is the index over the prices of all varieties of home and foreign manufacturing goods, $p_t(h)$ and $p_t(f)$.

The relative demand functions for domestic residents implied from our specification of preferences are listed below:

$$C_{T,t} = \nu \left(\frac{P_{T,t}}{P_t} \right)^{-\eta} C_t \tag{9}$$

$$C_{N,t} = (1-\nu) \left(\frac{P_{N,t}}{P_t} \right)^{-\eta} C_t \tag{10}$$

$$c_t(j) = \left(p_t(j) / P_{T,t} \right)^{-\phi} C_{T,t} \text{ for varieties } j = \{h, f\} \tag{11a,b}$$

3.2. Households

The representative home household derives utility from consumption (C_t), and from holding real money balances (M_t/P_t); it suffers disutility from labor (l_t). The household derives income from working at the nominal wage rate W_t, profits rebated from home firms denoted with $\left(\Pi_t\right)$ in real terms and defined below, interest income on bonds in home currency ($i_{t-1}B_{H,t-1}$), net of government lump-sum taxes (T_t). Home households are precluded by government policy from international asset trade, and only have access to domestic currency bonds, which only can be traded domestically.

Household optimization for the home country may be written:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, l_t, \frac{M_t}{P_t}\right)$$

where utility is defined by

$$U_t = \frac{1}{1-\sigma} C_t^{1-\sigma} + \ln \frac{M_t}{P_t} - \frac{1}{1+\psi} l_t^{1+\psi} ,$$

subject to the budget constraint:

$$P_t C_t + \left(M_t - M_{t-1}\right) + \left(B_{Ht} - B_{Ht-1}\right) = W_t l_t + \Pi_t + i_{t-1} B_{Ht-1} - T_t .$$

In the utility function, the parameter σ denotes risk aversion and ψ is the inverse of the Frisch elasticity.

Household optimization implies an intertemporal Euler equation:

$$\beta\left(1+i_t\right) E_t \left[\frac{P_t C_t^{\sigma}}{P_{t+1} C_{t+1}^{\sigma}}\right] = 1 , \tag{12}$$

a labor supply condition:

$$\frac{W_t}{P_t} = l_t^{\psi} C_t^{\sigma} , \tag{13}$$

and a money demand condition:

$$\frac{M_t}{P_t} = C_t^{\sigma} \left(\frac{1+i_t}{i_t}\right) . \tag{14}$$

The problem and first-order conditions for the foreign household are analogous, except the foreign household does not face an explicit prohibition on international asset trade.

3.3. Firms in traded goods sector

In the manufacturing sector, the production of each differentiated variety follows

$$y_t\left(h\right) = \alpha_T \left[G_t(h)\right]^{\zeta} \left[l_t\left(h\right)\right]^{1-\zeta} , \tag{15}$$

where $l_t(h)$ is the labor employed by firm h, and $G_t(h)$ is a composite of differentiated goods used by firm h as an intermediate input. $G_t(h)$ is specified as an index of home and foreign differentiated varieties that mirrors the consumption index specific to differentiated goods ($C_{T,t}$). α_T is a common TFP level to all firms, and there is no firm heterogeneity.[13] If we sum across firms, $G_t = n_t G_t(h)$ represents economy-wide demand for differentiated goods as intermediate inputs, and given that the index is the same as for consumption, this implies demands for differentiated goods varieties analogous to equation (11).

There is free entry in the sector, but, once active, firms are subject to an exogenous death shock. Since all differentiated goods producers operating at any given time face the same exogenous probability of exit δ , a fraction δ of them exogenously stop operating each period. The number of firms active in the differentiated sector, n_t, at the beginning of each period evolves according to:

$$n_{t+1} = (1-\delta)(n_t + ne_t)\,, \tag{16}$$

where ne_t denotes new entrants.

To set up a firm, managers incur a one-time sunk cost, K_t, and production starts with a one-period lag. Entry costs are in units of differentiated goods, allocated over varieties analogously to demands for consumption of differentiated good in equation (11).

We now can specify total demand facing a domestic differentiated goods firm:

$$d_t(h) = c_t(h) + d_{G,t}(h) + d_{K,t}(h) \tag{17}$$

which includes the demand for consumption ($c_t(h)$) by households, and the demand by firms for intermediate inputs ($d_{G,t}(h)$), and firm entry investment ($d_{K,t}(h)$). Firms face iceberg trade cost τ for exports.[14] Market clearing for a firm's variety is:

$$y_t(h) = d_t(h) + (1+\tau)d_t^*(h)\,, \tag{18}$$

Firm profits are computed as:

$$\pi_t(h) = p_t(h)d_t(h) + e_t p_t^*(h)d_t^*(h) - mc_t y_t(h)\,. \tag{19}$$

---

[13] In the absence of firm heterogeneity, the model pins down the number of firms, n, that can divide up total demand for home products, and still imply sufficient profits per firm to justify payment of the entry cost. One reason to avoid heterogeneity in this context is that it would imply that new entrants systematically would be less productive than incumbents; yet in the case of China, where incumbent firms include less productive state-owned enterprises and new entrants are private firms, this implication may well be inappropriate.

[14] There is no fixed trade cost, so all tradable goods varieties are, in fact, traded.

where $mc_t = \zeta^{-\zeta}\left(1-\zeta\right)^{\zeta-1} P_{T,t}{}^{\zeta} W_t^{1-\zeta} / \alpha_{T,t}$ is the marginal cost.

Thus the value function of firms that enter the market in period *t* may be represented as the discounted sum of profits of domestic sales and export sales:

$$v_t\left(h\right) = E_t\left\{\sum_{s=0}^{\infty}\left(\beta\left(1-\delta\right)\right)^s \frac{\mu_{t+s}}{\mu_t}\pi_{t+s}\left(h\right)\right\},$$

where we assume firms use the discount factor of the representative household, who owns the firm, to value future profits. With free entry, new producers will invest until the point that a firm's value equals the entry sunk cost:

$$v_t\left(h\right) = P_{T,t} K_t \,. \tag{20}$$

By solving for cost minimization, we can express the relative demand for labor and intermediates as a function of their relative costs:

$$\frac{P_{T,t} G_t(h)}{W_t l_t(h)} = \frac{\zeta}{1-\zeta} \,. \tag{21}$$

And we can solve for the optimal price setting by the firm:

$$p_t\left(h\right) = \frac{\phi}{\phi-1} mc_t \,. \tag{22}$$

where *mc* is marginal cost defined above. The good price in foreign currency moves one-to-one with the exchange rate, net of trade costs:

$$p_t^*\left(h\right) = \left(1+\tau\right) p_t\left(h\right) / e_t \,, \tag{23}$$

where recall the nominal exchange rate, *e*, measures home currency units per foreign.

Note that, since households own firms, they receive firm profits but also finance the creation of new firms. In the household budget, the net income from firms may be written:

$$\Pi_t = n_t \pi_t\left(h\right) - ne_t P_{T,t} K \,.$$

In reporting our quantitative results, we will refer to the overall home gross production of differentiated goods defined as: $y_{T,t} = n_t y_t\left(h\right)$, using the fact that all firms are the same size.

3.4. Firms in non-traded sector

In the second sector, firms are assumed to be nontraded, as well as perfectly competitive. The production function for the home non-traded good is linear in labor:

$$y_{N,t} = \alpha_N l_{N,t} \,. \tag{24}$$

It follows that the price of the homogeneous goods in the home market is equal to marginal costs:

$$p_{N,t} = W_t / \alpha_N . \tag{25}$$

Analogous conditions apply to the foreign non-traded sector.

3.5. Government policies

The home government issues money (M_t) and home currency bonds (B^s_{Ht}), and levies lump sum taxes on domestic households (T_t). The home government has the ability to purchase foreign currency bonds in the international asset market, to hold as foreign currency reserves (R_{Ft}). The home government faces the following budget constraint:

$$T_t + \left(M_t - M_{t-1}\right) + \left(B^s_{H,t} - \left(1+i_{t-1}\right)B^s_{H,t-1}\right) = e_t\left(R_{F,t} - \left(1+i^*_{t-1}\right)R_{F,t-1}\right), \tag{26}$$

The corresponding budget constraint for the foreign government is:

$$T^*_t + \left(M^*_t - M^*_{t-1}\right) + \left(B^{s*}_{F,t} - \left(1+i^*_{t-1}\right)B^{s*}_{F,t-1}\right) = 0 . \tag{27}$$

where $B^{s*}_{F,t}$ is the issuance of foreign currency bonds by the foreign government.

The home government policy of international asset controls and sterilization of foreign exchange operations is similar to the model in Chang et al. (2015), designed to represent Chinese-style capital account policies.[15] As in their case, the home country's net foreign assets are equal to its reserves, and the level of reserves completely determines the trade balance and the real exchange rate.

The closed home capital market allows the home government to affect the real exchange rate by adjusting the level of reserves it holds. To match the empirical specification above, the reserves policy will be defined as a time path for the change reserves as a ratio to home GDP

$$e_t\left(R_{F,t} - \left(1+i^*_{t-1}\right)R_{F,t-1}\right)\Big/GDP_t = \Omega_t .\text{[16]} \tag{28}$$

Define the real exchange rate as usual: $rer_t = e_t P^*_t / P_t$. Reserve accumulation will imply depreciation of the home nominal exchange rate. Since the closed capital account prevents private asset trades from undoing the effect of official reserves purchases, the home government can

[15] The model simplifies several details relative to Chang et al. (2015), such as assuming the capital market is completely closed, the home government issues no bonds, and monetary policy and sterilization work through direct transfers to domestic households rather than bond issuance. Further, there is no price stickiness, and there are no external shocks in our deterministic environment.

[16] We net out interest on reserves holdings in our definition of the policy rule. This would be zero in the case where the reserve currency offers zero interest.

sterilize the effect of foreign exchange operations on the domestic money supply, so it retains control over the domestic price level. The simulations will assume that the government fully sterilizes and holds domestic money supply constant regardless of foreign exchange operations:

$$M_t = \overline{M}\,. \tag{29}$$

Given the lack of nominal frictions in the model, the specification of monetary policy is irrelevant to the results reported below.[17] We further assume that the home government holds constant its supply of domestic currency bonds:

$$B^s_{H,t} = \overline{B^s_H}\,. \tag{30}$$

Given the fixed money and bond supplies, the home government budget constraint implies that the purchase of reserves is paid for by taxes on home households.

The activity of the foreign government is modeled as simply as possible. The foreign government holds foreign money supply and government issued foreign-currency bonds constant ($M^*_t = \overline{M^*}$, $B^{s*}_{Ft} = \overline{B^{s*}_F}$).

3.6. Market clearing

The market clearing condition for the traded goods market is given in equation (18) above. Market clearing for the home non-traded good market requires:

$$y_{N,t} = C_{N,t}\,. \tag{31}$$

Labor market clearing requires:

$$l_t = \int_0^{n_t} l_t(h)\,dh = n_t l_t(h)\,. \tag{32}$$

Given the prohibition on home households purchasing foreign bonds or exporting domestic bonds, bond market clearing requires:

$$B_{Ht} = B^s_{Ht} \tag{33}$$

for the home bond, and

$$B^*_{Ft} + R_{F,t} = B^{s*}_{Ft} \tag{34}$$

for the foreign bond.

[17] It is nonetheless useful to use money as a numeraire in the model, given the fact there are multiple traded goods.

Combining household, firm and government budget constraints along with the goods market clearing condition implies a balance of payments constraint:

$$n_{t-1}e_t p_t^*\left(h\right)d_t^*\left(h\right)+P_{Ht}^*C_{H,t}^*-n_{t-1}^*p_t\left(f\right)d_t\left(f\right)-P_{F,t}C_{F,t}=e_t\left(R_{Ft}-\left(1+i_{t-1}^*\right)R_{Ft-1}\right). \quad (35)$$

This states that a home trade surplus will imply an accumulation of home reserves or net unilateral transfers.

3.7. Equilibrium and model solution

Equilibrium is defined as sequences of the following 30 home-country variables— P_t, $P_{T,t}$, $P_{N,t}$, $p_t\left(h\right)$, $p_t^*\left(h\right)$, $C_{T,t}$, $C_{N,t}$, $c_t(h)$, $c_t(f)$, $d_{G,t}(h)$, $d_{G,t}(f)$, $d_{K,t}(h)$, $d_{K,t}(f)$, C_t, l_t, i_t, $l_t(h)$, $G_t(h)$, $y_t(h)$, $\pi_t(h)$, n_t, ne_t, $d_t(h)$, $y_{H,t}$, $l_{H,t}$, W_t, B_{Ht}, M_t, T_t, $B_{H,t}^s$ —along with their 30 foreign-country counterparts, as well as $R_{F,t}$ and the nominal exchange rate, e_t, satisfying the following 30 home-country equilibrium conditions—price indexes (7, 8), price setting rules (22, 23, 25), demand conditions (9, 10, 11a, 11b), demand conditions analogous to (11a) and (11b) for traded varieties used in intermediate input and in the entry cost, consumption Euler (12), labor supply (13), money demand (14), production function (15), choice between production factors (21), market clearing for traded variety (18), definition of firm profit (19), firm entry condition (20), firm number law of motion (16), definition of home demand facing a variety (17), production function for non-traded good (24), market clearing for non-traded good (31), labor market clearing (32), government budget constraint (26), money supply rule (29), government bond supply rule (30), home bond market clearing condition (33)—along with their foreign counterparts, plus the reserves policy rule (28), and the balance of payments condition (35).

The numerical experiment assumes the economy starts in period 1 at a symmetric steady state in which holdings of reserves are $R_{F,1}=0$, and the real exchange rate is $rer_t=1$. The benchmark experiment specifies that starting in period 1 and for every period in the 50-period simulation, the home country purchases foreign currency bonds as reserves in the amount of 5% of home GDP. This policy is not anticipated by the private agents, but there are no further surprises. Solution for the dynamic model is found by solving the model as a nonlinear forward looking deterministic system using a Newton-Raphson method as described in Laffargue (1990). This method solves simultaneously all equations for each period over the simulation horizon.

3.8. Some Analytical Relationships

This section develops some analytical relationships to provide intuition regarding the main mechanism by which production delocation affects manufacturing labor productivity. A statistic of particular interest from the empirical analysis above is labor productivity. Following the definition in the empirical section, we compute the ratio of value-added divided by labor input implied by the model. To compute a measure of labor productivity specific to the traded goods sector, $LP_{T,t}$, we compute value-added by netting out the use of traded goods as inputs: [18]

$$LP_{T,t} = \frac{n_{t-1}\left(\left(p_t(h)/P_{Tt}\right)y_t(h) - G_t(h)\right)}{n_{t-1}l_t(h)}. \tag{36}$$

The counterpart for the economy as a whole is measured as total value-added over both sectors divided by total labor input:

$$LP_t = \frac{\left(n_{t-1}\left(p_t(h)y_t(h) - P_{Tt}G_t(h)\right) + P_{Nt}y_{Nt}\right)/P_t}{n_{t-1}l_t(h) + L_{Nt}}. \tag{37}$$

To understand model implications for the measure of manufacturing labor productivity, rewrite equation (36) as:

$$LP_{T,t} = \frac{\frac{p_t(h)}{P_{T,t}}y_t(h) - G_t(h)}{l_t(h)}$$

and substitute in for production from equation (15):

$$= \alpha_T \frac{p_t(h)}{P_{T,t}}\left(\frac{G_t(h)}{l_t(h)}\right)^{\zeta} - \frac{G_t(h)}{l_t(h)}.$$

[18] We use the current sector price index, P_{Tt}, both to evaluate the cost of inputs and to deflate the nominal value added, which reflects the accounting practices of the KLEMS source for our data in the empirical exercise. This price index includes changes in the set of varieties over time. First, when firms report their value added, they know the price of inputs actually paid, which changes with changes in the set of home and foreign varieties in the bundle of intermediates. So it is appropriate to measure the price of inputs using the actual index of traded goods. Second, when KLEMS computes its sector deflators, it claims to account for changes in the composition and quality of the basket of goods. This is appropriate for use in evaluating our simulation, which has the goal of tracking the long-run effect of policies after a 20-year time span, which is a different situation than tracking volatility of price indexes over short horizons in quarterly data as in Ghironi and Melitz (2005), which instead hold constant the number of firms when computing a data-consistent price index.

Then substitute in input demand from (21):

$$LP_{T,t} = \alpha_T \frac{p_t(h)}{P_{T,t}} \left(\frac{\zeta}{1-\zeta} \frac{W_t}{P_{T,t}} \right)^{\zeta} - \frac{\zeta}{1-\zeta} \frac{W_t}{P_{Tt}}$$

and for firm price setting from (22): $p_t\left(h\right) = \frac{\phi}{\phi - 1} \zeta^{-\zeta} \left(1-\zeta\right)^{\zeta-1} P_{T,t}{}^{\zeta} W_t^{1-\zeta} / \alpha_{T,t}$

$$LP_{T,t} = \left(\frac{\phi}{\phi-1} - \zeta \right) \left(\frac{1}{1-\zeta} \right) \frac{W_t}{P_{T,t}}. \tag{38}$$

This equation indicates that the manufacturing labor productivity depends on the relative cost of material inputs to labor inputs (W_t / P_T), as well as the share of intermediates in marginal costs (ζ). In particular, since $0 < \zeta < 1 < \frac{\phi}{\phi-1}$, so $\left(\frac{\phi}{\phi-1} - \zeta \right) > 0$ and $\left(\frac{1}{1-\zeta} \right) > 0$, we know that labor productivity rises with a fall in the relative cost of materials.

Further, differentiating (38) with respective to the intermediates share:

$$\frac{\partial LP_{T,t}}{\partial \zeta} = \left(\frac{1}{\phi-1} \right) \left(\frac{1}{(1-\zeta)^2} \right) \frac{W_t}{P_{T,t}} > 0 .$$

Thus, for a given relative cost of intermediates, a rise in intermediate share leads to an increase in labor productivity.

There are several channels by which this fall in the cost of materials affects our measure of labor productivity. First, by standard economic logic, the resulting rise in usage of materials inputs relative to labor in the Cobb-Douglas production function increases the marginal product of the other factor, labor. Further, the rise in the relative price of a given home variety, $p_t\left(h\right)$, to the materials price index, $P_{T,t}$, also raises the value of a firm's output relative to materials inputs, implying a higher value added. Finally, when we deflate value added, a decline in the sectoral price deflator, which is also $P_{T,t}$, works to raise value added.

It is well understood in the trade literature that firm delocation can benefit consumers by lowering the price index of traded goods, and this occurs through a saving on trade costs when a larger share of these goods are produced domestically (see Ossa, 2011; Bergin and Corsetti, 2020). This logic applies directly in the present context to the price index of material inputs, which is the same as the consumer price index of traded goods. Consider the definition of this price index (equation (8)), substituting in firm price setting behavior (equation (22) and its foreign counterpart):

$$P_{T,t} = \left(n_t \left(\frac{\phi}{\phi-1} \zeta^{-\zeta} \left(1-\zeta\right)^{\zeta-1} P_{T,t}{}^{\zeta} W_t^{1-\zeta} / \alpha_{T,t} \right)^{1-\phi} + n_t^* \left(\frac{\phi}{\phi-1} \zeta^{-\zeta} \left(1-\zeta\right)^{\zeta-1} \left(1+\tau\right) e_t P^*_{T,t}{}^{\zeta} W_t^{*1-\zeta} / \alpha^*_{T,t} \right)^{1-\phi} \right)^{\frac{1}{1-\phi}}$$

While the price index clearly is part of a simultaneous system, one can see that, holding other endogenous variables constant, a firm delocation raising n_t and lowering n_t^* will reduce the share of intermediates that are imported and thus subject to trade costs, and will thereby lower the home price index for materials. The exact effect depends, of course, on the endogenous movement of wages in the general equilibrium. To study this issue more completely, we need to rely upon numerical simulation.

3.9. Model parameterization

Where possible, parameter values are taken from standard values in the literature. Risk aversion is set at $\sigma = 2$. Time preference is set at $\beta = 0.96$, consistent with an annual frequency. Labor supply elasticity is set at $1/\psi = 1.9$ following Hall (2009). The traded goods share is set to $\nu = 0.5$, and the elasticity of substitution between traded and nontraded goods is set to $\eta = 0.5$, both taken from chapter 8 of Uribe and Schmitt-Grohé (2017). To set the elasticity of substitution among the differentiated (traded) varieties, ϕ, we draw on the estimate in Broda and Weinstein (2006) of 5.2 (the sample period is 1972-1988, with differentiated classification based on Rauch (1999)).

The firm death rate is set at $\delta = 0.1$, which is four times the standard rate of 0.025 to reflect the annual frequency. The sunk cost of entry is normalized, $\overline{K}$ =1, as are the level of productivities in both sectors: $\alpha_T = \alpha_N = 1$. The benchmark calibration of share of intermediates in differentiated goods production is set to ζ =0.55, based on Yamano and Ahmad (2006), though other values will be considered in robustness analysis.[19]

Trade cost, τ is set so that exports represent 26% of GDP, as is the average in World Bank national accounts data for both China and the OECD average from 2001-2019.[20] In model simulation, this requires a value of τ =0.33.[21] This is similar to the value of trade costs typically

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[19] This value is computed from the input-output table for the U.S. in Yamano and Ahmad (2006), based on the ratio of intermediates to the sum of intermediates plus value added in the primary manufacturing sector.
[20] See https://data.worldbank.org/indicator/NE.EXP.GNFS.ZS?locations=OE. The value for China is 25.7, and for OECD 25.6.
[21] To coincide with standard accounting definitions, differentiated goods used as intermediates are included in the measure of exports, and excluded in the measure of GDP.

assumed by macro research, such as 0.25 in Obstfeld and Rogoff (2001). But it is small compared to some trade estimates, such as 1.7 suggested by Anderson and van Wincoop (2004), and adopted by Epifani and Gancia (2017).

The benchmark experiment specifies reserve accumulation at the rate of Ω_t = 5% for each year. This was chosen as a quantitatively reasonable value, since this is the average reserve accumulation for China during the period 2006-2014.[22] For simplicity and without loss of generality, the money and government bond supplies are set at: $\overline{M} = \overline{M^*} = 0$ and $\overline{B_H^s} = \overline{B_F^{s*}} = 0$.

See Table 4 for a summary of parameter values.

[Insert Table 4 about here]

4. Model Simulation Results

The primary experiment specifies that the home country adopts a policy of purchasing reserves each year at the rate of 5% of GDP starting in period 1 and continuing for the full simulation period. In the initial period prior to the adoption of this reserves policy, the two countries start from a symmetric steady state with zero reserves holdings, balanced trade, and where the real exchange rate is 1.0. The adoption of this policy is a surprise to agents, but we assume no further surprises thereafter. We solve for the perfect-foresight equilibrium. To reflect the length of our empirical dataset, the effects of this policy are tracked for 25 years, assuming agents expect this policy to continue indefinitely. To facilitate formation of this expectation in the perfect-foresight environment, the simulation is run for 50 years assuming no change in reserves policy; robustness checks will consider the implications of alternative assumptions regarding the duration of the reserves policy.

4.1. Benchmark model simulations

Figure 1 plots the dynamic responses of selected variables as percent deviations from the initial steady state, and the top portion of Table 5 reports the values of the cumulative percentages after

[22] Based on data from International Financial Statistics from the IMF, we computed average annual change in international reserves as a share of GDP equal to 4.89% during this period. We note that the annual reserve accumulation reached a high of 14.9% of GDP in 2009.

5 years.[23] First consider the mechanics of the reserves policy. Figure 1 shows reserves purchases constant at 5% of annual GDP, as was specified above for the reserves policy.[24] As shown in Figure 1, the accumulation of reserves implies an immediate depreciation of the home real exchange rate of nearly 3%. This currency undervaluation attenuates over time, as growth dynamics in the traded goods sector described below create pressure for real exchange rate appreciation à la Balassa-Samuelson. Given that the model specifies that the home country fully sterilizes any effect of the foreign exchange operation on the domestic nominal money supply, the purchase of reserves is financed entirely by a rise in taxes levied on home households (The figure shows this tax attenuates after the initial period, as interest revenue on previously accumulated reserves offsets some of the cost to the home government of reserves purchases).

The reserves purchase each period translates directly into a trade surplus of equal size, as dictated by the balance of payments identity along with capital controls that preclude offsetting adjustment in private asset transactions. The trade surplus implies a shift in production from the nontraded sector to the traded sector. Employment in the traded (manufacturing) sector and value-added in this sector rise steeply (both around 10% in the initial period of the policy in impulse responses), while employment in the nontraded sector falls. Overall GDP rises by a substantial 6% in the initial period of the policy, largely due to a similarly sized rise in overall labor supply. This rise in labor supply can be attributed to the negative wealth effect of the rise in taxes used to finance reserve purchases.

Figure 1 shows a large rise in investment in new firm creation in the traded goods sector in the initial periods after the policy adoption. Given that capital controls prevent the home country from borrowing abroad to finance this investment, this investment requires a rise in domestic saving and hence a fall in domestic consumption in the short run, despite the rise in overall GDP. We note that the rise in the number of firms is gradual, and requires nearly 20 years to approach its new long-run level. Although the model imposes no explicit quadratic cost of changing

[23] Impulse responses report percent deviations from initial values where possible. Variables with zero steady state values, such as trade balance and tax, are reported as changes as a share of GDP. Variables measured as shares, such as the intermediate share, are reported as changes in the share.

[24] In the benchmark simulation experiment the accumulated level of reserves reaches 137% of GDP by year 20, which is somewhat higher than, but of the same order of magnitude as, the ratio of reserves to GDP in Chinese data. Using IFS data, the ratio of international liquidity to GDP reaches a high in 2018 of 105%. While the exponential reserve accumulation in the simulation is not sustainable indefinitely, it is sustainable over a finite horizon as in the experiments of this paper.

investment in the stock of firms, investment spending is spread over time because it is costly to households in terms of consumption, which cannot be smoothed due to capital controls.

[Insert Figure 1 about here]

[Insert Table 5 about here]

The gradual accumulation of firms becomes the source of growth dynamics in subsequent periods. By the end of 20 years, the number of home firms in Figure 1 rises 8.7%, even somewhat above the rise in domestic production of traded goods by 7.8%, which indicates that production in this sector is entirely at the extensive margin of new firms. Home production in the nontraded sector falls (by 1.1%), confirming the shift in production between sectors. Foreign variables move in the opposite direction to home variables by a similar magnitude, with a fall in the number of foreign firms and production in the traded goods sector. This reflects the so-called firm delocation effect, as discussed in Ossa (2011). The positive home trade balance creates a rise in the overall demand facing home producers, which encourages more firm entry in the home market, since the benefit of entry in terms of profits exceeds the sunk entry cost. The home country thus represents a greater share of the total varieties of traded goods in global production.

Consider next the implications for labor productivity in the manufacturing (traded) sector, our variable of primary interest. Figure 1 shows that labor productivity in the traded sector initially falls, but then rises over time, and eventually exceeds the initial level prior to the adoption of the reserves policy. The initial fall in productivity is due to the fact that the initial rise in output is generated primarily by raising labor input. Currency devaluation makes imported intermediates more expensive, shifting the input demand from intermediates to labor. But this changes as the number of home firms rises.

The benefits of firm delocation for productivity are similar to the benefits for consumers, which have been studied extensively in the trade literature. A rise in the share of varieties in the traded goods bundle that are produced domestically implies that consumers pay less trade cost, lowering the price index of traded goods and raising overall consumption. Similarly, the price index of intermediate inputs falls over time since a smaller share of prices in this bundle is affected by trade costs. This shifts the mix in inputs toward intermediates, and raises the productivity of home traded goods producers. Figure 1 shows that the share of domestic varieties in the intermediates bundle rises on impact due to the rise in the cost of foreign intermediates, and then rises further as the rise in the number of home producers increase the share of home traded varieties in the world.

As discussed in the analytical section (3.8), a rise in labor productivity is associated with a fall in the relative price of material inputs compared to labor inputs. Figure 1 shows that in the initial five years of the reserves policy, these prices move in the opposite direction: real wage falls and materials price rises. As discussed above, the fall in wage can be attributed the rise in labor supply following the income effect of the tax increase, and the rise in input costs due to the rising cost of imports following the devaluation. This period of rising relative price of material inputs corresponds with the temporary fall in labor productivity seen in Figure 1. But over time, as home firms and varieties rises, the home price in intermediates falls. Impulse responses in Figure 1 show that the subsequent period of rising labor productivity is associated with the fall in relative price of material inputs, as predicted in the analytical section

The bottom portion of Table 5 reports the percent changes in labor productivity over the span of the first 5 years of the reserve policy, in order to provide quantities we can use to compare to the empirical regressions.[25] In particular, column (1) shows that in the benchmark model simulation, home labor productivity in manufacturing grew 2.2% over the first 5-year period of the reserves policy. Recall that the empirical exercise regressed the cumulative productivity growth during a 5-year period on the average annual reserve accumulation during that period. One comparable metric for the simulation is to divide the productivity growth above by 5, which is the constant percentage reserve accumulation during each of the periods. This ratio is 0.446 for the benchmark simulation. This value may be compared to the effect of a unit average annual reserve accumulation in the empirical regression, which is the sum of the coefficient on the interaction term and that on reserves to GDP changes, which equals 1.82 – 0.45 = 1.37 for column (1) of Table 2, while it equals 1.24 in column (2), and 1.11 in column (3), for varying estimation methods. By this metric, the theoretical model is able to explain between a third to 40% of the rise in productivity in terms of firm dynamics without appealing the learning-by-doing at the firm level.

A second metric is to apply more literally the empirical regression methodology to simulated data. To reflect the empirical sample of 45 countries, we conduct 45 separate simulations,

[25] For comparability with the empirical measurement, we track the change in productivity from the first period of the reserves policy until the 5th period of the policy (from period 1 to period 6 of the simulation). This means we track the change in productivity starting from the low point in period 1 in the impulse response shown in Figure 1.

each with a distinct reserves policy for the home country. Summary statistics for our empirical sample in Appendix Table 1 show that reserves accumulation varies in our sample from -2.9% to 10.9%. In model simulations, this range of values for reserve accumulation is divided into 45 increments, and each used to define the constant reserves accumulation policy for one of the 45 simulations. The home country data from the 45 simulations comprise the cross-section dimension of the panel in our regression of simulated data. The simulations are run for 25 years, and again reflecting the empirical specification, we compute 5-year averages, which comprise the time-series dimension of the panel.[26] We also include the initial period as an observation in the time series. We then conduct a panel regression of the log change in labor productivity during the 5-year periods on the average annual level of reserve accumulation, as well as on a constant and the lagged level of productivity. Since all simulated data apply to a country with capital controls, there is no need in this regression for a separate regressor for capital controls or for the interaction term with capital controls.

The regression coefficients for the benchmark model specification are reported at the bottom of Table 5. The coefficient on the reserve accumulation in this simulated regression is 0.322. Since there is no interaction term in this regression on simulated data, this regression coefficient may be compared directly with the composite empirical values cited above for the empirical regressions (1.37, 1.24 and 1.11). By this metric, the benchmark model is able to explain about one-quarter of the rise in productivity purely in terms of our firm dynamics mechanism.

We wish to highlight three features of the rise in home labor productivity implied by this model. First, it is gradual, tracking the accumulation in the number of domestic firms in this sector. Second, it is associated with a rise in the domestic share of intermediates. And third, productivity in this model rises despite the absence of standard stories of learning-by-doing at the firm level. Instead, our story is based on a rise in industry-level productivity derived from the interaction of domestic producers in a complex production structure.

4.2. Sensitivity Analysis

[26] To match the specification of data use in the empirical regression, the measure of productivity change is the cumulative change over the 5-year period, and the change in reserves is the average annual accumulation of reserves during the 5-year period.

Sensitivity analysis is useful to highlight the essential roles of two model features: endogenous firm delocation and roundabout production. Figure 2 shows the change in dynamics of key variables when the number of firms is held exogenously fixed at the initial value from the benchmark simulation, and column (2) of Table 5 records the cumulative deviation from steady state after 5 years. Impulse responses show that all variables now jump immediately to their long run level in the absence of firm dynamics. Without a gradual rise in firm number, there is no additional rise over time in home GDP or traded goods production after the initial rise in labor supply. And there is no force raising home productivity in the traded goods sector. Labor productivity falls in the initial period with the rise in labor inputs, as in the previous figure, but rather than rising over time to a net positive value as in that earlier scenario, it now stays at the lower level of productivity. This result confirms the essential role of firm dynamics in the mechanism described above.

[Insert Figure 2 about here]

Consider next the case when roundabout production using intermediates is removed ($\varsigma =$ 0), while still allowing free firm entry. Table 5 (column 3) shows that the rise in labor productivity in the traded sector is less than the benchmark case. While the degree of production relocation is even greater than the benchmark simulation, with the number of home firms, production of traded goods, and price index of trade goods all changing by somewhat larger magnitudes than the benchmark case, this production relocation nonetheless has a smaller impact on labor productivity in the absence of materials inputs. In fact, the change in labor productivity in manufacturing observed here is fully attributed to the fact that value added in this sector is deflated by the price index of traded goods, which falls due to the effect of trade costs discussed above. If manufacturing value added instead is deflated by the price of a given variety rather than an index, there is exactly zero rise in labor productivity in this case without intermediates.[27]

Sensitivity analysis for alternative parameterizations is also useful for identifying environments where the rise in labor productivity is amplified, and hence may account for a larger share of the estimates from the empirical section. Given the result immediately above, it is logical to conjecture that one such environment could involve a material share that is larger. For example,

[27] We note that in the benchmark simulation, while the fall in the price index used as the deflator contributes to the measured rise in labor productivity, there is still a substantial rise in manufacturing labor productivity if this alternative deflator is used. Productivity over 5 periods rises by 1.2% when using firm price as a deflator, compared to by 2.2% when using the benchmark price index deflator.

a material share raised from $\varsigma = 0.55$ to 0.63 (which is the largest value for which the algorithm can find a solution), results in a modestly increased impact of the given reserves policy on productivity relative to the benchmark case (see column (4) of Table 5).

An environment that even more greatly amplifies firm delocation and hence productivity growth is one with a greater degree of substitutability between traded and nontraded good. If this elasticity in the consumption aggregator is increased from $\eta = 0.55$ to 0.88 (the largest value for which the algorithm can find a model solution), firm numbers increase more over 5 years than in the benchmark case (7.3% versus 5.1%), as does manufacturing labor productivity (3.1% versus 2.2%; see column (5) of Table 5). The logic is that as firm entry lowers the price of traded goods relative to non-tradeds, domestic demand shifts more strongly toward traded goods, creating even more demand to encourage additional domestic firm entry in this sector. Hence, the production delocation mechanism becomes amplified, and the effect of reserve accumulation on the share of traded goods in home GDP more than doubles relative to the benchmark simulation (rising by 4.1% rather than 1.7%). Regarding the empirical summary statistics, the 5-year ratio rises to 0.619 and the regression coefficient to 0.458, which are larger than in the benchmark case, and imply that the firm delocation mechanism in this environment can explain around half of the effect of reserves policy on productivity found in empirical estimates.

As noted in earlier discussion, trade costs play an essential role in the firm delocation mechanism, since saving on these trade costs is the reason for a drop in the price index of manufacturing goods when a country's market share in this sector rises. (See Appendix Figure A.2 for a demonstration that when trade cost is set to zero, $\tau = 0$, the simulation implies no fall in the price index of manufacturing goods, and no rise in manufacturing productivity above its initial level.) So another environment that can amplify the effects of firm delocation is one with a higher trade cost. Column (6) of Table 5 reports simulation results when trade cost is set at $\tau = 0.7$ (the highest value for which a numerical solution can be found), showing an amplification in the effects on all variables compared to the benchmark parameterization. In particular, manufacturing labor productivity after the first 5 years rises 2.5% compared to 2.2% in the benchmark case.[28] The greater saving on trade cost from firm delocation also implies a greater drop in the consumer price index and hence a rise in consumption (though overall welfare still falls).

[28] The higher trade cost also implies less openness of the economy. For this parameterization (τ =0.7), the trade share falls to just 4.1% of GDP.

4.3. Comparison with Learning-by-Doing

4.3.1. Model comparison

This section compares the production delocation mechanism to the more standard mechanism for growth in this literature based on learning-by-doing. It also takes the opportunity to discuss the longer-run implications for productivity after a temporary reserves policy has ended.

While previous studies discussed the micro background of learning-by-doing in detail, the conventional (macro) form shows that knowledge increases at a rate that depends on the cumulative output. For example, Arrow (1962) and Romer (1986) link knowledge with cumulative investment. Knowledge (or productivity), $\alpha_t = \rho k^{\iota}$, where ι is a learning parameter and ρ is a constant coefficient. Romer (1986) assumes that there are exact constant returns to scale in accumulable factors, which requires that the sum of ι and the elasticity parameter of aggregate output with respect to capital equals 1. If this sum is greater than unity, growth accelerates without limit, but if this sum is less than 1, learning will decay and lead to stagnation, which converges to the original steady-state (Thompson 2010). Also, capital can be replaced with alternative contemporary factors such as labor or cumulative production.

Here, we incorporate into our model the learning-by-doing specification of a parsimonious version below (e.g., Aizenman and Lee (2010)). This specifies that productivity of firms in the trade goods sector rises with overall sector production in the preceding period:

$$\alpha_{T,t} = \overline{\alpha}\left(1 + y_{T,t-1}\right)^{\iota},$$

where the parameter ι dictates a learning parameter or the scale of the effect on productivity. Our learning-by-doing specification is conservative, unlike Aizenman and Lee (2010), which does not include cumulative factors or production over the whole period, but only a one-period lag of traded goods output. Modifying our benchmark model is a simple matter of replacing the fixed parameter α_T with the endogenous variable $\alpha_{T,t}$ in equations that include it, such as the production function for traded goods (15) and the definition of marginal cost, mc_t. But as in Aizenman and Lee (2010), since learning-by-doing here is external to the firm, there is no need to re-derive firm first-order conditions governing pricing or production. We adopt a value for the scaling parameter less than 1, ι=0.4. Thus, our learning-by-doing does not have a permanent effect but a temporary effect, which will decay over time. Note that our simulation results are qualitatively the same for various learning parameters if they are less than 1.

[Insert Table 6 about here]

Simulation results for the model augmented with learning-by-doing are reported in Figure 3 (solid line) and Table 6 (column 1). Given our interest in studying the dynamics after the cessation of the reserves policy, the simulation in this section specifies reserve accumulation ends after 30 periods, so that the last 20 years of the 50-year simulation hold reserves constant. Table 6, again showing levels at the 5-year mark, shows that the modified model significantly amplifies the increase in manufacturing productivity, which rises 4.7% compared to 2.2% in the benchmark model. Further, the metrics to compare to the empirical regression are also significantly amplified. The 5-year ratio now is 0.934 and the regression coefficient 0.844, indicating that the combination of learning-by-doing and the firm delocation mechanism together can explain two thirds of the empirical estimate of the effect of reserve accumulation on productivity. The logic of learning-by-doing is that when the policy induces a rise in demand for home traded goods, the current rise in production leads to a fall in future marginal costs, which translates into a yet higher level of production in future periods. The simulation result indicates this mechanism also amplifies the production delocation effect, as both the number of home firms and the degree of home specialization in traded goods rise more in the modified model (column (1) of Table 6) compared to the benchmark (column (1) of Table 5).

Impulse responses in Figure 3 provide additional information regarding the dynamic effect of learning-by-doing. The modified model is plotted as a solid line, and for comparison, the benchmark model simulation is plotted as a dotted line.[29] To establish a baseline for comparison, consider first the dynamics of the benchmark model. The dynamics up to period 20 are essentially the same as in Figure 1, but the new figure plots 45 periods to show the transition back to the original steady state once the policy ends, which did not occur during the simulation period in the original simulation. These dynamics show that firm number and manufacturing productivity begin to decline well before the end of the reserves policy. Since firm entry is based on expectations of future firm profits, new firm entry is discouraged when the reserves policy is expected to end in

[29] The latter simulation differs from the benchmark simulation in Figure 1 only in that the policy ends in period 30 rather, than running the whole 50 periods of the simulation.

the near horizon. By the time the policy officially ends in period 30, the number of firms and the level of manufacturing productivity have fully returned to their initial steady-state levels.

[Insert Figure 3 about here]

Now consider the dynamics of the model augmented with learning-by-doing. Confirming the results from Table 6, manufacturing productivity and firm numbers rise more at their peak than in the benchmark model without learning-by-doing. While dynamics show a gradual return in both variables to their initial steady-state values, this decline starts later than in the benchmark model, and a substantial increase in each remains well beyond the end of the reserves policy. It takes until year 45 to approach their initial steady-state levels. So the presence of learning-by-doing confers a degree of persistence to the effect of reserve accumulation policy.[30] We also note that in this modified model, reserve accumulation raises consumption over part of the simulation period, and single-period welfare actually rises during some periods. Nonetheless, the present value of overall welfare over the full sample period still falls as a result of the reserves policy.[31]

To disentangle the effects of learning-by-doing on its own from its interaction with firm delocation, we also report result from a simulation of a version of the model that includes learning-by-doing, but removes firm delocation by holding the number of firms constant at its steady-state level. Results are reported in Column (2) of Table 6 and in the dashed line in Figure 3. These results are striking. While the interaction of learning-by-doing with firm delocation generates larger and more persistent effects on productivity, learning-by-doing on its own does not. In the absence of a rise in firms, the magnitude of the rise in manufacturing productivity is very small, and there is no persistence beyond the reserves policy. This suggests that the large and persistent effects of reserves policy on production in the augmented model come not from learning-by-doing per se, but rather its interaction with firm delocation. The logic is simple, in that the learning-by-doing mechanism relies upon a rise in overall sector production, and production delocation shows that an effective way to achieve this is to foster an increase in the number of domestic firms in this

[30] One also notes that the real exchange rate appreciates in later periods of the simulation rather than depreciates. As was true in the benchmark model simulation, productivity gains specific to the traded goods sector lead to Balassa-Samuelson effects favoring real exchange rate appreciation. Since productivity gains are larger in the model with learning-by-doing, this pressure for appreciation is all the stronger. Nonetheless, the policy of reserve accumulation implies that the real exchange rate appreciation is smaller than would otherwise be the case for this level of productivity gain.

[31] We again experimented with the learning-by-doing model using alternative values of the parameters considered in earlier sensitivity analysis, as well as other parameters, such as the intertemporal elasticity. Again we found no case where reserves accumulation of any size implies a net rise in welfare defined as the present value of utility over the full transition path.

market and push out foreign firms. Further, this result underscores that the primary source of the rise in manufacturing labor productivity is the substitution of domestically-produced material inputs for labor due to a drop in the relative price of materials. Firm delocation generates this through cost saving on trade costs, which appears to be a potent effect, while learning-by-doing does not have a mechanism to affect relative input prices in this way.

5. Welfare and Optimal policy [to be completed]

Conventional wisdom suggests that capital account policy, a combination of capital controls and/or reserve accumulation, is (static) welfare-reducing while it can promote growth (e.g., Korinek and Serven, 2016; Liu et al., 2021; Benigno et al., 2022). Either capital controls or reserve accumulation can be considered optimal in limited cases: when a financial crisis can occur (Benigno et al., 2022; Gurkaynak et al., 2022) or under extreme parameterizations that value the future highly (e.g., very high elasticity of inter-temporal substitution) (Korinek and Serven, 2016).

In this section, we examine the welfare implications of the firm delocation mechanism driven by reserves and capital controls. We focus on dynamic welfare gains from the capital account policy by tracing household utility over the transition path to the new steady state and computing the present discounted value of utility. The simulation period is 300 years to approximate an infinite horizon and ensure the economy converges to its steady state. We will consider experiments with capital account policy. First it lasts various durations, from 1 to 40 years and then we vary the reserve size from 0 to 0.08 (8%). The reference point for welfare comparison is the case with a policy of no reserves accumulation, where the original steady state is maintained throughout the simulation period.

Figure 7 depicts the present discounted values (PDV) of welfare (vertical axis) based on the size and duration of reserves policy. The point where the reserves ratio and policy periods are zero indicates the present discounted values of utility without a reserve policy (the reference case). We compare the results for two versions of the model, one with LBD only and one with LBD combined with firm delocation.

As shown in Panel A of Figure 4, a policy of reserve accumulation in the LBD-only model lowers welfare for the home country compared to no reserve policy, regardless of the duration and size of the policy. Red stars, indicating the maximum value, will appear when the reserve size is at zero. However, when we include the new mechanism of firm delocation in Panel B, we find that country 1's undervaluation policy increases welfare compared to the welfare of no reserve policy. We observe that the of PDV welfare reaches a local maximum when the reserve policy is sustained over 40 years at a level of 4.7%.

[Insert Table 7 about here]

6. Conclusion

The growth success of China and other Asian economies has spurred interest in reserve accumulation and currency undervaluation as a policy to promote export-led economic growth. This paper proposes a novel channel by which this may occur, by promoting growth in new firm entry and the extensive margin of trade. This explanation complements, but is distinct from the widespread theory of export-led growth based on learning-by-doing; it instead builds on recent developments in the firm dynamics literature, and extends the concept of firm delocation developed in trade theory. A novel prediction of the theory is that undervaluation promotes agglomeration through the redirection of inputs in production chains, pointing out a potential benefit of policies aimed at capturing a larger share of manufacturing production chains domestically. In particular, locating production chains domestically lowers the cost of materials inputs, and thereby works to raise manufacturing labor productivity. This approach has the benefit of accounting for observations in the growth literature that export-led growth is associated with expansion in the extensive margin of trade, and that it depends on the complexity in a country's manufacturing sector. We provide original empirical evidence supporting this approach, showing that a capital account policy combining capital controls with reserve accumulation promotes growth in manufacturing labor productivity, and this works in part through a channel reshaping firm dynamics and production chains.

In addition to contributing to the large literature on currency valuation and export-led growth, this paper also contributes to the recent literature on premature deindustrialization and industry polarization. The paper also contributes something new to the trade literature studying firm delocation, proposing the combination of capital account policy and exchange rate management as an alternative to tariffs as a policy tool. Finally, we also contribute to the macro literature studying currency devaluations. While competitive devaluations have long been a staple of international macro theory and policy, our work shows how they can be particularly effective in the context of capital controls and firm dynamics. An overarching argument of this paper is that the broader macro literature tends to under-appreciate the role that exchange rate regimes can play in longer term phenomena like structural change and economic growth.

References

Anderson, James E. and Eric van Wincoop, 2004. "Trade Costs," *Journal of Economic Literature* 42, 691-751.

Aizenman, Joshua, and Jaewoo Lee, 2010. "Real Exchange Rate, Mercantilism and the Learning by Doing Externality," *Pacific Economic Review* 15(3), 324-335.

Aizenman, Joshua, and Jaewoo Lee, 2007. "International Reserves: Precautionary Versus Mercantilist Views, Theory and Evidence," *Open Economies Review* 18(2), 191-214.

Arellano, Manuel, and Stephen Bond, 1991. "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations," *Review of Economic Studies* 58, 277-297.

Arellano, Manuel, and Olympia Bover, 1995. "Another Look at the Instrumental-Variable Estimation of Error-Components Models," *Journal of Econometrics* 68, 29-51.

Arrow, K.J. (1962). "The economic implications of learning by doing". *Review of Economic Studies* 29 (3), 155–173.

Bacchetta, Philippe, Kenza Benhima, and Yannick Kalantzis, 2013. "Capital Controls with International Reserve Accumulation: Can This be Optimal?" *American Economic Journal: Macroeconomics* 5(3), 229-262.

Barro, Robert and Jong Wha Lee, 2013. "A New Data Set of Educational Attainment in the World, 1950-2010," *Journal of Development Economics* 104, 184-198.

Benigno, Gianluca, Luca Fornaro and Michael Wolf, 2022. "Reserve Accumulation, Growth and Financial Crises," *Journal of International Economics*, 103660.

Bergin, Paul R. 2022. "Currency Undervaluation and Comparative Advantage," *European Economic Review* 150, 104316

Bergin, Paul R., and Ching-Yi Lin, 2012. "The Dynamic Effects of a Currency Union on Trade," *Journal of International Economics*, *87*(2), 191-204.

Bergin, Paul R., and Giancarlo Corsetti, 2020. "Beyond competitive devaluations: The monetary dimensions of comparative advantage." *American Economic Journal: Macroeconomics* 12(4), 246-86.

Bergin, Paul R., Woo Jin Choi, and Ju Hyun Pyun, 2023. "Catching Up by Deglobaling: Capital Account Policy and Economic Growth," *Journal of International Money and Finance* 128, 102920.

Blundell, Richard, and Stephen Bond, 1998. "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models," *Journal of Econometrics* 87(1), 115-143.

Broda, Christian and David E. Weinstein, 2006. "Globalization and the Gains from Variety," *The Quarterly Journal of Economics* 121, 541-585.

Brunnermeier, Markus, Pierre-Olivier Gourinchas, and Oleg Itskhoki, 2020. "Consumption-Led Growth," mimeo.

Chang, C., Liu, Z., & Spiegel, M. M., 2015. "Capital controls and optimal Chinese monetary policy," *Journal of Monetary Economics*, *74*, 1-15.

Chang, C., Liu, Z., Spiegel, M. M., & Zhang, J., 2019. "Reserve requirements and optimal Chinese stabilization policy," *Journal of Monetary Economics*, *103*, 33-51.

Chinn, Menzie D., and Hiro Ito, 2008. "A New Measure of Financial Openness," *Journal of Comparative Policy Analysis* 10(3), 309-322.

Choi, W. J., & Taylor, A. M., 2022. Precaution versus mercantilism: Reserve accumulation, capital controls, and the real exchange rate. *Journal of International Economics*, 103649.

Ciccone, Antonio, and Kiminori Matsuyama, 1996. "Start-up costs and pecuniary externalities as barriers to economic development," *Journal of Development Economics* 49, 33-59.

Dooley, Michael P., David Folkerts-Landau, and Peter Garber, 2004. "The Revived Bretton Woods System," *International Journal of Finance and Economics* 9(4), 307-313.

Epifani, Paolo and Gino Gancia, 2017. "Global Imbalances Revisited: The Transfer Problem and Transport Costs in Monopolistic Competition," *Journal of International Economics* 108, 99-116.

Feenstra, Robert C., 1994. "New Product Varieties and the Measurement of International Prices," *American Economic Review* 84, 157-177.

Feenstra, Robert C., Lipsey, R. E., Deng, H., Ma, A. C., and H. Mo, 2005. "World Trade Flows: 1962-2000," NBER Working Paper 11040.

Freund, Caroline and Martha Denisse Pierola, 2012. "Export Surges," *Journal of Development Economics* 97(2), 387-395.

Fujiwara, I. and K. Matsuyama, 2022. "A Technology-gap Model of Premature Deindustrialization." CEPR Discussion Paper 15530.

Ghironi, Fabio and Marc J. Melitz, 2005. "International Trade and Macroeconomic Dynamics with Heterogeneous Firms," *The Quarterly Journal of Economics* 120(3), 865-915.

Gürkaynak, R. S., Lee, S. S., Luk, P., & Pyun, J. H. (2022). "Output Concerns and Precautionary Savings in Emerging Markets' Debt and Reserve Accumulation", CEPR working paper *DP16969*.

Hall, Robert E., 2009. "By How Much Does GDP Rise If the Government Buys More Output?" *Brookings Papers on Economic Activity* 2, 183-231.

Hummels, David, and Peter J. Klenow, 2005. "The Variety and Quality of a Nation's Trade," *American Economic Review* 95, 704-723.

Huneeus, Federico and Richard Rogerson, 2020. "Heterogeneous Paths of Industrialization." Working Paper 27580, National Bureau of Economic Research.

Jeanne, Olivier, 2013. "Capital Account Policies and the Real Exchange Rate," NBER International Seminar on Macroeconomics, University of Chicago Press 9(1), 7-42.

Kee, Hiau Lui and Tang, Heiwai, 2016. "Domestic Value Added in Exports: Theory and Firm Evidence from China". *American Economic Review 106*(6) 1402-36.

Korinek, Anton, and Luis Serven, 2016. "Undervaluation through Foreign Reserve Accumulation: Static Losses, Dynamic Gains," *Journal of International Money and Finance* 64, 104-136.

Laeven, Luc, and Fabian Valencia, 2020. "Systemic Banking Crises Database II," *IMF Economic Review* 68**,** 307-361. https://doi.org/10.1057/s41308-020-00107-3

Laffargue, J.P., 1990. Resolution d'un modele macroeconomique avec anticipations rationnelles, *Annales d'Economie et Statistique* 17, 97-119.

Liu, Z., Spiegel, M. M., & Zhang, J., 2021. "Optimal capital account liberalization in China," *Journal of Monetary Economics*, 117, 1041-1061.

Matsuyama, Kiminori, 2008. "Structural Change," in *The New Palgrave Dictionary of Economics*, 2nd edition , Ed. Steven N. Durlauf and Lawrence E. Blume, 1-6.

McMillan, Rodrik, Dani Rodrik, and Inigo Verduzco-Gallo, 2014, "Globalization, Structural Change, and Productivity Growth, with an Update on Africa," *World Development* 63, 11-32.

Michaud, Amanda, and Jacek Rothert, 2014. "Optimal Borrowing Constraints and Growth in a Small Open Economy," *Journal of International Economics* 94(2), 326-340.

Nickell, Stephen, 1981. "Biases in Dynamic Models with Fixed Effects," *Econometrica* 49(6), 1417-1426.

Obstfeld, Maurice, and Kenneth Rogoff. 2001. “The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?” In NBER Macroeconomics Annual 2000, Vol. 15, edited by Ben S. Bernanke and Kenneth Rogoff, 339–412. Cambridge, MA: MIT Press.

Ossa, Ralph, 2011. “A “New Trade” Theory of GATT / WTO Negotiations,” *Journal of Political Economy* 119, 122–152.

Ottonello, Pablo, Diego J. Perez, and William Witheridge, 2023, ”The Exchange Rate as an Industrial Policy,” mimeo.

Rauch, James E., 1999. “Networks Versus Markets in International Trade,” *Journal of International Economics* 48, 7–35.

Rodrik, Dani, 2008. “The Real Exchange Rate and Economic Growth,” *Brookings Papers on Economic Activity* 39(2), 769-797.

Rodrik, Dani, 2016. “Premature Deindustrialization,” *Journal of Economic Growth* 21(1), 1-33.

Romer, P.M. (1986). “Increasing returns and long-run growth”. *Journal of Political Economy* 94 (5), 1002–1037.

Ruhl, Kim J, 2008. “The International Elasticity Puzzle,” mimeo.

Sanderson, Eleanor, and Frank Windmeijer, 2016. “A Weak Instrument F-test in Linear IV Models with Multiple Endogenous Variables,” *Journal of Econometrics* 190(2), 212-221.

Sposi, Michael, Kei-Mu Yi, and Jing Zhang, 2021. “Deindustrialization and Industry Polarization,” NBER Working Paper 29483.

Timmer, P. Marcel, Erik Dietzenbacher, Bart Los, Robert Stehrer, Gaaitzen J. de Vries 2015. An Illustrated Guide to the World Input-Output Database: the Case of Global Automotive Production. *Review of International Economics* 23(3): 575–605.

Thompson, P. (2010). Learning by doing. *Handbook of the Economics of Innovation*, *1*, 429-476.

Uribe, M. Schmitt-Grohé, S., 2017. *Open Economy Macroeconomics*: Princeton University Press, Princeton New Jersey.

Yamano, N. and Ahmad, N., 2006. The OECD input-output database: 2006 edition.

Table 1. Sample countries (45 countries, 1985-2007)

Panel A. list of countries

Advanced countries		Emerging market countries	
Australia	Italy*	Argentina	Indonesia
Austria*	Japan*	Bolivia※	Israel⊙
Belgium*	Netherlands*	Brazil	Korea, Rep.*
Canada*	New Zealand※	Chile*	Malaysia
Denmark*	Norway	China*	Mexico*
Finland*	Portugal*	Colombia	Peru*
France*	Spain*	Costa Rica*	Philippines
Germany*	Sweden*	Cyprus*	Russian Federation*
Greece*	Switzerland	Egypt	Singapore
Iceland	United Kingdom*	Hong Kong, China	Thailand
Ireland*	United States*	India*	Turkey
			Venezuela

*domestic intermediate share data are available ※sectoral productivity data is available after 1990. ⊙ setoral productivity data is available after 2000.

Panel B. Average share of total intermediate input to gross output

Low group (lower 33%)		Middle group (33~66%)		High group (over 66%)	
Austria	0.632485	Russia†	0.660526	Mexico†	0.7042505
Denmark	0.636164	Colombia†	0.66201	Portugal	0.7171726
United Kingdom	0.639832	Finland	0.662856	Italy	0.7200581
Germany	0.649829	Cyprus†	0.668226	Spain	0.7206021
Ireland	0.651942	Greece	0.675283	Belgium	0.7247325
Japan	0.650326	Peru†	0.677565	Chile†	0.7263173
United States	0.655565	Canada	0.678246	China†	0.7295762
Sweden	0.655894	France	0.683684	Korea, Rep. †	0.7612507
Costa Rica†	0.656546	Netherlands	0.6981	India†	0.7707036

† Emerging market countries

Table 2. Capital account policy and manufacturing productivity growth

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Manufacturing productivity growth			Non-Manufacturing productivity growth		
Methods	Panel within	System GMM	System GMM	Panel within	System GMM	System GMM
Sample	Full sample		Emerging market	Full sample		Emerging market
Initial productivity	-0.0666***	0.0124	0.0076	-0.0145	0.0117	0.0175
	(0.0132)	(0.0078)	(0.0073)	(0.0321)	(0.0136)	(0.0109)
Capital controls (CC)	0.0068	-0.0061	0.0106	0.0040	-0.0008	0.0038
	(0.0145)	(0.0234)	(0.0272)	(0.0126)	(0.0246)	(0.0312)
d.Reserves/GDP	-0.4464**	-0.3574	-0.2349	-0.0824	0.0202	0.2951
	(0.2054)	(0.2495)	(0.4409)	(0.1899)	(0.2410)	(0.3401)
Capital controls	1.8161***	1.5981***	1.3395*	-0.0179	0.0816	-0.2946
× d.Reserves/GDP	(0.3014)	(0.5009)	(0.7183)	(0.4886)	(0.6196)	(0.7129)
Private credit/GDP	-0.0086	0.0079	0.0015	-0.0166*	-0.0118	-0.0140
	(0.0113)	(0.0157)	(0.0159)	(0.0083)	(0.0116)	(0.0222)
(log) terms of trade	-0.0116	0.0123	0.0051	-0.0007	-0.0011	0.0024
	(0.0158)	(0.0201)	(0.0273)	(0.0123)	(0.0200)	(0.0334)
Trade openness	-0.0415**	0.0064	0.0109*	-0.0041	0.0021	0.0010
	(0.0179)	(0.0048)	(0.0065)	(0.0165)	(0.0061)	(0.0090)
Population growth	-0.4013	-0.5994	-0.1512	-1.1166**	-0.3840	-0.6052
	(0.5559)	(0.4789)	(0.7399)	(0.4374)	(0.4083)	(0.7527)
Human capital	0.0029*	-0.0001	0.0008	-0.0012	-0.0020	-0.0043*
	(0.0016)	(0.0009)	(0.0015)	(0.0010)	(0.0021)	(0.0026)
Institution quality	-0.0012	-0.0027	-0.0074	-0.0011	-0.0012	-0.0013
	(0.0025)	(0.0027)	(0.0045)	(0.0016)	(0.0030)	(0.0041)
Crisis	-0.0038	-0.0170	-0.0379**	-0.0121*	-0.0201*	-0.0202
	(0.0111)	(0.0149)	(0.0178)	(0.0061)	(0.0116)	(0.0193)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
AR(1) (p-value)		0.001	0.002		0.018	0.03
AR(2) (p-value)		0.827	0.892		0.958	0.654
Weak IV (p-value)		0.11	0.07		0.34	0.04
Over-id test (p-value)		0.611	0.773		0.125	0.1
# of instruments		19	19		19	19
# of countries	45	45	23	45	45	23
Observations	177	177	102	175	175	101
R-squared	0.612			0.597		

Note: Two-step system GMM results are reported in columns (2), (3), (5) and (6). Initial value of labor productivity is considered an endogenous variable. Weak IV test reports F-test of excluded instruments for the initial value of productivity, of which the null hypothesis is that instruments are weak. Over-id test report the validity of instruments, the null is that instruments are valid. Clustered robust standard errors at country level are reported in parentheses. *, ** and *** are the significance level at 10%, 5% and 1%, respectively.

Table 3. Captial account policy and channels

	(1)	(2)	(3)	(4)	(5)
Dependent variable	Manufacturing labor shares	Extensive margins of exports	Intensive margins of exports	(log) # of listed domestic firms	Domestic intermediate shares
Capital controls	0.020***	0.005	-0.004	0.354*	0.214***
	(0.007)	(0.017)	(0.011)	(0.196)	(0.057)
d.Reserves to GDP	-0.237	-0.882***	-0.047	-5.008**	-0.077
	(0.147)	(0.292)	(0.152)	(2.254)	(0.670)
Capital controls	**0.540****	**2.437*****	0.035	**12.077***	**2.849***
× d.Reserves to GDP	**(0.246)**	**(0.646)**	(0.269)	**(7.136)**	**(1.535)**
log rGDP per capita	0.455***	0.612***	0.154*	-0.922	-0.644*
	(0.091)	(0.173)	(0.088)	(1.399)	(0.316)
log rGDP per capita squared	-0.026***	-0.033***	-0.008	0.076	0.031*
	(0.005)	(0.009)	(0.005)	(0.076)	(0.018)
Terms of trade	-0.012	0.010	0.013	-0.249	-0.067
	(0.009)	(0.020)	(0.013)	(0.268)	(0.059)
Crisis	-0.007	0.000	-0.004	-0.074	-0.074**
	(0.006)	(0.012)	(0.009)	(0.162)	(0.034)
Country FE	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes
R-squared	153	156	156	143	83
Observations	0.929	0.975	0.936	0.971	0.968

Note: Clustered robust standard errors at country level are reported in parentheses. *, ** and *** are the significance level at 10%, 5% and 1%, respectively.

Table 4. Benchmark Parameter Values

Preferences	
Risk aversion	$\sigma = 2$
Time preference	β =0.96
Labor supply elasticity	$1/\psi = 1.9$
Traded goods share	$\nu = 0.5$
Substitution elasticity between sectors	$\eta = 0.5$
Differentiated (traded) goods elasticity	ϕ = 5.2
Technology	
Firm death rate	$\delta = 0.1$
Intermediate input share	$\varsigma = 0.55$
Trade cost	τ =0.33
Firm sunk entry cost	$\overline{K} = 1$
Productivities	$\alpha_T = \alpha_N = 1$
Policy	
Monetary policy	$\overline{M} = \overline{M^*} = 1$
Reserves	$\Omega_t = 0.05, t > 1$

Table 5. Simulation Results:
Effect of undervaluation policy after 5 years

	(1) Bench-mark model	(2) No firm entry ($n = \bar{n}$)	(3) No intermed-iates ($\varsigma = 0$)	(4) Higher intermed-iate share ($\varsigma = 0.63$)	(5) More subst. non-traded good ($\eta = 0.88$)	(6) High trade cost (τ=0.7)
Percent change in year 5 compared to steady state:						
Number of firms:						
Home (n)	5.129	0.000	8.561	4.586	7.252	5.691
Foreign (n*)	-5.081	0.000	-8.371	-4.576	-7.222	-5.468
Production by sector:						
Home, traded (y_T)	8.287	5.654	9.903	8.183	11.303	8.853
Foreign, traded (y_T^*)	-8.095	-5.479	-9.763	-7.998	-11.051	-8.463
Home, nontraded (y_N)	-1.400	-1.121	-1.169	-1.473	-1.511	-1.430
Foreign, nontraded (y_N^*)	1.479	1.144	1.192	1.566	1.551	1.476
Home traded prod. share	1.661	1.349	4.571	1.287	4.072	1.907
GDP (home)	6.639	3.961	5.440	6.895	6.977	7.090
Labor (home)						
Overall (L)	5.518	4.431	4.597	5.815	3.667	5.246
Traded sector (L_T)	7.971	6.400	9.995	7.874	5.751	8.024
Nontraded sector (L_N)	-1.400	-1.121	-1.169	-1.473	-0.940	-1.430
Relative wage (W/P_T)	1.566	0.804	1.205	1.641	1.055	1.649
Consumption	-1.203	-1.617	-1.058	-1.296	-0.777	-0.831
Utility	-5.872	-5.360	-5.266	-6.065	-3.963	-5.330
PDV Utility	-4.484	-5.126	-4.557	-4.266	-3.164	-3.811
For comparison to empirical regression:						
5-year %Δ labor productivity*:						
Manufacturing sector	2.231	0.000	1.882	2.336	3.096	2.518
Overall	1.563	0.000	0.832	1.760	1.615	1.695
Ratio of 5-year Δ productivity to Δ reserves*	0.446	0.000	0.376	0.467	0.619	0.504
Regression coefficient	0.322	0.000	0.187	0.363	0.456	0.451

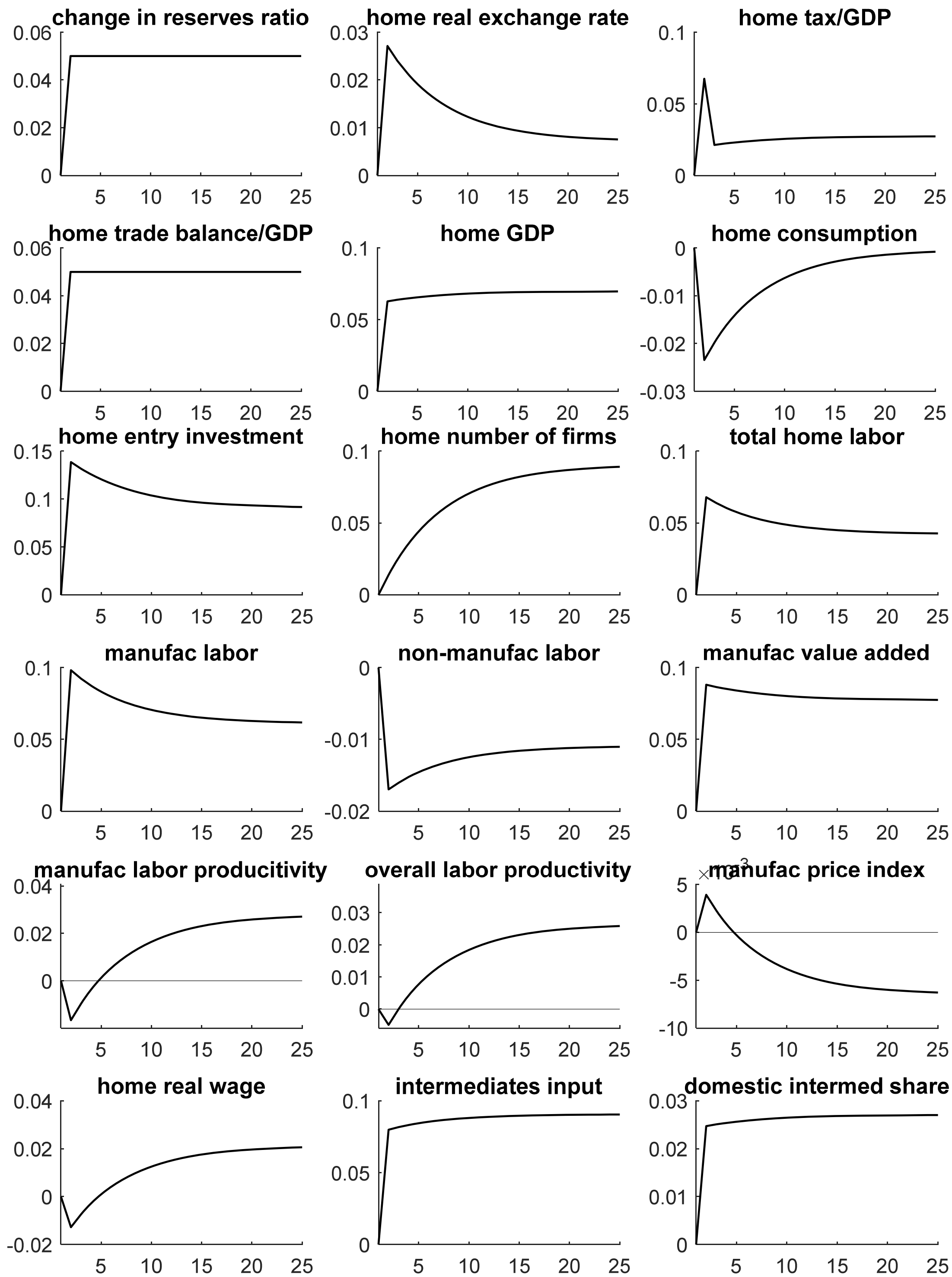
Simulation specifies home reserves accumulation of 5% of GDP each year of 50-year simulation.
*Productivity measures percentage change from first year of policy rather than from steady state.

Table 6. Simulation for model with Learning-By-Doing (LBD): Effect of undervaluation policy after 5 years

	(1) LBD & delocation (ι=0.4)	(2) LBD & no delocation (ι=0.4, $n=\bar{n}$)	(3) Delocation, no LBD * (ι=0)
Percent change in year 5 compared to steady state:			
Number of firms:			
Home (n)	5.452	0.000	5.123
Foreign (n*)	-5.685	0.000	-5.074
Production by sector:			
Home, traded (y_T)	11.447	6.952	8.282
Foreign, traded (y_T^*)	-11.119	-6.725	-8.090
Home, nontraded (y_N)	-1.313	-0.941	-1.399
Foreign, nontraded (y_N^*)	1.445	0.984	1.478
Home traded prod. share	2.010	1.466	1.661
GDP (home)	8.283	4.573	6.634
Labor (home)			
Overall (L)	5.104	3.667	5.515
Traded sector (L_T)	8.008	5.752	7.967
Nontraded sector (L_N)	-1.313	-0.941	-1.399
Relative wage (W/P_T)	2.010	1.055	1.565
Consumption	-0.187	-0.777	-1.203
For comparison to empirical regression:			
5-year %Δ labor productivity*:			
Manufacturing sector	4.671	1.831	2.230
Overall	3.393	1.221	1.562
Ratio of 5-year %Δ productivity manufac. to Δ reserves	0.934	0.366	0.446
Regression coefficient	0.844	0.225	0.322

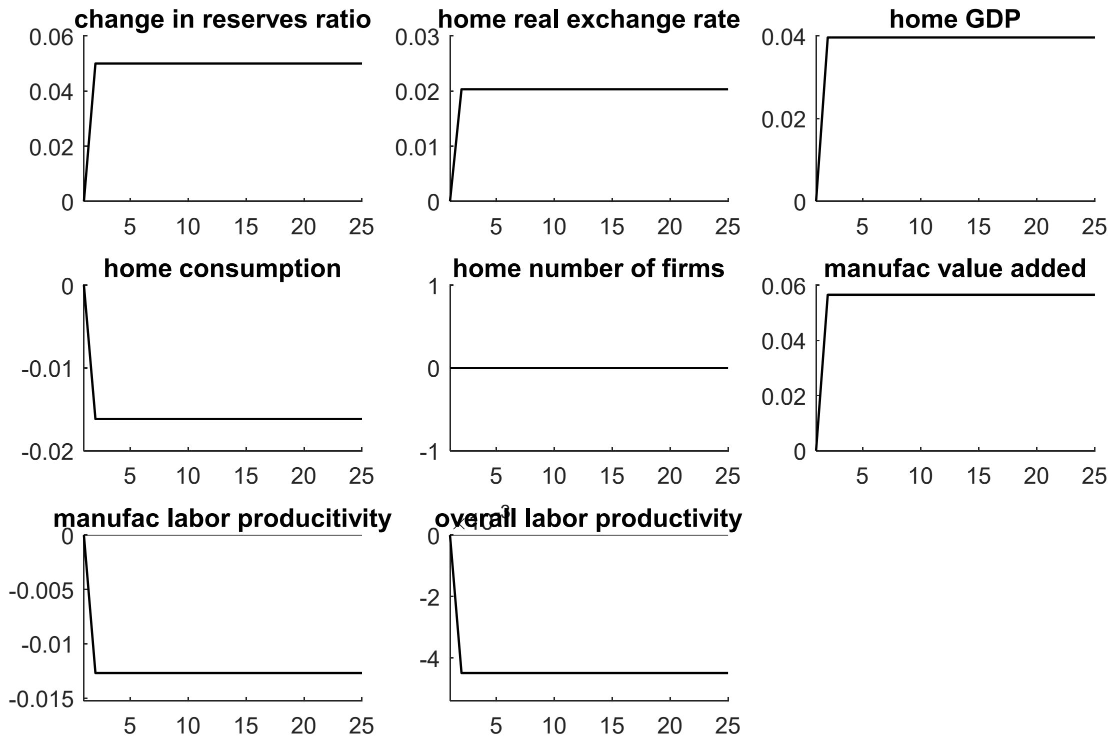
Simulation specifies home reserves accumulation of 5% of GDP for first 30 years of the 50-year simulation.
*Productivity measures percentage change from first year of policy rather than from steady state

Figure 1. Simulation for benchmark model



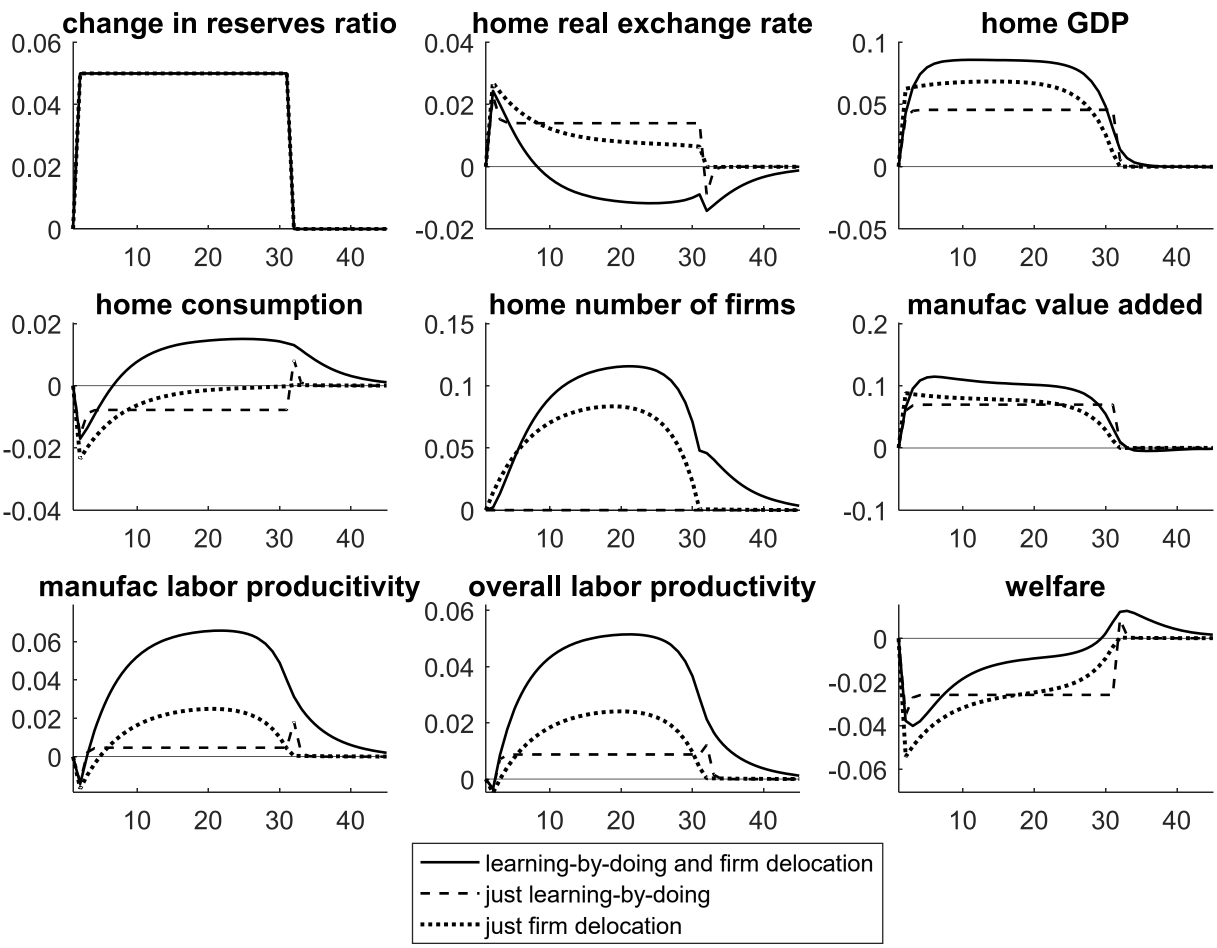
Vertical axes show percent change from value prior to change in reserves policy. Horizontal axes show years.

Figure 2. Simulation for model with no firm entry



Vertical axes show percent change from value prior to change in reserves policy. Horizontal axes show years.

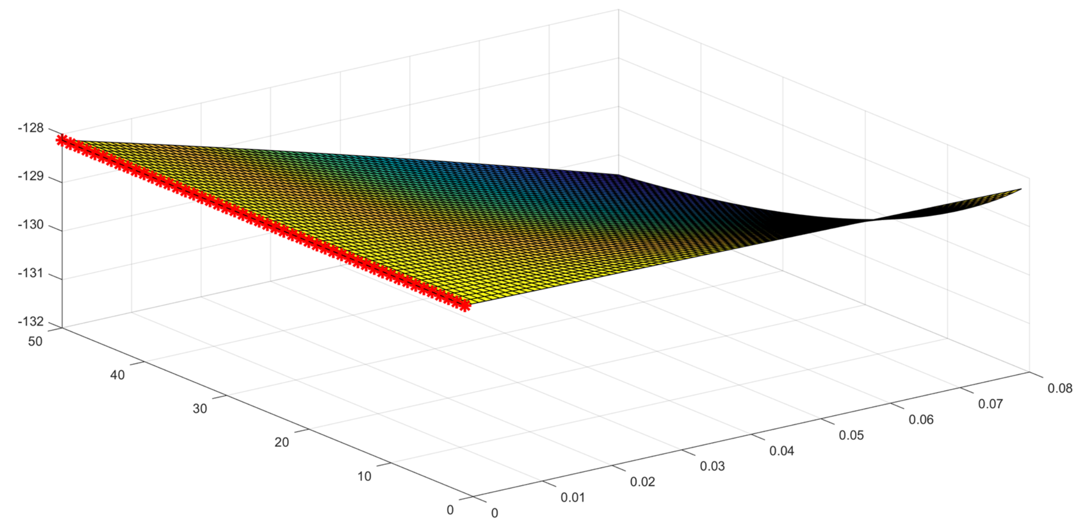
Figure 3. Simulation for model with learning-by-doing
(reserves policy runs periods 1-30)



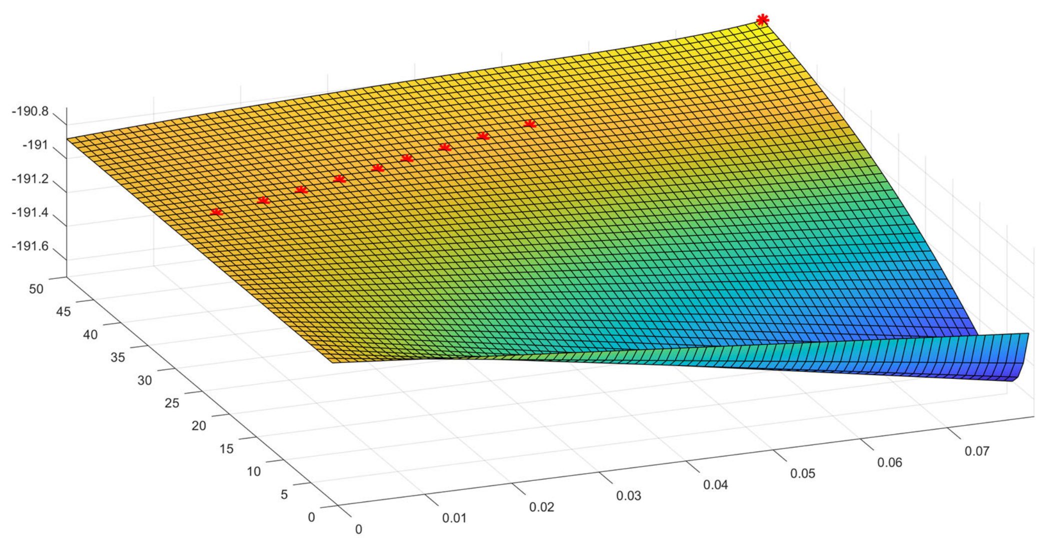
Vertical axes show percent change from value prior to change in reserves policy.
Horizontal axes show years.

Figure 4. Optimal Policy: Present discount values of welfare under undervaluation policy: LBD vs. LBD with firm delocation

Panel A. LBD only



Panel B. LBD and firm delocation



Note: The simulation horizon is 300 years. PDV welfare is on the vertical axis. To compute PDV welfare, we trace welfare changes from the reserve shocks supported by tax (capital control).

Appendix

A.1.Data Construction for Sectoral Value Added, Price Index, and Labor

Our data comes from various sources. First, we use sectoral real value added per worker as our measure for labor productivity. Our baseline data for sectoral real value added comes from World Input Output Table (WIOD), Socio Economic Accounts.[32] To cover as many observations as possible, we directly incorporate nominal value added and the deflator, instead of incorporating gross output and intermediate input using respective price indices(double deflation). Nominal value added is denominated in current national currencies(millions). Price deflator index is re-anchored at 1995=100. For labor, we use the number of employement engaged (thousands). Manufacturing or non-manufacturing data is aggregated using the share of current nominal value added.

First, we take the WIOD November 2016 release as our baseline benchmark, and then supplement the WIOD July 2014 release if needed.[33] Among ten sectors (agriculture, mining, manufacturing, utilities, construction, trade service, transport service, business service, and government service), we take the manufacturing sector as a tradable goods sector, and all other sectors as a non-tradable goods sector. For the manufacturing sector, we aggregate C10-C12 to C33 of ISIC Rev.4 code; and 15t16 to 36t37 of ISIC Rev.3 code.

We further combine EU KLEMS, GGDC, and STAN from the OECD data. We take EU KLEMS Growth and Productivity Accounts, March 2007 Release as our benchmark ones for KLEMS data.[34] The sectoral data is constructed based on ISIC Rev.3. For the manufacturing sector, we aggregate the following industries; 15t16 to 36t37. Groningen Growth and Development Centre(GGDC) 10-sector data comes with three variables, VA, QVA, and EME, which stands for valued added, value added at constant 2005 prices, and persons engaged.[35] Sectoral deflator is calculated by dividing VA with QVA. We use EME for our measure for labor.

Lastly, we combine STAN from the OECD data for Norway, Switzerland, New Zealand, Iceland, and Israel.[36] We use SNA08, ISIC Rev.4 data as our benchmark data and supplement with SNA93, ISIC Rev.3 data if needed. For the manufacturing sector, we aggregate D10T33 of ISIC Rev.4 code; and 15tt37 of ISIC Rev.3 code.

KLEMS data from 1985 to 2005 and WIOD from 2005 to 2012 covers the United States, the United Kingdom, Belgium, Denmark, France, Germany, Italy, Netherland, Sweden, Japan, Finland, Greece, Ireland, Portugal, Spain. STAN data covers Norway(1989-2012), Switzerland, New Zealand(1989-2012), Iceland(1991-2012), and Israel(2000-2007). WIOD data from 1995 to 2012 covers Canada, Turkey, Australia, Argentina, Russia. GGDC data from 1985 to 2010 covers Bolivia, Chile, Colombia, Peru, Egypt, Hong Kong, Malaysia, Philippines, Singapore, Thailand. GGDC data from 1985 to 1994 and WIOD from 1995 to2012 covers Brazil, Mexico, Indonesia, India, Korea and China.

For a few countries, slight discrepancies between ISIC Rev.3 and ISIC Rev.4 or between different sources of data rise. To prevent the discontinuity of the series, we impute the data using the growth rate of the supplement data.

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[32] http://www.wiod.org/home.
[33] Please see Timmer et al. (2015) for further details.
[34] http://www.euklems.net/.
[35] https://www.rug.nl/ggdc/productivity/10-sector.
[36] http://www.oecd.org/industry/ind/stanstructuralanalysisdatabase.

Table A.1. Summary statistics based on annual observations (45 countries, 1985-2007)

	Full sample					Emerging markets countries				
Variables	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
(log) manufacturing productivity	795	0.029	0.035	-0.077	0.180	464	0.027	0.041	-0.077	0.180
(log) non-manufacturing productivity	795	0.017	0.023	-0.033	0.122	464	0.021	0.027	-0.033	0.122
Capital controls (CC)	795	0.344	0.349	0	1	464	0.525	0.326	0	1
d.Reserves to GDP	795	0.006	0.016	-0.029	0.109	464	0.010	0.018	-0.029	0.109
CC×d.Reserves to GDP	795	0.003	0.008	-0.022	0.046	464	0.005	0.010	-0.022	0.046
Extensive margins	795	0.217	0.140	0.018	0.599	464	0.156	0.093	0.018	0.494
Intensive margins	795	0.123	0.050	0.026	0.295	464	0.112	0.040	0.026	0.207
# of listed domestic firms	708	822.852	1423.942	12	8090	401	582.451	1018.193	12	5978
Domestic intermediate shares[a]	386	0.855	0.134	0.341	0.990	175	0.883	0.117	0.356	0.986
Private credit to GDP	795	0.741	0.486	0.109	2.681	464	0.538	0.404	0.109	1.649
(log) terms of trade	795	4.631	0.169	3.845	5.178	464	4.619	0.181	3.845	5.178
Institutional quality	795	8.126	2.358	2.9722	12	464	7.172	1.927	2.972	12
Human capital (% of tertiary complete)[b]	795	8.712	5.646	0.7616	24.370	464	6.705	5.229	0.762	24.370
Crisis dummy	795	0.184	0.317	0	1	464	0.276	0.362	0	1

a.Domestic intermeidate shares are only avaiable for 27 countries. b. Human capital index comes from Barro and Lee (2013), which is only available in 5 year period term.

Table A.2. Controlling for possible endogeneity in Table 2

	(1)	(2)	(3)
Dependent variable	Manufacturing labor productivity growth		
Methods	Panel within	System GMM	System GMM
Sample	Full sample	Full sample	Emerging market
Endogeneity controls	Instrumented d.(Res/GDP) (Choi and Taylor, 2022)	Lagged values	
Endogenous regressors in System GMM	Initial productivity, TOT, Prv. credit/GDP	Initial productivity, TOT, Prv. credit/GDP, d.(Res./GDP), and d.(Res./GDP)×CC	
Initial productivity	0.0149*	0.0104	0.0063
	(0.0089)	(0.0079)	(0.0062)
Capital controls (CC)	-0.0101	0.0008	0.0102
	(0.0460)	(0.0231)	(0.0306)
d.Reserves/GDP	-0.8553	-0.1484	-0.4460
	(1.0403)	(0.4015)	(0.5349)
Capital controls *d.Reserves/GDP	4.1287*	1.6316**	2.0736***
	(2.4981)	(0.6766)	(0.7656)
Private credit/GDP	0.0012	0.0023	-0.0128
	(0.0205)	(0.0180)	(0.0413)
(log) terms of trade	0.0721*	0.0334	0.0170
	(0.0404)	(0.0284)	(0.0489)
Trade openness	0.0162	0.0037	0.0142
	(0.0134)	(0.0054)	(0.0122)
Population growth	-0.5374	-0.4282	-0.4581
	(0.7582)	(0.5106)	(0.8289)
Human capital	0.0002	0.0003	0.0010
	(0.0014)	(0.0010)	(0.0015)
Institution quality	-0.0002	-0.0011	-0.0088
	(0.0029)	(0.0029)	(0.0079)
Crisis	-0.0155	-0.0293*	-0.0545*
	(0.0190)	(0.0152)	(0.0285)
Country FE	Yes	Yes	Yes
Period FE	Yes	Yes	Yes
AR(1) (p-value)	0.069	0.000	0.001
AR(2) (p-value)	0.455	0.702	0.895
Weak IV test (p-value)	0.11/0.00/0.00	0.31/0.01/ 0.00/0.12/0.08	0.44/ 0.02/0.00/0.08/0.00
Over-id test (p-value)	0.957	0.335	0.1
# of instruments	24	23	23
# of countries	40	45	23
Observations	132	177	102

Note: Two-step system GMM results are reported in all columns. Weak IV test reports F-test of excluded instruments, of which the null hypothesis is that instruments are weak. Over-id test reports the validity of instruments, the null is that instruments are valid. Clustered robust standard errors at the country level are reported in parentheses. *, ** and *** are the significance level at 10%, 5% and 1%.

Figure A.1. China's capital account policy and firm dynamics

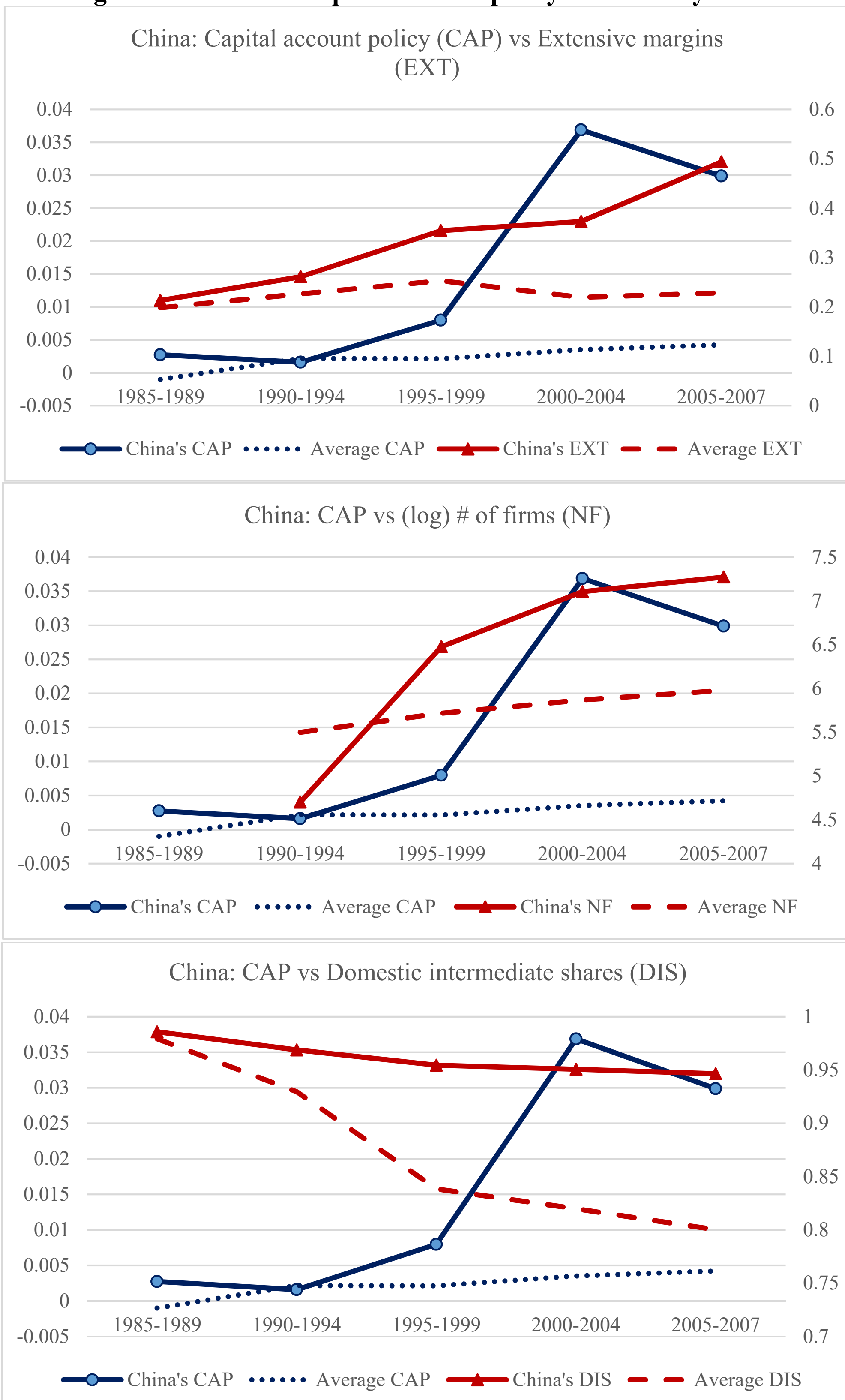
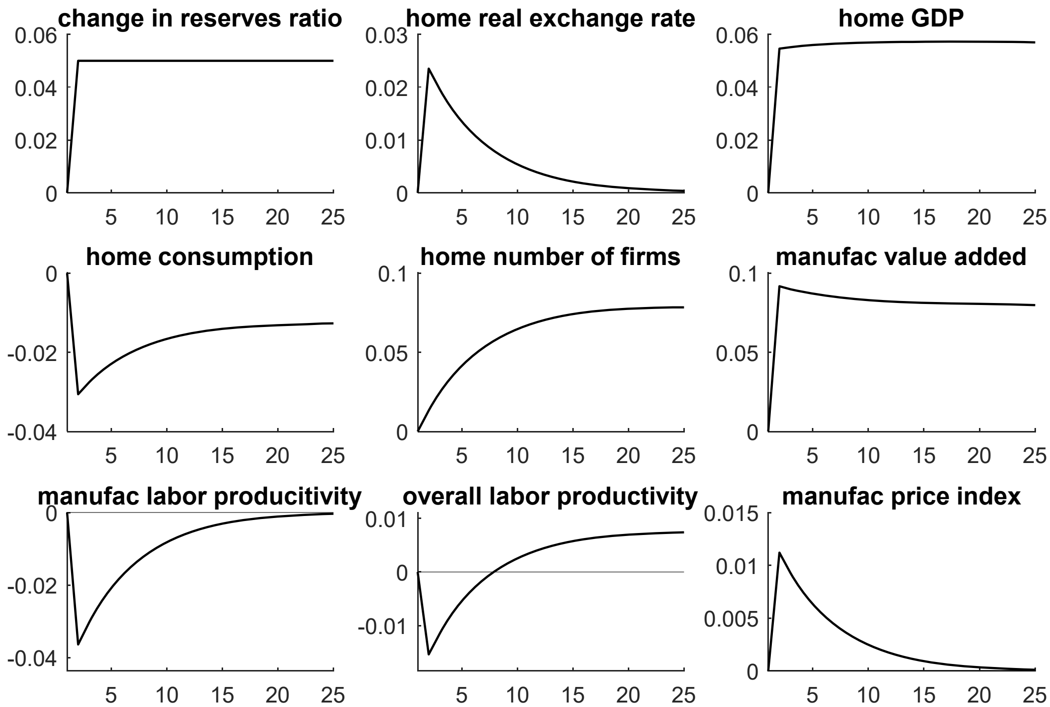


Figure A.2. Simulation for model with no trade cost (τ =0)



Vertical axes show percent change from value prior to change in reserves policy. Horizontal axes show years.