The Exchange Rate as an Industrial Policy*

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January 14, 2024

Abstract

We study the role of exchange rates as a tool for industrial policy. We construct an open-economy macroeconomic framework with production externalities and show that the desirability of these policies critically depends on the dynamic patterns of externalities. When they are stronger in earlier stages of development, economies converging to the technological frontier can improve welfare by intervening in foreign exchange markets, keeping the exchange rate undervalued, and speeding up the transition; economies that are not converging to the technological frontier are better off by not using the exchange rate as an industrial policy tool. Capital-flow mobility plays a central role in the effectiveness of this policy, which becomes fully ineffective under perfectly open capital accounts. We apply our framework to the case of China's take-off and show that the optimal exchange rate industrial policy has large output effects in the first decades of the transition, albeit with small welfare gains. We also discuss the role of capital controls as an industrial policy tool.

Keywords: Exchange rates, industrial policy, imperfect financial markets, growth take-off, capital controls

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1. Introduction

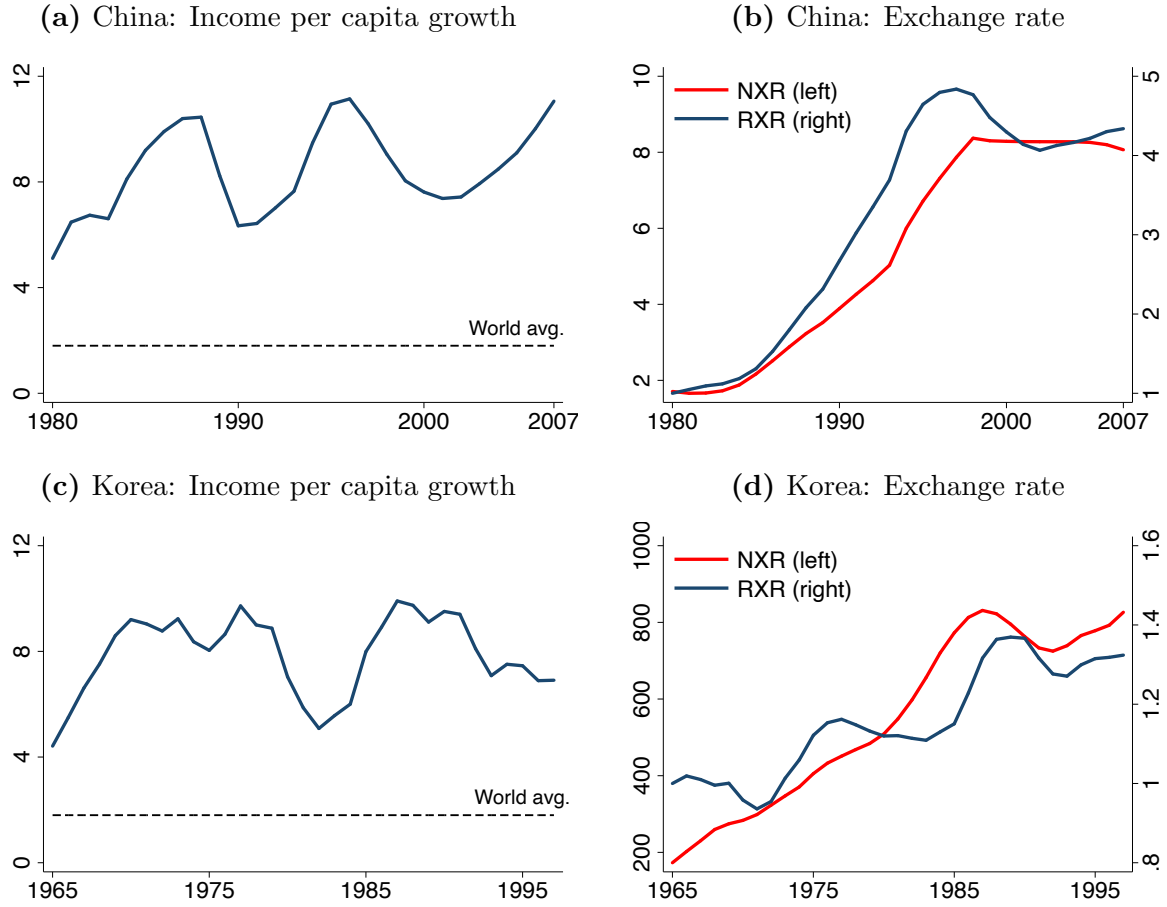
A long-held view in policy circles is that the exchange rate can be used as a tool for fostering development. The idea behind this view is that maintaining a depreciated exchange rate can stimulate the growth of strategic sectors by enhancing their competitiveness, and this helps speed growth processes. This narrative is based on salient examples of emerging-market economies' prolonged growth, which include the case of South Korea from the 1960s until the 1990s and the recent case of China from the 1980s until the 2010s. These economies experienced decades of high growth rates in per capita output that were on average more than three times higher than the world growth rate. These processes were accompanied by significant depreciations of the nominal and real exchange rates (see Figure 1).

In this paper, we address the question of how the exchange rate can be used as an industrial policy. To do so, we construct an open-economy framework in which transitions to the technological frontier are characterized by production externalities. We show that the dynamic pattern of these externalities enables scope for foreign exchange interventions aimed at keeping the currency undervalued at early stages of the transition, increasing labor supply, and directing resources to the tradable sector. We then study the quantitative relevance of these policies by applying our framework to the case of China's take-off, and show that the optimal exchange rate industrial policy accounts for more than half of the first-best welfare gains.

The paper begins by constructing a theoretical framework to study the role of exchange rates as an industrial policy. The model embeds production externalities in a canonical open-economy framework with tradable and nontradable goods. Externalities exhibit a dynamic pattern that depend on the development stage of the economy, with stronger spillovers in economies that are further from the technological frontier (see, e.g., Redding, 1999). The model also features imperfect financial markets, which allow the government to influence the path of the real exchange rate through foreign exchange interventions (see, e.g., Gabaix and Maggiori, 2015; Itskhoki and Mukhin, 2021a).

The competitive equilibrium in the economy features an inefficiently slow speed of con-

Figure 1: The Macroeconomic Effects of Exchange Rate Industrial Policy



Notes: Panels (a) and (c) show the 5-year moving average of the annual growth rate of per capita GDP. Panels (b) and (d) show the 5-year moving average of the nominal exchange rate per USD and multilateral real exchange rate (expressed as domestic currency per units of a basket of foreign currencies). Data sources: BIS, OECD, World Bank.

vergence to the technological frontier. Individual agents do not internalize that the social returns of labor are larger than private ones, and especially so in the early stages of development. Hence, the economy features inefficiently low levels of labor during the transition. In addition, if production externalities are stronger in the tradable sector (as in Krugman, 1987), the competitive equilibrium features a distorted marginal rate of transformation between goods, with too little production of tradable goods. In this environment, a government with time-varying, sector-specific labor subsidies can attain the first-best allocation.

In the absence of these fiscal tools, the government can still use exchange rate policies

to exploit the dynamic pattern of externalities and move the economy closer to its first-best allocation. The optimal "exchange rate industrial policy" features a depreciated exchange rate during early stages of the transition, which is attained with currency market interventions and the accumulation of international reserves. This policy affects the dynamic path of allocations through two channels. First, by purchasing foreign currency the return on saving in local currency increases, which stimulates savings, decreases consumption, and increases labor supply. Second, the depreciated exchange rate induces firms to redirect labor to the tradable sector.

Our theoretical framework emphasizes the role of dynamic externalities in providing a rationale for exchange rate industrial policies. When the government purchases foreign currency it depreciates the current exchange rate at the expense of appreciating it in the future. Therefore, this type of policy is undesirable in the particular case in which externalities are constant over time. We also show that allocations under the optimal exchange rate industrial policy can be implemented with time-varying taxes on debt. Therefore, our framework provides a rationale for the use of capital controls as an industrial policy.

In the last part of the paper we conduct a quantitative analysis of our model applied to the case of China to assess the quantitative relevance of the exchange rate industrial policy. We first build on the work of Bartelme, Costinot, Donaldson and Rodriguez-Clare (2019), which estimates sector-specific production externalities using cross-country sectoral trade data and an instrumental variables approach. We expand on their work by estimating how these externalities depend on a country's distance to the technological frontier. We then calibrate the model to match salient features of the Chinese economy and compute the optimal exchange rate industrial policy for the transition path over the last three decades.

The results indicate that the optimal exchange rate industrial policy is quantitatively effective: It significantly stimulates tradable production in the first years of the transition and attains half of the welfare gains of the first-best allocation. We also show that the observed accumulation of international reserves by China falls short of what the optimal exchange rate industrial policy indicates.

Related Literature. Our paper is related to several strands of the literature. First, the paper builds on the new generation of macroeconomic models of the exchange rate and imperfect financial markets, surveyed by Maggiori (2022). These models have been used to study exchange rate dynamics, their connection with the macroeconomy, and the effectiveness of foreign exchange interventions (see, for example, Gabaix and Maggiori, 2015; Fanelli and Straub, 2021; Itskhoki and Mukhin, 2021a,b). We contribute to this literature by studying exchange rate market interventions in economies with production externalities.

Second, the paper contributes to the literature that studies the role of exchange rates for economic development. Our work builds on the idea that depreciated exchange rates can foster development by stimulating tradable production (see, e.g., Hirschman, 1958; Rodrik, 1986; Krugman, 1987; Baldwin and Krugman, 1989; Rodrik, 2008, for early contributions). More recently, Korinek and Serven (2016) and Guzman, Ocampo and Stiglitz (2018) show that maintaining an undervalued exchange rate and managing capital inflows is desirable when there are spillovers in tradable production. Benigno, Fornaro and Wolf (2022) develop a model with knowledge spillovers and firms' financing frictions to explain emerging economies with fast growth, current account surpluses, and reserve accumulation.[1] We complement this literature by providing a theoretical framework that highlights the role of dynamic externalities in providing a rationale for the use of the exchange rate as an industrial policy.

Our paper is also related to the literature that studies how capital flows to fast-growing developing economies (see, e.g., Lucas, 1990; Alfaro, Kalemli-Ozcan and Volosovych, 2008; Aguiar and Amador, 2011; Gourinchas and Jeanne, 2013, among others). Closest to our paper, a rising literature studies China's integration into international capital markets. This literature has highlighted the central role of exchange rate policy and capital controls in the process of international integration (see, for example, Jeanne, 2013; Farhi and Maggiori, 2019; Bahaj and Reis, 2020; Clayton, Dos Santos, Maggiori and Schreger, 2022). We contribute to this literature by showing that growth processes without capital inflows can result from the use of exchange rates and capital controls as industrial policies to redirect resources to

[1] A related literature studies the connection between international financial markets, technology spillovers, and growth. Recent contributions in this area include Alberola and Benigno (2017); Gopinath, Kalemli-Ozcan, Karabarbounis and Villegas-Sanchez (2017); Queralto (2020); Ates and Saffie (2021).

strategic sectors.

Finally, our paper is also related to the literature that studies industrial policy. Notable contributions in the area of international trade include Redding (1999); Melitz (2005); Bartelme *et al.* (2019) and Gaubert, Itskhoki and Vogler (2021). Harrison and Rodríguez-Clare (2010) provide a survey of this literature. Other applications have been studied in the context of network economies (Liu, 2019); economies with financial frictions (Itskhoki and Moll, 2019); and the financial sector (Farhi and Tirole, 2021). Most of this work advocates industrial policies that take the form of import tariffs, taxes or subsidies to sectoral production, and direct financial interventions. Our work complements this literature by focusing on exchange rate policies as a tool for industrial policy. Also, the quantitative analysis uses the methodology proposed by Bartelme *et al.* (2019) to estimate sectoral production externalities.

The rest of the paper is organized as follows. Section 2 presents the model economy and Section 3 characterizes the optimal exchange rate industrial policy. Section 5 conducts the quantitative analysis applied to China, and Section 6 concludes.

2. Theoretical Framework

We consider a canonical small-open-economy (SOE) model with tradable and nontradable goods. There are three type of agents in the domestic economy: households, firms, and the government. We enrich this setting to include dynamic production externalities and segmented asset markets. The rest of the world trades tradable goods and an external asset with the domestic economy.

We study the optimal exchange rate policy when the economy experiences a growth process and externalities dissipate as the economy transitions to the technological frontier.

2.1. Environment

Households. The environment is deterministic and time is infinite, discrete, and denoted by $t = 0, 1, ...$ The representative household has preferences over an infinite stream of

consumption C_t and labor L_t:

$$\sum_{t=0}^{\infty} \beta^t \left[\frac{{C_t}^{1-\sigma}}{1-\sigma} - \phi \frac{L_t^{1+\nu}}{1+\nu} \right]. \tag{1}$$

The consumption good is a composite aggregator of tradable C_{Tt} and nontradable C_{Nt} consumption,

$$C_t = \left[\omega^{\frac{1}{\eta}} (C_{Tt})^{1-\frac{1}{\eta}} + (1-\omega)^{\frac{1}{\eta}} (C_{Nt})^{1-\frac{1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{2}$$

where $\omega \in (0,1)$ is the weight on the tradable good and $\eta > 0$ is the elasticity of substitution between tradable and nontradable consumption. Households receive their income from labor and profits from domestic firms. They can save or borrow using a domestic currency bond. Their budget constraint expressed in domestic currency is given by

$$P_{Tt} C_{Tt} + P_{Nt} C_{Nt} + B_{t+1} = W_t L_t + \Pi_t + T_t + R_t B_t, \tag{3}$$

where P_{Tt}, P_{Nt} are the prices of tradables and nontradables; B_{t+1} are the bonds purchased in t that mature in $t+1$; R_t is the domestic currency interest rate; W_t is the nominal wage; Π_t are the profits from firms in the tradable and nontradable sectors; and T_t are transfers from the government.

The household's problem is to choose allocations $\{C_t, C_{Tt}, C_{Nt}, L_t, B_{t+1}\}_{t=0}^{\infty}$ that maximize utility (1), subject to the aggregation technology (2); the sequence of budget constraints (3), given a sequence of prices, profits and transfers; and an initial level of bonds B_0. The first-order conditions that characterize the solution to the household's problem are

$$\left(\frac{1-\omega}{C_{Nt}} \right)^{\frac{1}{\eta}} = p_t \left(\frac{\omega}{C_{Tt}} \right)^{\frac{1}{\eta}}, \tag{4}$$

$$\left(\frac{\omega}{C_{Tt}} \right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} \frac{W_t}{P_{Tt}} = \phi L_t^{\nu}, \tag{5}$$

$$\left(\frac{\omega}{C_{Tt}} \right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R_{t+1} \frac{P_{Tt}}{P_{Tt+1}} \left(\frac{\omega}{C_{Tt+1}} \right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{6}$$

where $p_t \equiv P_{Nt}/P_{Tt}$ is the relative price of nontradable goods. The first equation relates the marginal utility of consuming tradables and nontradables to its relative price. The second equation equates the marginal disutility of supplying labor to the product of the real wage in tradable goods and the marginal utility of consuming tradables. The last equation is the Euler equation, where the relevant interest rate is the real interest rate of the bond in local currency.

Firms. There is a representative firm in each sector. The firm in sector $i = T, N$ employs labor l_{it} and produces goods according to the following decreasing-returns-to-scale production technology:

$$y_{it} = A_t L_{it}^{\gamma_{it}} l_{it}^{\alpha}. \tag{7}$$

The firm's productivity $Z_{it} \equiv A_t L_{it}^{\gamma_{it}}$ is the product of an exogenous and endogenous component. The exogenous component A_t evolves according to

$$A_t = \rho \overline{A} + (1 - \rho) A_{t-1}, \tag{8}$$

where $\overline{A}$ is the technological frontier; $A_0 < \overline{A}$ and $\rho \in (0, 1)$. The endogenous component, $L_{it}^{\gamma_{it}}$, captures the Marshallian production externalities by which aggregate sectoral labor, L_{it}, increases the productivity of firms working in that sector. In equilibrium, $L_{it} = l_{it}$ given the representative firm assumption. These production externalities can arise due to learning-by-doing, knowledge spillovers, or labor pooling (Lucas, 1988; Krugman, 1992). Given our purposes, we remain agnostic about which are the fundamental reasons that give rise to the externalities. We assume that the externalities are sector-dependent and a function of the distance to the technological frontier, i.e., $\gamma_{it} = \Gamma_i(\overline{A}/A_t)$, and make the following assumption regarding the relative strength and dynamics of these sectoral externalities.

ASSUMPTION 1. *Suppose that* $\Gamma_T(\overline{A}/A_t) > \Gamma_N(\overline{A}/A_t) = 0$, *and* Γ_T *is increasing in* $\overline{A}/A_t$.

The first condition assumes that externalities are only present in the tradable sector, and

is common in the literature on industrial policy in open economies (see, e.g., Krugman, 1987). The logic for this assumption is that learning-by-doing and knowledge spillovers are more likely to be present in exporting sectors such as manufacturing and less so in the nontradable sectors of developing economies, which prior to growth take-off are more concentrated in local agricultural sectors. In Section 4, we relax this assumption and characterize optimal exchange rate industrial policy when the economy features externalities in the nontradable sector that could be stronger or weaker than those in the tradable sector.

The second condition assumes that externalities are stronger the further the economy is from the technological frontier. This captures the idea that externalities are larger in the initial growth phase of a sector, when the role of learning and knowledge acquisition is more relevant. See Redding (1999) and Melitz (2005) for examples of papers that study industrial policies in economies with dynamic externalities that die out after sectors grow and achieve a certain scale.

Firms choose labor to maximize their profits, which are given by $\Pi_{it} = P_{it} A_t l_{it}^{\alpha} L_{it}^{\gamma_{it}} - W_t l_{it}$, which gives rise to the following aggregate labor demand:

$$\alpha A_t L_{it}^{\alpha+\gamma_{it}-1} = W_t / P_{it}. \tag{9}$$

Government. The government manages a portfolio of bonds in local and foreign currency and lump-sum transfers its proceedings to households. Its budget constraint is given by

$$F_{t+1} + \mathcal{E}_t F_{t+1}^* + T_t = R_t F_t + \mathcal{E}_t R^* F_t^*, \tag{10}$$

where F_{t+1} and F_{t+1}^* are the local and foreign currency bonds purchased in period t, respectively; R^* is the foreign currency interest rate; and $\mathcal{E}_t$ is the nominal exchange rate expressed as domestic currency per unit of foreign currency.

Rest of the world. The rest of the world exchanges tradable goods and foreign currency bonds with the government of the small open economy, and provides a perfectly elastic supply of funds at interest rate R^*. Financial markets are segmented and the rest of the

world cannot trade domestic currency bonds. Finally, we assume that the law of one price holds for tradable goods and normalize the foreign currency price of tradables, so that $P_{Tt} = \mathcal{E}_t$.

Competitive equilibrium. We can now define a competitive equilibrium for given government policies.

***Definition* 1** (Competitive equilibrium)**.** *Given initial asset positions F_0, F_0^*, a competitive equilibrium is a sequence of private allocations $\{C_t, C_{Tt}, C_{Nt}, L_t, B_{t+1}, L_{Tt}, L_{Nt}\}_{t=0}^{\infty}$, prices $\{P_{Tt}, P_{Nt}, W_t, \mathcal{E}_t, R_t\}_{t=0}^{\infty}$, and government policies $\left\{F_{t+1}, F_{t+1}^*, T_t\right\}_{t=0}^{\infty}$ such that:*

1. *Allocations solve the households' and firms' problem, given prices;*
2. *Government policies satisfy the government budget constraint;*
3. *Markets clear:*

$$L_t = L_{Tt} + L_{Nt}, \tag{11}$$

$$C_{Nt} = A_t L_{Nt}^{\alpha}, \tag{12}$$

$$F_{t+1} + B_{t+1} = 0. \tag{13}$$

Equations (11), (12), and (13) are the market-clearing conditions for labor, nontradable goods, and the local currency bond. Due to financial market segmentation, households and the government need to take opposing asset positions in local currency.

We now derive the equations that characterize the competitive equilibrium allocations. These will serve as implementability conditions for the optimal policy problem. Combining (4), (5), (9), and (11), we obtain

$$\left(\frac{1-\omega}{\omega}\frac{C_{Tt}}{C_{Nt}}\right)^{\frac{1}{\eta}} = \frac{L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt}^{\alpha-1}}, \tag{14}$$

$$\frac{\phi\left(L_{Tt}+L_{Nt}\right)^{\nu}}{\left(\omega/C_{Tt}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma}} = \alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}. \tag{15}$$

The first equation equates the marginal rate of substitution between tradable and nontradable goods to their private marginal rate of transformation. The second equation equates the marginal rate of substitution between tradables and labor with the private marginal product of labor. Finally, competitive equilibrium allocations are also characterized by the maket-clearing condition for nontradables (12), and the balance of payments condition (or tradable goods market clearing),

$$C_{Tt} - A_t L_{Tt}^{\alpha+\gamma_{Tt}} = R^* F_t^* - F_{t+1}^*, \tag{16}$$

which states that net imports should be financed with external debt. Note that the household's Euler equation is not an implementability condition and is used to pin down the local currency interest rate R_t.

3. Exchange Rate Industrial Policy

This section characterizes the optimal exchange rate industrial policy (XR-IP). We begin by characterizing the first-best allocation, which serves as a useful benchmark.

***Definition* 2** (First best)**.** *A first-best allocation is the allocation that maximizes utility* (1)*, subject to the consumption aggregator definition* (2)*, the balance of payments condition* (16)*, and market-clearing conditions for labor* (11) *and nontradable goods* (12)*.*

The first order conditions that characterize the first-best allocation are

$$\left(\frac{1-\omega}{\omega}\frac{C_{Tt}}{C_{Nt}}\right)^{\frac{1}{\eta}} = \frac{(\alpha+\gamma_{Tt})}{\alpha}\frac{L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt}^{\alpha-1}}, \tag{17}$$

$$\frac{\phi\left(L_{Tt}+L_{Nt}\right)^{\nu}}{(\omega/C_{Tt})^{\frac{1}{\eta}}\, C_t^{\frac{1}{\eta}-\sigma}} = (\alpha+\gamma_{Tt}) A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}, \tag{18}$$

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R^* \left(\frac{\omega}{C_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}. \tag{19}$$

The first equation equates the marginal rate of substitution between tradable and nontradable goods to their social marginal rate of transformation. The second equation equates the

marginal rate of substitution between tradables and labor with the social marginal product of labor. The last equation is the Euler equation that equates the intertemporal marginal rate of substitution to the foreign currency interest rate.

The social marginal rate of transformation and the social marginal product of labor are higher than their private counterparts due to production externalities in the tradable sector. These differences introduce wedges in the intratemporal allocation of labor and consumption in the competitive equilibrium, relative to the first-best allocation, that cannot be undone with foreign exchange (FX) intervention. The following proposition formalizes this result.

***Proposition* 1** (Impossibility result)**.** *The first-best allocation is not attainable with FX intervention.*

We include all proofs in Appendix A. FX intervention affects the intertemporal margin of consumption by affecting the path of the exchange rate and the rate of return of domestic savings. This policy cannot attain the first-best allocation because the wedges introduced by the production externality affect the intratemporal allocation of consumption and labor. On the other hand, as the next proposition states, fiscal policy can attain the first-best allocation through time- and sector-specific labor subsidies.

***Proposition* 2.** *The first-best allocation is attainable with FX intervention and the following time-varying labor subsidies to the tradable sector:*

$$\tau_{Tt}^{L} = \frac{\gamma_{Tt}}{\alpha + \gamma_{Tt}}.$$

This is a familiar result from the macro-public finance literature. Labor subsidies undo the wedges between the social and private marginal rates of transformation, and the FX intervention is such that the returns on saving in local and foreign currency are equal. While this is the most desirable policy from a social perspective, it may be difficult to implement from a political economy perspective.

We now study the optimal exchange rate policy as a second-best policy. The optimal exchange rate policy consists of a government policy that maximizes the lifetime utility

of households subject to the implementability conditions that characterize a competitive equilibrium. We formally define this problem below.

***Definition* 3.** *An optimal exchange rate industrial policy is a government policy that solves the following problem:*

$$\max_{\{C_{it},L_{it},F^*_{t+1}\}^{i=T,N}_{t\geq 0}} \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \phi\frac{(L_{Tt}+L_{Nt})^{1+\nu}}{1+\nu}\right] \quad \textit{subject to} \tag{P1}$$

$$\left(\frac{1-\omega}{\omega}\frac{C_{Tt}}{C_{Nt}}\right)^{\frac{1}{\eta}} = \frac{L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt}^{\alpha-1}},$$

$$\frac{\phi\left(L_{Tt}+L_{Nt}\right)^{\nu}}{\left(\omega/C_{Tt}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma}} = \alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1},$$

$$C_{Tt} - A_t L_{Tt}^{\alpha+\gamma_{Tt}} = R^* F_t^* - F_{t+1}^*,$$

the consumption aggregator definition (2)*, and the market-clearing conditions for nontradable goods* (12)*.*

This problem is characterized by the following modified Euler equation

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R^* \frac{\theta(\mathbf{x}_{t+1},\gamma_{Tt+1})}{\theta(\mathbf{x}_t,\gamma_{Tt})}\left(\frac{\omega}{C_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{20}$$

where $\theta(\mathbf{x}_t,\gamma_{Tt})$ is a function that depends on the allocations of the economy, $\mathbf{x}_t \equiv \{C_t, C_{Tt}, C_{Nt}, L_t, L_{Tt}, L_{Nt}, A_t\}$, and the strength of the externality at a given time period t. We provide an expression for this function in Appendix A.3. To further characterize the allocations that satisfy this optimality condition, we make the following parametric assumption.

Assumption 2. *Suppose* $\sigma = \eta = 1$ *and* $\nu = 0$.

The first condition corresponds to the Cole and Obstfeld (1991) preference parameterization, and the second condition assumes a perfectly elastic labor supply. We now contrast the allocations under the optimal exchange rate industrial policy relative to a benchmark allocation that corresponds to a competitive equilibrium in which the government is a passive

agent. We formalize this benchmark notion below.

***Definition* 4.** *A laissez-faire competitive equilibrium is a competitive equilibrium with an associated government policy that is such that UIP holds, i.e.,* $R_{t+1} = R^* \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}$.

This benchmark corresponds to the case in which the government intermediates capital flows such that it is as if households have direct access to saving and borrowing at the foreign currency interest rate. The proposition below characterizes the optimal policy.

***Proposition* 3** (Optimal exchange rate industrial policy)**.** *Suppose that tradable externalities are only present in* $t = 0$*, i.e.,* $\gamma_{T0} > \gamma_{Tt} = 0$ *for* $t \geq 1$*, and* $\gamma_{T0} < 1 - \alpha$*. The optimal exchange rate industrial policy implies:*

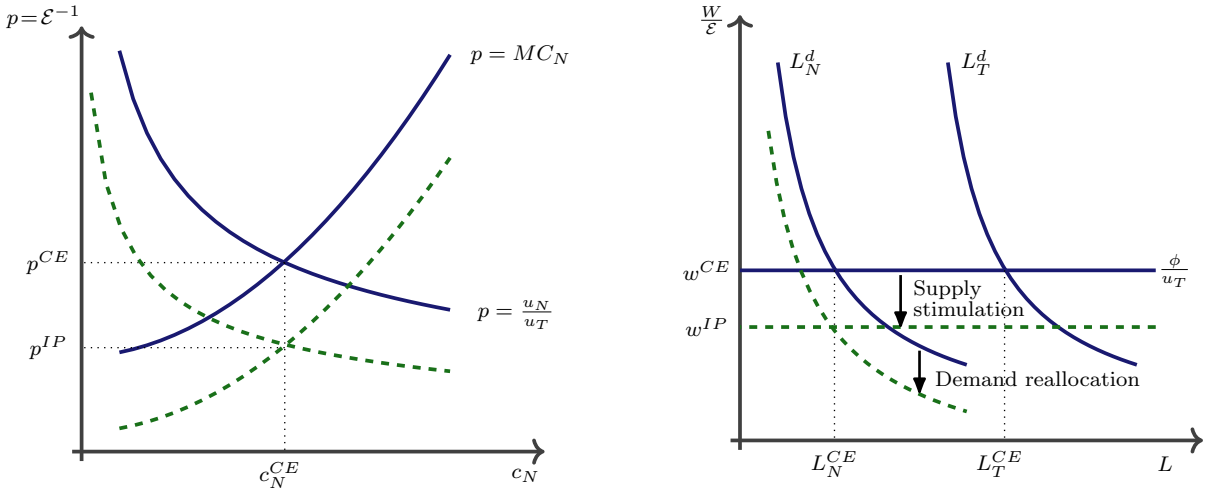
$$\mathcal{E}_0^{IP} > \mathcal{E}_0^{CE}, \quad L_{T0}^{IP} > L_{T0}^{CE}, \quad c_{T0}^{IP} < c_{T0}^{CE}, \quad CA_0^{IP} > CA_0^{CE}, \quad F_1^{*IP} > F_1^{*CE}.$$

The optimal exchange rate industrial policy features a depreciated exchange rate relative to the laissez-faire competitive equilibrium exchange rate in the initial period when the externality is present. The depreciated exchange rate is attained with currency market interventions and the accumulation of international reserves. This policy affects the dynamic path of allocations through two channels. First, the policy induces a stimulation of labor supply. By purchasing foreign currency financed with local currency debt, the return on saving in local currency for households increases, which stimulates savings. This in turn decreases consumption and increases labor supply when consumption and leisure are normal goods. Second, the depressed aggregate demand reduces the demand for tradable and nontradable goods, depreciates the exchange rate, and lowers labor demand from the nontradable sector.

Figure 2 shows the effects of the policy in the nontradable goods market and in the labor market during the initial period. The policy implies more labor and production and lower consumption in the tradable sector, and a current account surplus relative to the laissez-faire equilibrium. For the parameterization under Assumption 2, the positive supply stimulation and negative demand reallocation effects for the nontradable labor market cancel out, which implies the same level of nontradable production as in the laissez-faire equilibrium.

Figure 2: The Macroeconomic Effects of Exchange Rate Industrial Policy

(a) Non-tradable Goods Market in $t = 0$ **(b)** Labor Market in $t = 0$



Notes: This figure shows the allocations of the laissez-faire competitive equilibrium (blue line) and the optimal exchange rate industrial policy (green dotted line) in the nontradable goods market and the labor market in $t = 0$.

By generating a current account surplus and accumulating international reserves, the economy generates a net creditor position that implies a current account deficit, larger tradable consumption, lower tradable production, and a more appreciated exchange rate in future periods when the production externality dissipates.

4. Model Extensions and Additional Results

In this section we analyze the optimal exchange rate industrial policy in various departures from the baseline model. We show that the optimal policy is similar in a model with fixed labor supply or nontradable externalities. We also provide conditions for when the optimal policy is to not intervene. Finally, we argue that the same allocation can be attained with a capital control policy.

4.1. Relaxing baseline assumptions

Fixed labor supply. Consider a model variant with a setup similar to the baseline model but with fixed labor supply. In this model, the optimal policy does not feature a supply stimulation channel, and only affects allocation through a reallocation of sectoral labor demand. The following result shows that the optimal exchange rate industrial policy shares the same characteristics as in the baseline model.

***Proposition* 4** (XR-IP with fixed labor supply)**.** *Consider the model with $\sigma = \eta = 1$, fixed labor supply, and suppose that $\gamma_{T0} > \gamma_{Tt}$ for $t \geq 1$, and $\gamma_{T0} < 1 - \alpha$. The optimal exchange rate industrial policy implies:*

$$\mathcal{E}_0^{IP} > \mathcal{E}_0^{CE}, \quad L_{T0}^{IP} > L_{T0}^{CE}, \quad c_{T0}^{IP} < c_{T0}^{CE}, \quad CA_0^{IP} > CA_0^{CE}, \quad F_1^{*IP} > F_1^{*CE}.$$

In this setup it is still optimal to intervene in the FX market and depreciate the exchange rate initially to redirect resources to the tradable sector and exploit the production externalities.

Externalities in the nontradable sector. Consider a generalization of the baseline model in which $\gamma_{Nt} > 0$ for $t \geq 0$. In principle, the presence of time- and sector-specific production externalities can imply different paths of exchange rate policies depending on the relative strength of externalities. However, the following proposition characterizes the optimal policy under a particular parameterization.

***Proposition* 5** (XR-IP with nontradable externalities)**.** *Let Assumption 2 be satisfied. Consider the model with an arbitrary path of externalities in the nontradable sector, $\gamma_{Nt} > 0$ for $t \geq 0$, and a decreasing path of externalities in the tradable sector, $\gamma_{T0} > \gamma_{Tt} = 0$ for $t \geq 1$ and $\gamma_{T0} < 1 - \alpha$. The optimal exchange rate industrial policy implies*

$$\mathcal{E}_0^{IP} > \mathcal{E}_0^{CE}, \quad L_{T0}^{IP} > L_{T0}^{CE}, \quad c_{T0}^{IP} < c_{T0}^{CE}, \quad CA_0^{IP} > CA_0^{CE}, \quad F_1^{*IP} > F_1^{*CE}.$$

In this case the optimal exchange rate industrial policy shares the same characteristics

as the baseline model. The reason is that Assumption 2 implies that nontradable production and consumption is independent of the dynamic aspects of the economy. This implies that the optimal policy addresses the dynamic path of the externalities in the tradable sector and is independent of the path of externalities in the nontradable sector.

4.2. When is the policy undesirable?

The optimal exchange rate industrial policy exploits the dynamic path of production externalities. It keeps the exchange rate depreciated when externalities in the tradable sector are stronger. When externalities are permanent there is no role for this type of policy because any exchange rate depreciation that the govermment induces in early periods is associated with an appreciation in later periods when the current account balance is reversed. The following proposition formalizes this result.

***Proposition* 6** (XR-IP with constant externalities)**.** *Consider an economy at the technological frontier with time-invariant sectoral production externalities,* $\gamma_{Tt} = \gamma_T$ *and* $\gamma_{Nt} = \gamma_N$ *for all* $t \geq 0$*, and* $\beta R^* = 1$*. Allocations from the optimal exchange rate industrial policy coincide with the laissez-faire competitive equilibrium.*

4.3. Capital Controls as an Industrial Policy

By intervening in the FX market, the government affects the return on savings that households perceive and thus affects the dynamic path of tradable consumption through the Euler equation. The same macroeconomic effects can be attained in an economy in which households have access to saving and borrowing in foreign currency and the government can impose capital controls in the form of a tax on saving/debt. This result echoes those of Farhi, Gopinath and Itskhoki (2014), who show that exchange rate devaluations can be replicated with a combination of fiscal tools.

***Proposition* 7** (XR-IP with capital controls)**.** *Consider a model variant in which households can save or borrow in foreign currency and the government can impose a capital control. The*

allocations of the optimal exchange rate policy can be attained by imposing the following time-varying capital control:

$$\tau_t = \frac{\theta(\mathbf{x}_{t+1}, \gamma_{Tt+1})}{\theta(\mathbf{x}_t, \gamma_{Tt})} - 1.$$

5. An Application to China's Take-Off

This section studies the quantitative relevance of the exchange rate as an industrial policy by applying the theoretical framework to China's growth take-off. Section 5.1 discusses model parameterization. Section 5.2 examines how the optimal exchange rate industrial policy influences the transition to the technological frontier and compares it with the laissez-faire competitive equilibrium and first-best allocation.

5.1. Parameterization

We begin by discussing empirical evidence that informs the path of production externalities, which is the most novel part of our parameterization. We then describe the remaining model parameterization, which is more standard in the open-economy literature.

Estimating production externalities. To discipline the path of production externalities, we build on the methodology proposed by Bartelme *et al.* (2019) (henceforth, BCDR), who use variation in sectoral production across countries to estimate sector-specific production spillovers. In particular, we estimate sectoral production functions $Y_{ci} = A_{ci} L_{ci}^{\alpha+\Gamma_i(\mathrm{df}_c)}$, which is a cross-country version of (7). The only departure from their method is that we allow the production externality to be a function of the distance to frontier, df_c. To implement this approach, we estimate the empirical model

$$y_{c,i} = a_c + a_i + (\gamma_{i0} + \gamma_{i1}\mathrm{df}_c) \ln L_{c,i} + \varepsilon_{c,i}, \tag{21}$$

where $y_{c,i}$ log sales from country c in sector i, averaged across all destinations $L_{c,i}$ is a measure of employment in sector i, country c;[2] df_c is the distance to the technological frontier of country c, measured as $df_c = \frac{GDP_{US}}{GDP_c} - 1$, where GDP_c and GDP_{US} denote GDP per capita in country c and the United States; a_c and a_i are country and sector fixed effects that absorb productivity shifters and other country and sector characteristics. As do BCDR, we estimate (21) using data for 61 countries (listed in Table B1) and 15 manufacturing sectors from the OECD's Inter-Country Input-Output tables and population data from the Penn World Tables (for additional data description, see Appendix B.3). Also following BCDR, we estimate (21) using a demand-side instrumental variable strategy, in which we instrument country-sector size with the population and expenditure shares of country c. The logic for this instrument is that, within each sector, employment should be higher in countries that are larger and/or have a stronger taste for goods from that sector.

Appendix Table B2 reports IV results from estimating (21) for each sector. Consistent with Bartelme *et al.* (2019), we estimate average positive and significant production externalities, which average 0.17 across sectors. In addition, our estimates indicate that emerging-market economies exhibit stronger production externalities than advanced economies, with an average of 0.24 for emerging-market economies and an average of 0.08 for advanced economies. This pattern is generalized across sectors, with stronger externalities for emerging-market economies relative to advanced economies in all sectors considered. Appendix B.4 shows that this relationship for 2010 also holds for 1995, 2000, and 2005.

Calibration. We parameterize the model in two steps. In the first step, we fix a subset of parameters that are standard in the open-economy literature. Table 1 reports values for these parameters. We set the time period to a year; the coefficient of relative risk aversion to $\sigma = 2$; the gross interest rate on the external asset to $R^* = 1.02$; the Frisch elasticity of labor supply to $\frac{1}{\nu} = 1$; the share of labor to $\alpha = \frac{2}{3}$; and the elasticity of substitution between

[2]Formally, $y_{c,i} \equiv \left(\frac{1}{J}\sum_d \ln X_{cd,i}\right)/\theta_i$ is log expenditure $X_{cd,i}$ on goods from country c in sector i averaged across all destinations d, and adjusted by the trade elasticity θ_i; BCDR use the median estimate for θ_i from prior studies listed in Table B.1 of their paper. $L_{c,i}$ is constructed using country population data and sectoral sales shares. In particular, $L_{c,i} = (S_{c,i}/S_c)\,\widehat{L}_c$, where $S_{c,i} = \sum_d X_{cd,i}$, $S_c = \sum_{d,i} X_{cd,i}$; and $X_{cd,i}$ are bilateral trade flows in sector i from country i to country d.

tradable and nontradable goods to 0.8.

Table 1: Fixed Parameters

Parameter		Value
Coefficient of relative risk aversion	σ	2
Gross interest rate	R^*	1.02
Discount factor	β	$1/R^* = 0.98$
Frisch elasticity of labor supply	$1/\nu$	1
Returns to scale	α	2/3
Tradable-Nontradable elasticity	η	0.8

Notes: This table shows the fixed parameter values of the model.

The second step of the calibration is linked to the set of parameters that govern the dynamics of the transition to the technological frontier, which is the most novel part of the model. We calibrate the initial state of the economy (denoted $t = 0$) to match key moments of the Chinese economy in 1997. We calibrate the weight of tradables in consumption, ω, to match the tradable share of output, and the level of foreign currency bonds, F^*, to match the ratio of international reserves to GDP. We set the disutility of labor, ϕ, to a tradable-sector labor supply, $L_T = 1$, to ensure that the initial steady-state allocation for the laissez-faire competitive equilibrium and XR-IP coincide. Finally, following the evidence presented in the previous section, we set $\gamma_{T0} = 0.24$, the average estimated production externality in emerging-market economies. We parameterize the path of production externalities with a first-order autoregressive process, $\gamma_{Tt} = \rho_\gamma \gamma_{Tt-1}$, with $\rho_\gamma = 0.9$, so that after 12 years the externality reaches the average advanced economy estimate of $\gamma_{Tk} = 0.08$.[3] Appendix B.5 details the algorithm used to solve the transition path.

[3]In Appendix B.7, we show similar results for a transition to a new steady state where $\gamma_T = 0.08$, the average advanced economy externality estimate.

Table 2: Calibrated Parameters

Parameter		Value	Target in Steady State
Initial production externality	γ_{T0}	0.24	Empirical estimates based on Bartelme *et al.* (2019)
Disutility of labor	ϕ	0.08	$L_T = 1$
Weight on tradables in CES	ω	0.50	Tradables share of GDP
Foreign currency bonds	F^*	0.31	Reserves share of GDP

Notes: This table shows the calibrated parameter values of the steady state of the model for China in 1997, which are the same for the laissez-faire competitive equilibrium and XR-IP. Data source: World Bank.

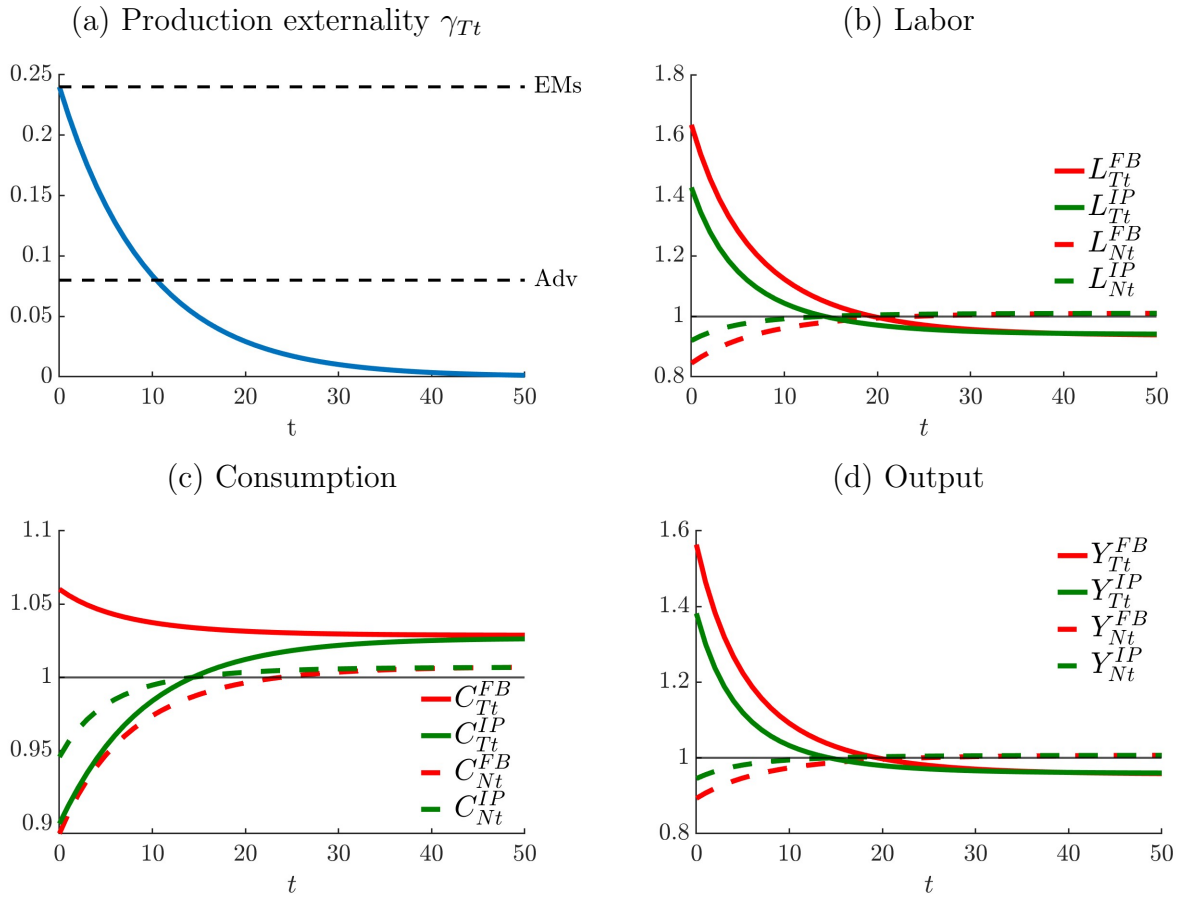
5.2. Economic Transition under the Optimal Exchange Rate Industrial Policy

We now compare the transitional paths from economies that start from the same initial condition, but follow alternative industrial policies. Figure 3 depicts the dynamics of labor, consumption, and output in the first-best allocation and in the optimal exchange rate industrial policy relative to the laissez-faire competitive equilibrium for the first 50 years of the transition to the new steady state.[4] Panel (a) depicts the assumed path for production externalities discussed in the calibration. Panel (b) shows that both the first best and XR-IP exhibit transitional dynamics characterized by more labor in the tradable sector and less labor in the nontradable sector than the laissez-faire equilibrium. Panel (c) shows that in the first best, the consumption of tradables increases while nontradables decrease, whereas under XR-IP, tradables consumption also decreases, as predicted by Proposition 3. This occurs due to the XR-IP implementability constraint, which requires that for tradable sector labor to increase, tradable consumption must decrease relative to the nontradable sector. Panel (d) shows that for output, similar to labor, there is a significant increase in the tradable sector and a contraction in nontradables, with the optimal XR-IP achieving around 60% percent of the first-best tradable sector expansion.

Figure 4 displays the path of external variables for XR-IP relative to the laissez-faire equilibrium, which align with results for the analytical case in Proposition 3.[5] Panel (a)

[4]Figures B2, B3, and B4 provide these variables in levels for each case.
[5]Figure B5 provides these for the first best.

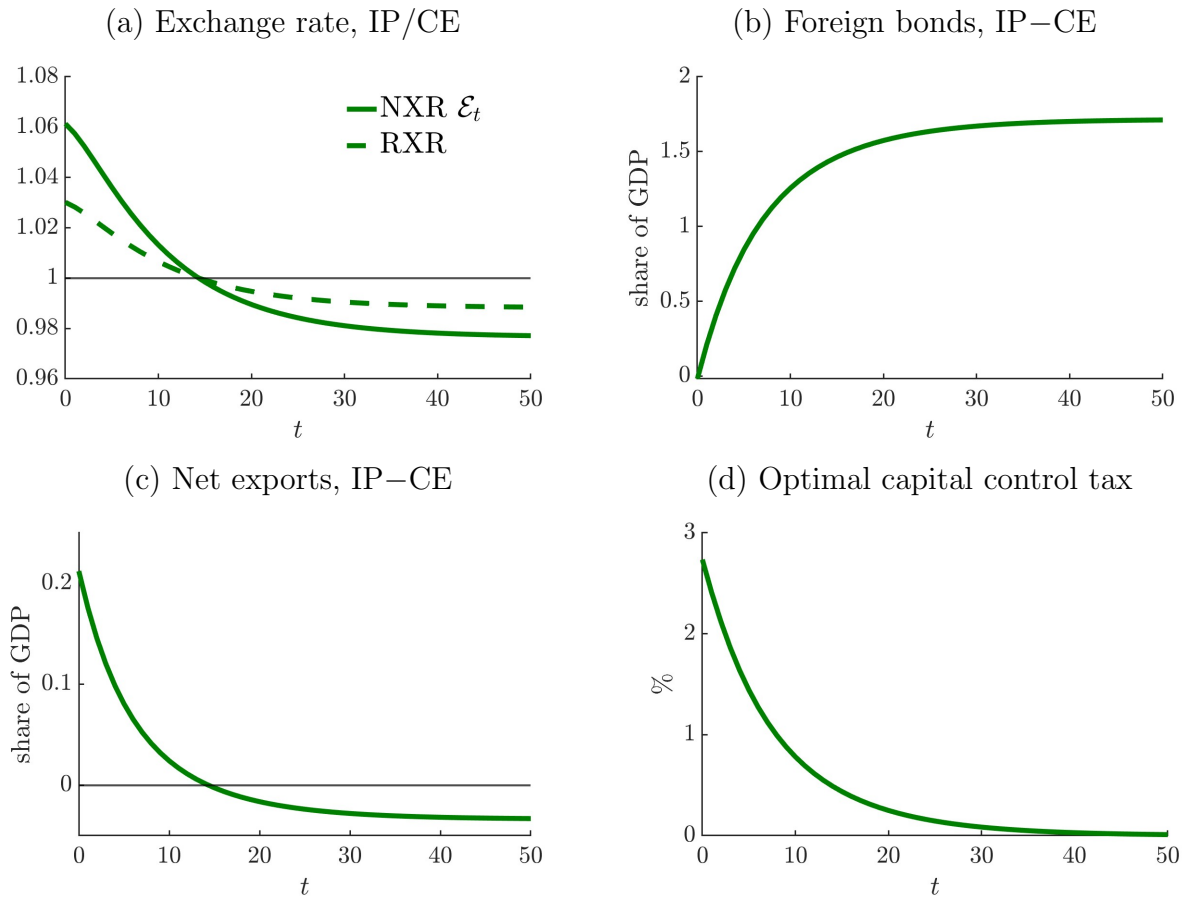
Figure 3: Transition – First Best and XR-IP Relative to Competitive Equilibrium



Notes: This figure shows the transition dynamics for the model from the initial steady state calibrated for China in 1997, following an unanticipated decline in the production externality γ_{Tt} shown in Panel (a). The variables in Panels (b)-(d) are relative to the laissez-faire competitive equilibrium, with the first best shown by "FB" and optimal XR-IP by "IP." Figures B2, B3, and B4 provide the variables in levels for each case.

shows that with a decline in the production externality, the optimal XR-IP involves a depreciation of the exchange rate, averaging approximately 4% more than the competitive equilibrium in nominal terms over the first 10 years. This reduction in the relative price of tradables expands the size of the tradable sector. Panel (b) illustrates that the government intervenes in the foreign exchange market to accumulate significant foreign asset holdings during the transition. Panel (c) reveals a substantial increase in exports, averaging around 10 percentage points of GDP over the first 10 years, which results from the rise in tradable output and decrease in tradables consumption shown in Figure 3. Finally, Panel (d) plots

Figure 4: Transition – XR-IP Relative to Competitive Equilibrium



Notes: This figure shows the transition dynamics for the model from the initial steady state calibrated for China in 1997, following an unanticipated decline in the production externality γ_{Tt} shown in Figure 3 Panel (a). The variables in Panels (a)-(c) are for the optimal XR-IP relative to the laissez-faire competitive equilibrium. Panel (d) shows the optimal capital control tax that implements the XR-IP allocation. Figures B2, B3, and B4 provide the variables in levels for each case.

the optimal capital control tax from Proposition 7, which implements the XR-IP allocation as an alternative policy instrument.[6]

We next examine welfare relative to the first best. Table 3 Panel (a) shows a significant increase in aggregate output in the initial phase of the transition, driven by the tradable sector for both the XR-IP and first best. In Panel (b) we observe the initial decrease in aggregate consumption but an increase in the new steady-state level due to the accumulation

[6]Figures B6-B8 show similar quantitative results for a transition to a new steady state where $\gamma_T = 0.08$, the average advanced economy externality estimate from Section 5.1.

of foreign currency bonds. Panel (c) provides the consumption equivalent welfare effect for the full transition path.[7] From this, we can see that XR-IP increases household welfare by 0.17% of aggregate consumption each period and achieves almost 60% of the first-best welfare gains.[8]

Table 3: Effects of XR-IP and First Best relative to Competitive Equilibrium

	XR-IP / CE, %Δ		FB / CE, %Δ	
	10-yr avg.	New SS	10-yr avg.	New SS
a. Output				
Aggregate	7.2	-1.6	11.7	-1.7
Tradable	16.5	-4.0	28.1	-4.3
Nontradable	-2.5	0.7	-6.1	0.7
b. Consumption				
Aggregate	-4.0	1.7	-0.9	1.8
Tradable	-5.5	2.7	4.7	2.9
Nontradable	-2.5	0.7	-6.1	0.7
c. Welfare (including transition)				
Cons. equiv.	0.17		0.29	

Notes: This table shows the average for the first 10 years of the transition for the optimal XR-IP and first best relative to the laissez-faire competitive equilibrium.

5.3. Effects of Foreign Exchange Intervention in China

In this section we compare the optimal XR-IP with the observed foreign exchange accumulation for China, which significantly increased as a share of GDP through the 2000s, as shown in Figure B1. Specifically, we match the observed increase in China's reserves to GDP of almost 30 percentage points over 1997-2007 in the model for the first 10 years of the transition described in Section 5.2.

[7] Section B.9 provides details on the consumption equivalent welfare calculation.

[8] Table B4 shows similar welfare gains for XR-IP relative to the competitive equilibrium when varying key model parameters.

Table 4 reports the results for the observed foreign reserve accumulation by China and the optimal XR-IP. The cumulative increase in China's reserves as a share of GDP is approximately one-quarter of the magnitude of the optimal reserve accumulation. Panels (a) and (b) compare the path of output and consumption for the observed and optimal XR-IP. The observed reserve accumulation leads to a smaller increase in aggregate and tradable output and a smaller decrease in consumption than XR-IP.

Table 4: Observed Reserves for China and XR-IP Relative to Competitive Equilibrium

	Obs. / CE, %Δ 10-yr avg.	XR-IP / CE, %Δ 10-yr avg.
Reserves to GDP (cum.)	28.3	119.5
a. Output		
Aggregate	1.8	7.2
Tradable	4.2	16.5
Nontradable	-0.7	-2.5
b. Consumption		
Aggregate	-1.2	-4.0
Tradable	-1.8	-5.5
Nontradable	-0.7	-2.5

Notes: This table shows the average for the first 10 years of the transition in the model for the observed foreign reserve accumulation for China from 1997 shown in Figure B1 and for the optimal XR-IP relative to the laissez-faire competitive equilibrium, following an unanticipated decline in the production externality γ_{Tt} shown in Figure 3 Panel (a). Data source: World Bank.

6. Conclusion

In this paper, we studied how exchange rate policies can be used to foster development. These types of policies arise in economies whose transition to the technological frontier is characterized by production externalities. In the early stages of the transition, governments can optimally intervene in exchange rate markets and maintain currencies undervalued, thereby

increasing labor supply and redirecting resources to the tradable sector. Our paper also highlights the limits of exchange rate industrial policies. Since these policies imply persistently influenced real exchange rates, they cannot be plausibly implemented through monetary policy. They are also less effective in economies that are highly integrated into capital markets or feature large heterogeneity of production externalities among tradable sectors.

Although our analysis has concentrated on policies from the perspective of individual economies, our framework can be extended to study interactions in the global economy. An interesting application in this regard is the idea of "currency wars," which was coined during China's take-off. Our framework could be used to study the extent to which these global dynamics can arise as a result of multiple economies trying to exploit the dynamic patterns of production externalities. We leave the study of these global interactions for future research.

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A. Theoretical Appendix

A.1. Proof of Proposition 1

Given the initial foreign currency asset position F_0^*, the conditions that characterize the competitive equilibrium allocation $\{C_{Tt}, C_{Nt}, L_{Tt}, L_{Nt}, F_{t+1}^*\}_{t=0}^{\infty}$ are

$$\left(\frac{(1-\omega)}{\omega}\frac{C_{Tt}}{C_{Nt}}\right)^{\frac{1}{\eta}} = \frac{L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt}^{\alpha-1}}, \tag{A.1}$$

$$\frac{\phi\left(L_{Tt}+L_{Nt}\right)^{\nu}}{\left(\omega/C_{Tt}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma}} = \alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}, \tag{A.2}$$

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R_{t+1} \frac{L_{Nt}^{\alpha-1}/L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt+1}^{\alpha-1}/L_{Tt+1}^{\alpha+\gamma_{Tt+1}-1}} \left(\frac{\omega}{C_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{A.3}$$

$$C_{Nt} = A_t L_{Nt}^{\alpha}, \tag{A.4}$$

$$C_{Tt} - A_t L_{Tt}^{\alpha+\gamma_{Tt}} = R^* F_t^* - F_{t+1}^*, \tag{A.5}$$

where in eqution (A.3) we substitute $P_{Tt} = \frac{L_{Nt}^{\alpha-1}}{L_{Tt}^{\alpha+\gamma_{Tt}-1}}$ into (4) after normalizing $P_{Nt} \equiv 1$ without loss of generality, and combine firms' labor demand from (9).

The conditions that characterize the first-best allocation $\{C_{Tt}, C_{Nt}, L_{Tt}, L_{Nt}, F_{t+1}^*\}_{t=0}^{\infty}$ are

$$\left(\frac{(1-\omega)}{\omega}\frac{C_{Tt}}{C_{Nt}}\right)^{\frac{1}{\eta}} = \left(\frac{\alpha+\gamma_{Tt}}{\alpha}\right)\frac{L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt}^{\alpha-1}}, \tag{A.6}$$

$$\frac{\phi\left(L_{Tt}+L_{Nt}\right)^{\nu}}{\left(\omega/C_{Tt}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma}} = (\alpha+\gamma_{Tt}) A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}, \tag{A.7}$$

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R^* \left(\frac{\omega}{C_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{A.8}$$

$$C_{Nt} = A_t L_{Nt}^{\alpha}, \tag{A.9}$$

$$C_{Tt} - A_t L_{Tt}^{\alpha+\gamma_{Tt}} = R^* F_t^* - F_{t+1}^*. \tag{A.10}$$

Observe that to satisfy the first-best intertemporal optimality condition (A.8) in the

competitive equilibrium (A.3) requires government foreign exchange intervention $\{F^*_{t+1}\}_{t=0}^{\infty}$ such that $R_{t+1} = R^* \frac{L_{Nt}^{\alpha-1}/L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt+1}^{\alpha-1}/L_{Tt+1}^{\alpha+\gamma_{Tt+1}-1}}$ for all t. Further, equations (A.6)–(A.7) for the first best and (A.1)–(A.2) in the competitive equilibrium only concide if $\gamma_{Tt} = 0$ for all t. Therefore, in the presence of production externalities, $\gamma_{Tt} > 0$ for some t; then the first-best allocation cannot be achieved in the competitive equilibrium for any $\{F^*_t\}_{t=0}^{\infty}$.

A.2. Proof of Proposition 2

With tradable and nontradable sector-specific labor subsidies τ^L_{it}, the firm problem for each sector $i \in \{T, N\}$ is

$$\max_{l_{it}} \quad \pi_{it} = P_{it} A_t l_{it}^{\alpha} L_{it}^{\gamma_{it}} - (1 - \tau^L_{it}) W_t l_{it}. \tag{A.11}$$

The firm profit maximization conditions for labor demand in each sector l_T and l_N give

$$\alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1} = (1 - \tau^L_{Tt}) \frac{W_t}{P_{Tt}}, \tag{A.12}$$

$$\alpha A_t L_{Nt}^{\alpha-1} = (1 - \tau^L_{Nt}) \frac{W_t}{P_{Nt}}. \tag{A.13}$$

The government budget constraint is

$$F_{t+1} + \mathcal{E}_t F^*_{t+1} + T_t + \tau^L_{Tt} W_t L_{Tt} + \tau^L_{Nt} W_t L_{Nt} = R_t F_t + \mathcal{E}_t R^* F^*_t, \tag{A.14}$$

which, combined with the household budget constraint and firms' profits, gives the balance of payments condition (16).

Given τ_{Tt}^L, τ_{Nt}^L, the conditions that characterize the competitive equilibrium are

$$\left(\frac{(1-\omega)}{\omega}\frac{C_{Tt}}{C_{Nt}}\right)^{\frac{1}{\eta}} = \frac{(1-\tau_{Nt}^L)}{(1-\tau_{Tt}^L)}\frac{L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt}^{\alpha-1}}, \tag{A.15}$$

$$\frac{\phi\left(L_{Tt}+L_{Nt}\right)^{\nu}}{(\omega/C_{Tt})^{\frac{1}{\eta}}\,C_t^{\frac{1}{\eta}-\sigma}} = \frac{1}{(1-\tau_{Tt}^L)}\alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}, \tag{A.16}$$

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R_{t+1}\frac{L_{Nt}^{\alpha-1}/L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt+1}^{\alpha-1}/L_{Tt+1}^{\alpha+\gamma_{Tt+1}-1}}\left(\frac{\omega}{C_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{A.17}$$

$$C_{Nt} = A_t L_{Nt}^{\alpha}, \tag{A.18}$$

$$C_{Tt} - A_t L_{Tt}^{\alpha+\gamma_{Tt}} = R^* F_t^* - F_{t+1}^*. \tag{A.19}$$

Setting

$$\tau_{Tt}^L = \frac{\gamma_{Tt}}{\alpha+\gamma_{Tt}}, \tag{A.20}$$

$$\tau_{Nt}^L = 0, \tag{A.21}$$

gives identical conditions to the first best (A.6)–(A.7) for the competitive equilibrium. Government policies $\left\{F_{t+1}, F_{t+1}^*, T_t\right\}_{t=0}^{\infty}$ can then be used to equate $R_{t+1} = R^*\frac{L_{Nt}^{\alpha-1}/L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt+1}^{\alpha-1}/L_{Tt+1}^{\alpha+\gamma_{Tt+1}-1}}$ for all t so that (A.17) in the competitive equilibrium is equivalent to the first-best condition (A.8).

A.3. Optimal Exchange Rate Industrial Policy

In this section we solve the optimal exchange rate industrial policy problem (P1). After substituting the nontradable goods market-clearing condition $C_{Nt} = A_t L_{Nt}^{\alpha}$, the Lagrangian

is

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t \Bigg\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \phi \frac{1}{(1+\nu)} \left(L_{Tt} + (C_{Nt}/A_t)^{\frac{1}{\alpha}} \right)^{1+\nu}$$
$$+ \zeta_t \left[\frac{(C_{Nt}/A_t)^{\frac{\alpha-1}{\alpha}}}{L_{Tt}^{\alpha+\gamma_{Tt}-1}} \left(\frac{1-\omega}{C_{Nt}} \right)^{\frac{1}{\eta}} - \left(\frac{\omega}{C_{Tt}} \right)^{\frac{1}{\eta}} \right]$$
$$+ \xi_t \left[\phi \frac{\left(L_{Tt} + (C_{Nt}/A_t)^{\frac{1}{\alpha}} \right)^{\nu}}{\alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}} - \left(\frac{\omega}{C_{Tt}} \right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} \right]$$
$$+ \lambda_t \left[R^* F_t^* - F_{t+1}^* + A_t L_{Tt}^{\alpha+\gamma_{Tt}} - C_{Tt} \right] \Bigg\}. \tag{A.22}$$

The first-order conditions for $C_{Tt}, C_{Nt}, L_{Tt}, F_{t+1}^*$ are

$$\left(\frac{\omega}{c_{Tt}} \right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} + \zeta_t \frac{1}{\eta} \left(\frac{\omega}{c_{Tt}} \right)^{\frac{1}{\eta}} \frac{1}{c_{Tt}} + \xi_t \left[\frac{1}{\eta} \left(\frac{\omega}{C_{Tt}} \right)^{\frac{1}{\eta}} \frac{1}{C_{Tt}} C_t^{\frac{1}{\eta}-\sigma} - \left(\frac{1}{\eta} - \sigma \right) \left(\frac{\omega}{C_{Tt}} \right)^{\frac{2}{\eta}} C_t^{\frac{2}{\eta}-\sigma-1} \right] = \lambda_t, \tag{A.23}$$

$$\left(\frac{1-\omega}{C_{Nt}} \right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} - \phi (L_{Tt} + (C_{Nt}/A_t)^{\frac{1}{\alpha}})^{\nu} \frac{1}{\alpha} C_{Nt}^{\frac{1}{\alpha}-1} (1/A_t)^{\frac{1}{\alpha}}$$
$$+ \zeta_t \left[- \frac{(C_{Nt}/A_t)^{\frac{\alpha-1}{\alpha}}}{L_{Tt}^{\alpha+\gamma_{Tt}-1}} \frac{1}{\eta} \left(\frac{1-\omega}{C_{Nt}} \right)^{\frac{1}{\eta}} \frac{1}{C_{Nt}} + \frac{(\alpha-1)}{\alpha} \frac{C_{Nt}^{\frac{-1}{\alpha}} (1/A_t)^{\frac{\alpha-1}{\alpha}}}{L_{Tt}^{\alpha+\gamma_{Tt}-1}} \left(\frac{1-\omega}{C_{Nt}} \right)^{\frac{1}{\eta}} \right]$$
$$+ \xi_t \left[\phi\nu \frac{(L_{Tt} + (C_{Nt}/A_t)^{\frac{1}{\alpha}})^{\nu-1}}{\alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}} \frac{1}{\alpha} C_{Nt}^{\frac{1}{\alpha}-1} (1/A_t)^{\frac{1}{\alpha}} - \left(\frac{1}{\eta} - \sigma \right) \left(\frac{\omega}{C_{Tt}} \right)^{\frac{1}{\eta}} C_t^{\frac{2}{\eta}-\sigma-1} \left(\frac{1-\omega}{C_{Nt}} \right)^{\frac{1}{\eta}} \right] = 0, \tag{A.24}$$

$$- \phi (L_{Tt} + (C_{Nt}/A_t)^{\frac{1}{\alpha}})^{\nu} + \zeta_t \left[-(\alpha + \gamma_{Tt} - 1) \frac{(C_{Nt}/A_t)^{\frac{\alpha-1}{\alpha}}}{L_{Tt}^{\alpha+\gamma_{Tt}-1}} \left(\frac{1-\omega}{C_{Nt}} \right)^{\frac{1}{\eta}} \frac{1}{L_{Tt}} \right]$$
$$+ \xi_t \left[\phi\nu \frac{(L_{Tt} + (C_{Nt}/A_t)^{\frac{1}{\alpha}})^{\nu-1}}{\alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}} - (\alpha + \gamma_{Tt} - 1) \phi \frac{(L_{Tt} + (C_{Nt}/A_t)^{\frac{1}{\alpha}})^{\nu}}{\alpha L_{Tt}^{\alpha+\gamma_{Tt}-1}} \frac{1}{L_{Tt}} \right] = -\lambda_t (\alpha + \gamma_t) A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}, \tag{A.25}$$

$$\lambda_t = \beta R^* \lambda_{t+1}. \tag{A.26}$$

Combining these expressions gives

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \frac{\theta_{t+1}(\mathbf{x}_{t+1}, \gamma_{Tt+1})}{\theta_t(\mathbf{x}_t, \gamma_{Tt})} \beta R^* \left(\frac{\omega}{C_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{A.27}$$

where

$$\theta_t(\mathbf{x}_t, \gamma_{Tt}) \equiv 1 - \frac{M_t}{N_t}\left\{\frac{1}{\eta}\frac{1}{C_{Tt}} - \left(\frac{1}{\eta}-\sigma\right)\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-1} + \left(\frac{\alpha}{\alpha+\eta-\alpha\eta}\right)\frac{(C_{Nt}/A_t)^{\frac{1}{\alpha}}}{C_{Tt}}\right.$$
$$\left.\left[\nu\frac{1}{\left(L_{Tt}+(C_{Nt}/A_t)^{\frac{1}{\alpha}}\right)}\frac{1}{\alpha}\left(\frac{1}{A_t}\right)^{\frac{1}{\alpha}} - \left(\frac{1}{\eta}-\sigma\right) C_t^{\frac{1}{\eta}-1}(C_{Nt}/A_t)^{\frac{\alpha-1}{\alpha}}\left(\frac{1-\omega}{C_{Nt}}\right)^{\frac{1}{\eta}}\right]\right\}, \tag{A.28}$$

$$M_t \equiv \gamma_{Tt}\left(\frac{\omega}{C_{Tt}}\right)^{\frac{-1}{\eta}}(C_{Nt}/A_t)^{\frac{\alpha-1}{\alpha}}\left(\frac{1-\omega}{C_{Nt}}\right)^{\frac{1}{\eta}}, \tag{A.29}$$

$$N_t \equiv (\alpha+\gamma_{Tt}-1)\frac{1}{L_{Tt}}\eta C_{Tt}\left[\left(\frac{1}{\eta}-\sigma\right)\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-1}\right] + \nu\frac{1}{\left(L_{Tt}+(C_{Nt}/A_t)^{\frac{1}{\alpha}}\right)}$$
$$+ Q_t\left\{\frac{1}{\eta}\frac{1}{C_{Tt}} - \left(\frac{1}{\eta}-\sigma\right)\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-1} + \left(\frac{\alpha}{\alpha+\eta-\alpha\eta}\right)\frac{(C_{Nt}/A_t)^{\frac{1}{\alpha}}}{C_{Tt}}\right.$$
$$\left.\left[\nu\frac{1}{\left(L_{Tt}+(C_{Nt}/A_t)^{\frac{1}{\alpha}}\right)}\frac{1}{\alpha}\left(\frac{1}{A_t}\right)^{\frac{1}{\alpha}} - \left(\frac{1}{\eta}-\sigma\right) C_t^{\frac{1}{\eta}-1}(C_{Nt}/A_t)^{\frac{\alpha-1}{\alpha}}\left(\frac{1-\omega}{C_{Nt}}\right)^{\frac{1}{\eta}}\right]\right\}, \tag{A.30}$$

$$Q_t \equiv \left[(\alpha+\gamma_t)\left(\frac{\omega}{C_{Tt}}\right)^{\frac{-1}{\eta}}(C_{Nt}/A_t)^{\frac{\alpha-1}{\alpha}}\left(\frac{1-\omega}{C_{Nt}}\right)^{\frac{1}{\eta}} - (\alpha+\gamma_{Tt}-1)\frac{1}{L_{Tt}}\eta C_{Tt}\right]. \tag{A.31}$$

A.4. Proof of Proposition 3

We first solve the optimal exchange rate industrial policy problem in this case, then characterize the solution relative to the laissez-faire competitive equilibrium.

Under Assumption 2, the optimal exchange rate industrial policy problem for the more general case that allows for externalities in both the tradable and nontradable goods sectors is to solve for the tradables block C_{Tt}, L_{Tt}, and F^*_{t+1}:

$$\max_{\{C_{Tt},L_{Tt},F^*_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \left[\omega \log C_{Tt} - \phi L_{Tt}\right] + constant$$

$$s.t. \quad \left(\frac{\omega}{C_{Tt}}\right) = \phi \frac{1}{\alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}}, \tag{A.32}$$

$$C_{Tt} - A_t L_{Tt}^{\alpha+\gamma_{Tt}} = R^* F^*_t - F^*_{t+1}, \tag{A.33}$$

$$F^*_0 \text{ given.} \tag{A.34}$$

To see that the nontradables block $\{C_{Nt}, L_{Nt}\}_{t=0}^{\infty}$ is exogenous in this analytical case, we have the two constraints

$$\left(\frac{\omega}{C_{Tt}}\right) = \phi \frac{1}{\alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}}, \tag{A.35}$$

$$\left(\frac{\omega}{C_{Tt}}\right) = \frac{\left(\frac{C_{Nt}}{A_t}\right)^{\frac{\alpha+\gamma_{Nt}-1}{\alpha+\gamma_{Nt}}}}{L_{Tt}^{\alpha+\gamma_{Tt}-1}} \left(\frac{1-\omega}{C_{Nt}}\right). \tag{A.36}$$

Combining these two equations gives

$$\frac{\phi}{\alpha A_t} = \left(\frac{C_{Nt}}{A_t}\right)^{\frac{\alpha+\gamma_{Nt}-1}{\alpha+\gamma_{Nt}}} \left(\frac{1-\omega}{C_{Nt}}\right), \tag{A.37}$$

$$\Rightarrow C_{Nt} = A_t \left[\frac{\alpha(1-\omega)}{\phi}\right]^{\alpha+\gamma_{Nt}}, \tag{A.38}$$

and the nontradable goods market-clearing condition $C_{Nt} = A_t L_{Nt}^{\alpha+\gamma_{Nt}}$ determines L_{Nt}.

Continuing with the optimal exchange rate industrial policy problem above, we can

substitute out C_{Tt} using the first constraint

$$\max_{\{L_{Tt},F^*_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \left[\omega(\alpha+\gamma_{Tt}-1)\log L_{Tt} - \phi L_{Tt}\right] + constant$$

$$s.t. \quad \frac{\omega\alpha}{\phi} A_t L_{Tt}^{\alpha+\gamma_{Tt}-1} - A_t L_{Tt}^{\alpha+\gamma_{Tt}} = R^* F_t^* - F_{t+1}^*, \tag{A.39}$$

$$F_0^* \text{ given.} \tag{A.40}$$

The FOCs for L_{Tt}, F^*_{t+1} are

$$\omega(\alpha+\gamma_{Tt}-1)\frac{1}{L_{Tt}} - \phi = \lambda_t \left[\frac{\omega\alpha}{\phi}(\alpha+\gamma_{Tt}-1)A_t L_{Tt}^{\alpha+\gamma_{Tt}-2} - (\alpha+\gamma_{Tt})A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}\right], \tag{A.41}$$

$$\lambda_t = \beta R^* \lambda_{t+1}. \tag{A.42}$$

From the first FOC

$$\frac{\omega(\alpha+\gamma_{Tt}-1)\frac{1}{L_{Tt}} - \phi}{A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}\left[\frac{\omega\alpha}{\phi}(\alpha+\gamma_{Tt}-1)\frac{1}{L_{Tt}} - (\alpha+\gamma_{Tt})\right]} = \lambda_t. \tag{A.43}$$

Substituting into the second FOC and the constraint (A.32) gives the modified XR-IP Euler equation in this case:

$$\left(\frac{\omega}{C_{Tt}}\right) = \beta R^* \frac{\theta(L_{Tt+1},\gamma_{Tt+1})}{\theta(L_{Tt},\gamma_{Tt})}\left(\frac{\omega}{C_{Tt+1}}\right), \tag{A.44}$$

$$\theta(L_{Tt},\gamma_{Tt}) \equiv \frac{\frac{\omega\alpha}{\phi}(\alpha+\gamma_{Tt}-1)\frac{1}{L_{Tt}} - \alpha}{\left[\frac{\omega\alpha}{\phi}(\alpha+\gamma_{Tt}-1)\frac{1}{L_{Tt}} - (\alpha+\gamma_{Tt})\right]}. \tag{A.45}$$

For the laissez-faire competitive equilibrium, the intertemporal condition is

$$\left(\frac{\omega}{C_{Tt}}\right) = \beta R^* \left(\frac{\omega}{C_{Tt+1}}\right). \tag{A.46}$$

We now characterize the optimal XR-IP solution.

Without loss of generality, let $\beta R^* = 1$. For $t \geq 1$ with $\gamma_{Tt} = 0$, from (A.45) $\theta_t = \theta_{t+1} =$

1. Therefore from (A.44) and the constraint (A.32) for $t \geq 1$

$$L_{T1} = \left[\frac{A_1}{A_{t+1}}\right]^{\frac{1}{1-\alpha}} L_{Tt+1}, \tag{A.47}$$

$$C_{T1} = C_{Tt+1}. \tag{A.48}$$

For $t = 0$

$$\frac{1}{A_0 L_{T0}^{\alpha+\gamma_{T0}-1}}\theta_0 = \frac{1}{A_1 L_{T1}^{\alpha-1}}, \tag{A.49}$$

$$\text{where } \theta_0 \equiv \frac{\frac{\omega\alpha}{\phi}(\alpha+\gamma_{T0}-1)\frac{1}{L_{T0}} - \alpha}{\left[\frac{\omega\alpha}{\phi}(\alpha+\gamma_{T0}-1)\frac{1}{L_{T0}} - (\alpha+\gamma_{T0})\right]}. \tag{A.50}$$

Given $\alpha + \gamma_{T0} < 1 + \phi L_{T0}/\omega$, then $\theta_0 \in (0, 1)$.

The sequence of foreign currency bonds $\{F_{t+1}^*\}_{t=0}^{\infty}$ given F_0^* is determined by the balance of payments

$$C_{T0} - A_0 L_{T0}^{\alpha+\gamma_{T0}} = R^* F_0^* - F_1^*, \tag{A.51}$$

$$C_{Tt} - A_t L_{Tt}^{\alpha} = R^* F_t^* - F_{t+1}^* \text{ for } t \geq 1. \tag{A.52}$$

Substituting (A.47), the second equation becomes

$$\beta\left(C_{T1} - \left[\frac{A_t}{A_1}\right]^{\frac{1}{1-\alpha}} A_1 L_{T1}^{\alpha}\right) = F_t^* - \beta F_{t+1}^* \text{ for } t \geq 1. \tag{A.53}$$

Substitute C_{T0}, C_{T1} from (A.32) and the balance of payments equations are given by

$$\beta\left(\frac{\omega\alpha}{\phi} A_0 L_{T0}^{\alpha+\gamma_{T0}-1} - A_0 L_{T0}^{\alpha+\gamma_{T0}}\right) = F_0^* - \beta F_1^*, \tag{A.54}$$

$$\beta\left(\frac{\omega\alpha}{\phi} A_1 L_{T1}^{\alpha-1} - \left[\frac{A_t}{A_1}\right]^{\frac{1}{1-\alpha}} A_1 L_{T1}^{\alpha}\right) = F_t^* - \beta F_{t+1}^* \text{ for } t \geq 1. \tag{A.55}$$

Iterating the second equation forward

$$\frac{\beta}{(1-\beta)}\frac{\omega\alpha}{\phi}A_1 L_{T1}^{\alpha-1} - A_1\widetilde{A}_1 L_{T1}^{\alpha} = F_1^*, \tag{A.56}$$

where $\widetilde{A}_1 \equiv \sum_{t=1}^{\infty}\beta^t\left[\frac{A_t}{A_1}\right]^{\frac{1}{1-\alpha}}$, which is finite assuming that A_t is bounded above. Substituting for F_1^* into the first balance of payments equation gives

$$\frac{\omega\alpha}{\phi}A_0 L_{T0}^{\alpha+\gamma_{T0}-1} - A_0 L_{T0}^{\alpha+\gamma_{T0}} + \frac{\beta}{(1-\beta)}\frac{\omega\alpha}{\phi}A_1 L_{T1}^{\alpha-1} - A_1\widetilde{A}_1 L_{T1}^{\alpha} - \frac{1}{\beta}F_0^* = 0. \tag{A.57}$$

Substituting (A.49) gives

$$G(L_{T0}^{IP}, \theta_0(L_{T0}^{IP})) - \frac{1}{\beta}F_0^* = 0, \tag{A.58}$$

$$G(L_{T0}, \theta_0(L_{T0})) \equiv \left(1 + \frac{\beta}{1-\beta}\frac{1}{\theta_0}\right)\frac{\omega\alpha}{\phi}A_0 L_{T0}^{\alpha+\gamma_{T0}-1} - A_0 L_{T0}^{\alpha+\gamma_{T0}} - \beta A_1^{\frac{1}{1-\alpha}}\widetilde{A}_1\left(\frac{1}{\theta_0}A_0 L_{T0}^{\alpha+\gamma_{T0}-1}\right)^{\frac{\alpha}{\alpha-1}}, \tag{A.59}$$

which gives the solution for L_{T0}^{IP} for the optimal XR-IP.

We can sign the following

$$\begin{aligned}\frac{\partial G}{\partial L_{T0}} &= (\alpha+\gamma_{T0}-1)\left(1+\frac{\beta}{1-\beta}\frac{1}{\theta_0}\right)\frac{\omega\alpha}{\phi}A_0 L_{T0}^{\alpha+\gamma_{T0}-2} - (\alpha+\gamma_{T0})A_0 L_{T0}^{\alpha+\gamma_{T0}-1} \\ &\quad - \frac{\alpha(\alpha+\gamma_{T0}-1)}{\alpha-1}\beta A_1^{\frac{1}{1-\alpha}}\widetilde{A}_1\left(\frac{1}{\theta_0}A_0\right)^{\frac{\alpha}{\alpha-1}} L_{T0}^{\frac{\alpha(\alpha+\gamma_{T0}-1)}{\alpha-1}-1} < 0, \end{aligned} \tag{A.60}$$

$$\frac{\partial G}{\partial \theta_0} = -\frac{\beta}{1-\beta}\frac{1}{\theta_0^2}\frac{\omega\alpha}{\phi}A_0 L_{T0}^{\alpha+\gamma_{T0}-1} + \frac{\alpha}{(\alpha-1)}\beta A_1^{\frac{1}{1-\alpha}}\widetilde{A}_1\left(\frac{1}{\theta_0}\right)^{\frac{\alpha}{\alpha-1}-1}\frac{1}{\theta_0}A_0^{\frac{\alpha}{1-\alpha}} L_{T0}^{\frac{\alpha(\alpha+\gamma_{T0}-1)}{\alpha-1}} < 0. \tag{A.61}$$

We can follow the same steps for the laissez-faire competitive equilibrium, which gives

$$G(L_{T0}^{CE}, 1) - \frac{1}{\beta}F_0^* = 0, \tag{A.62}$$

where L_{T0}^{CE} is the solution. Therefore, given $\theta_0 < 1$ and G is decreasing in the first argument

$$G(L_{T0}^{IP}, \theta_0(L_{T0}^{IP})) = G(L_{T0}^{CE}, 1), \tag{A.63}$$

$$\Rightarrow L_{T0}^{IP} > L_{T0}^{CE}. \tag{A.64}$$

For both the XR-IP and competitive equilibrium

$$C_{T0} = \frac{\omega\alpha A_0}{\phi} \frac{1}{L_{T0}^{1-\alpha-\gamma_{T0}}}, \tag{A.65}$$

$$\mathcal{E}_0 = \left(\frac{c_{N0}}{A_0}\right)^{\frac{\alpha-1}{\alpha}} L_{T0}^{1-\alpha-\gamma_{T0}}. \tag{A.66}$$

Therefore, since $L_{T0}^{IP} > L_{T0}^{CE}$

$$C_{T0}^{IP} < C_{T0}^{CE}, \tag{A.67}$$

$$\mathcal{E}_0^{IP} > \mathcal{E}_0^{CE}. \tag{A.68}$$

By definition of the current account balance

$$CA_0 = A_0 L_{T0}^{\alpha+\gamma_{T0}} - C_{T0} + (R^* - 1)F_0^*, \tag{A.69}$$

$$\Rightarrow CA_0^{IP} > CA_0^{CE}. \tag{A.70}$$

From the balance of payments at $t = 0$

$$F_1^* = R^* F_0^* + A_0 L_{T0}^{\alpha+\gamma_{T0}} - C_{T0}, \tag{A.71}$$

$$\Rightarrow F_1^{*IP} > F_1^{*CE}. \tag{A.72}$$

A.5. Proof of Proposition 4

We first characterize the competitive equilibrium and solve the optimal exchange rate industrial policy problem with fixed labor supply, then characterize the solution relative to the laissez-faire competitive equilibrium.

With fixed labor supply of 1 unit by the households, the labor market clearing condition is $L_{Tt} + L_{Nt} = 1$.

Competitive equilibrium. From the households' FOCs for C_{Tt} and C_{Nt}, combined with the firms' optimal labor demand, and nontradable goods market clearing

$$\left(\frac{(1-\omega)}{\omega}\frac{C_{Tt}}{C_{Nt}}\right)^{\frac{1}{\eta}} = \frac{L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt}^{\alpha-1}} \tag{A.73}$$

$$\left(\frac{(1-\omega)}{\omega}C_{Tt}\right)^{\frac{1}{\eta}} = \frac{A_t^{\frac{1}{\eta}} L_{Tt}^{\alpha+\gamma_{Tt}-1}}{(1-L_{Tt})^{\alpha-1-\frac{\alpha}{\eta}}}, \tag{A.74}$$

which characterizes the competitive equilibrium allocation and is the implementability constraint for the optimal exchange rate industrial policy problem. The remaining conditions for the laissez-faire competitive equilibrium are as in the baseline model.

Exchange rate industrial policy. The optimal exchange rate industrial policy problem with fixed labor supply is

$$\begin{aligned}
&\max_{\{C_{it},L_{it},F_{t+1}^*\}_{t\geq 0}^{i=T,N}} \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma}}{1-\sigma} \quad \text{subject to} \\
&\left(\frac{1-\omega}{\omega}\frac{C_{Tt}}{C_{Nt}}\right)^{\frac{1}{\eta}} = \frac{L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt}^{\alpha-1}}, \\
&L_{Tt} + L_{Nt} = 1, \\
&C_{Tt} - A_t L_{Tt}^{\alpha+\gamma_{Tt}} = R^* F_t^* - F_{t+1}^*,
\end{aligned} \tag{PA.1}$$

the consumption aggregator definition (2), and the market clearing conditions for nontradable goods (12).

Analytical case. In the analytical case with $\sigma = \eta = 1$, after substituting for nontradable consumption and labor, the XR-IP problem is given by

$$\max_{\{C_{Tt}, L_{Tt}, F^*_{t+1}\}_{t=0}^{\infty}} \quad \sum_{t=0}^{\infty} \beta^t [\omega \log C_{Tt} + (1-\omega)\alpha \log(1 - L_{Tt})]$$

$$s.t. \quad \frac{\omega}{C_{Tt}} = \frac{(1 - L_{Tt})^{-1}}{A_t L_{Tt}^{\alpha + \gamma_{Tt} - 1}} (1 - \omega), \tag{A.75}$$

$$C_{Tt} - A_t L_{Tt}^{\alpha + \gamma_{Tt}} = R^* F_t^* - F_{t+1}^*, \tag{A.76}$$

$$F_0^* \text{ given.} \tag{A.77}$$

Substituting out C_{Tt} gives

$$\max_{\{L_{Tt}, F^*_{t+1}\}_{t=0}^{\infty}} \quad \sum_{t=0}^{\infty} \beta^t [\omega(\alpha + \gamma_{Tt} - 1) \log L_{Tt} + [\omega + (1-\omega)\alpha] \log(1 - L_{Tt})] + constant$$

$$s.t. \quad \frac{\omega}{(1-\omega)} A_t L_{Tt}^{\alpha + \gamma_{Tt} - 1} - \frac{1}{(1-\omega)} A_t L_{Tt}^{\alpha + \gamma_{Tt}} = R^* F_t^* - F_{t+1}^*, \tag{A.78}$$

$$F_0^* \text{ given.} \tag{A.79}$$

The FOCs are

$$\omega(\alpha + \gamma_{Tt} - 1) \frac{1}{L_{Tt}} - [\omega + (1-\omega)\alpha] \frac{1}{(1 - L_{Tt})}$$

$$= \lambda_t \left[\frac{\omega}{(1-\omega)} (\alpha + \gamma_{Tt} - 1) A_t L_{Tt}^{\alpha + \gamma_{Tt} - 2} - \frac{1}{(1-\omega)} (\alpha + \gamma_{Tt}) A_t L_{Tt}^{\alpha + \gamma_{Tt} - 1} \right], \tag{A.80}$$

$$\lambda_t = \beta R^* \lambda_{t+1}. \tag{A.81}$$

From the first FOC

$$\frac{(1 - L_{Tt})^{-1}}{A_t L_{Tt}^{\alpha + \gamma_{Tt} - 1}} (1 - \omega) \left[\frac{\omega(\alpha + \gamma_{Tt} - 1) \frac{1}{L_{Tt}} - (\alpha + \omega\gamma_t)}{\omega(\alpha + \gamma_{Tt} - 1) \frac{1}{L_{Tt}} - (\alpha + \gamma_{Tt})} \right] = \lambda_t.$$

Substituting λ_t from the second FOC gives the modified XR-IP Euler equation in this

case

$$\left(\frac{\omega}{C_{Tt}}\right) = \beta R^* \frac{\theta(L_{Tt+1}, \gamma_{Tt+1})}{\theta(L_{Tt}, \gamma_{Tt})} \left(\frac{\omega}{C_{Tt+1}}\right), \tag{A.82}$$

$$\theta(L_{Tt}, \gamma_{Tt}) \equiv \frac{\omega(\alpha + \gamma_{Tt} - 1)\frac{1}{L_{Tt}} - (\alpha + \omega\gamma_{Tt})}{\omega(\alpha + \gamma_{Tt} - 1)\frac{1}{L_{Tt}} - (\alpha + \gamma_{Tt})} \in (0, 1]. \tag{A.83}$$

We now characterize the optimal XR-IP solution.

Without loss of generality, let $\beta R^* = 1$. For $t \geq 1$ with $\gamma_{Tt} = 0$, from (A.83) $\theta_t = \theta_{t+1} = 1$, therefore

$$L_{T1} = \left[\frac{A_1}{A_{t+1}}\right]^{\frac{1}{1-\alpha}} L_{Tt+1}, \tag{A.84}$$

$$C_{T1} = C_{Tt+1}. \tag{A.85}$$

For $t = 0$

$$\frac{(1 - L_{T0})^{-1}}{A_0 L_{T0}^{\alpha+\gamma_{T0}-1}}\theta_0 = \frac{(1 - L_{T1})^{-1}}{A_1 L_{T1}^{\alpha-1}}, \tag{A.86}$$

$$\Rightarrow (1 - L_{T0}) A_0 L_{T0}^{\alpha+\gamma_{T0}-1} = (1 - L_{T1}) A_1 L_{T1}^{\alpha-1}\theta_0. \tag{A.87}$$

The sequence of foreign currency bonds $\{F^*_{t+1}\}_{t=0}^{\infty}$ given F^*_0 is determined by the balance of payments

$$C_{T0} - A_0 L_{T0}^{\alpha+\gamma_{T0}} = R^* F_0^* - F_1^*, \tag{A.88}$$

$$C_{Tt} - A_t L_{Tt}^{\alpha} = R^* F_t^* - F_{t+1}^* \text{ for } t \geq 1. \tag{A.89}$$

As in Section A.4, substituting (A.84) and C_{T0}, C_{T1} from (A.75), and iterating the second balance of payments equation forward

$$\frac{\beta}{(1-\beta)}\frac{\omega}{(1-\omega)} A_1 (1 - L_{T1}) L_{T1}^{\alpha-1} - A_1 \widetilde{A}_1 L_{T1}^{\alpha} = F_1^*, \tag{A.90}$$

and substituting for F_1^* into the first balance of payments equation

$$\frac{\omega}{(1-\omega)}A_0(1-L_{T0})L_{T0}^{\alpha+\gamma_{T0}-1}-A_0L_{T0}^{\alpha+\gamma_{T0}}+\frac{\beta}{(1-\beta)}\frac{\omega}{(1-\omega)}A_1(1-L_{T1})L_{T1}^{\alpha-1}-A_1\widetilde{A}_1L_{T1}^{\alpha}-\frac{1}{\beta}F_0^*=0. \tag{A.91}$$

Substituting the optimality condition (A.87)

$$\frac{\omega}{(1-\omega)}A_0(1-L_{T0})L_{T0}^{\alpha+\gamma_{T0}-1}-A_0L_{T0}^{\alpha+\gamma_{T0}}+\frac{\beta}{(1-\beta)}\frac{\omega}{(1-\omega)}\frac{1}{\theta_0}A_0(1-L_{T0})L_{T0}^{\alpha+\gamma_{T0}-1}$$
$$-A_1\widetilde{A}_1L_{T1}^{\alpha}-\frac{1}{\beta}F_0^*=0 \tag{A.92}$$

$$H(L_{T0},\theta_0(L_{T0}))=L_{T1}, \tag{A.93}$$

$$H(L_{T0},\theta_0(L_{T0}))\equiv\frac{1}{(A_1\widetilde{A}_1)^{\frac{1}{\alpha}}}\left\{\frac{\omega}{(1-\omega)}A_0(1-L_{T0})L_{T0}^{\alpha+\gamma_{T0}-1}-A_0L_{T0}^{\alpha+\gamma_{T0}}\right.$$
$$\left.+\frac{\beta}{(1-\beta)}\frac{\omega}{(1-\omega)}\frac{1}{\theta_0}A_0(1-L_{T0})L_{T0}^{\alpha+\gamma_{T0}-1}-\frac{1}{\beta}F_0^*\right\}^{\frac{1}{\alpha}}. \tag{A.94}$$

We solve for L_{T0} in the XR-IP by plugging L_{T1} from (A.93) into (A.87)

$$(1-L_{T0})A_0L_{T0}^{\alpha+\gamma_{T0}-1}-(1-H(L_{T0},\theta_0))\,A_1\,(H(L_{T0},\theta_0))^{\alpha-1}\,\theta_0=0 \tag{A.95}$$

$$A_0L_{T0}^{\alpha+\gamma_{T0}-1}-A_0L_{T0}^{\alpha+\gamma_{T0}}-(1-H(L_{T0},\theta_0))\,A_1\,(H(L_{T0},\theta_0))^{\alpha-1}\,\theta_0=0. \tag{A.96}$$

Following the same steps to solve for L_{T0} in the laissez-faire competitive equilibrium

$$A_0L_{T0}^{\alpha+\gamma_{T0}-1}-A_0L_{T0}^{\alpha+\gamma_{T0}}-(1-H(L_{T0},1))\,A_1\,(H(L_{T0},1))^{\alpha-1}\,=0. \tag{A.97}$$

We can sign the following

$$\frac{\partial H}{\partial L_{T0}} = \frac{1}{A_1\widetilde{A}_1}\frac{1}{\alpha}H(L_{T0},\theta_0)^{1-\alpha}\Bigg\{\frac{\omega}{1-\omega}\left(-(1-\alpha-\gamma_{T0})A_0L_{T0}^{\alpha+\gamma_{T0}-2}-(\alpha+\gamma_{T0})A_0L_{T0}^{\alpha+\gamma_{T0}-1}\right)$$
$$-(\alpha+\gamma_{T0})A_0L_{T0}^{\alpha+\gamma_{T0}-1}+\frac{\beta}{(1-\beta)}\frac{\omega}{(1-\omega)}\frac{1}{\theta_0}A_0\left[-(1-\alpha-\gamma_{T0})L_{T0}^{\alpha+\gamma_{T0}-2}-(\alpha+\gamma_{T0})L_{T0}^{\alpha+\gamma_{T0}-1}\right]\Bigg\} \tag{A.98}$$
$$<0, \tag{A.99}$$
$$\frac{\partial H}{\partial \theta_0} = -\frac{1}{A_1\widetilde{A}_1}\frac{1}{\alpha}H(L_{T0},\theta_0)^{1-\alpha}\frac{\beta}{(1-\beta)}\frac{\omega}{(1-\omega)}\frac{1}{\theta_0^2}(1-L_{T0})L_{T0}^{\alpha+\gamma_{T0}-1}<0. \tag{A.100}$$

Treating L_{T0} as a function of θ_0 and differentiating (A.96) with respect to θ_0 gives

$$-\left[(1-\alpha-\gamma_{T0})A_0L_{T0}^{\alpha+\gamma_{T0}-2}-(\alpha+\gamma_{T0})A_0L_{T0}^{\alpha+\gamma_{T0}-1}\right]\frac{\partial L_{T0}}{\partial\theta_0}$$
$$+A_1(H(L_{T0},\theta_0))^{\alpha-1}\theta_0\left[\frac{\partial H}{\partial L_{T0}}\frac{\partial L_{T0}}{\partial\theta_0}+\frac{\partial H}{\partial\theta_0}\right]$$
$$+(1-\alpha)(1-H(L_{T0},\theta_0))A_1\theta_0(H(L_{T0},\theta_0))^{\alpha-1}\left[\frac{\partial H}{\partial L_{T0}}\frac{\partial L_{T0}}{\partial\theta_0}+\frac{\partial H}{\partial\theta_0}\right]$$
$$-(1-H(L_{T0},\theta_0))A_1(H(L_{T0},\theta_0))^{\alpha-1}=0. \tag{A.101}$$

Since $\frac{\partial H}{\partial\theta_0}<0$

$$A_1(H(L_{T0},\theta_0))^{\alpha-1}\theta_0\left[\frac{\partial H}{\partial\theta_0}\right]$$
$$+(1-\alpha)(1-H(L_{T0},\theta_0))A_1\theta_0(H(L_{T0},\theta_0))^{\alpha-1}\left[\frac{\partial H}{\partial\theta_0}\right]$$
$$-(1-H(L_{T0},\theta_0))A_1(H(L_{T0},\theta_0))^{\alpha-1}<0. \tag{A.102}$$

Therefore, the remaining terms must satisfy

$$\frac{\partial L_{T0}}{\partial \theta_0}\Bigg\{ -[(1-\alpha-\gamma_{T0})A_0 L_{T0}^{\alpha+\gamma_{T0}-2} - (\alpha+\gamma_{T0})A_0 L_{T0}^{\alpha+\gamma_{T0}-1}] + A_1(H(L_{T0},\theta_0))^{\alpha-1}\theta_0\left[\frac{\partial H}{\partial L_{T0}}\right] + (1-\alpha)(1-H(L_{T0},\theta_0))A_1\theta_0(H(L_{T0},\theta_0))^{\alpha-1}\left[\frac{\partial H}{\partial L_{T0}}\right]\Bigg\} > 0. \tag{A.103}$$

The terms in braces are negative, since $\frac{\partial H}{\partial L_{T0}} < 0$, which means that it must be that

$$\frac{\partial L_{T0}}{\partial \theta_0} < 0. \tag{A.104}$$

This shows that for the XR-IP solution when $\theta_0 < 1$, compared to the CE solution to (A.97),

$$L_{T0}^{IP} > L_{T0}^{CE}. \tag{A.105}$$

For both the XR-IP and CE

$$C_{T0} = \frac{\omega}{1-\omega}(1-L_{T0})A_0 L_{T0}^{\alpha+\gamma_{T0}-1} \tag{A.106}$$

$$\Rightarrow \frac{\partial C_{T0}}{\partial L_{T0}} < 0, \tag{A.107}$$

$$\mathcal{E}_0 = \frac{(1-L_{T0})^{\alpha-1}}{L_{T0}^{\alpha+\gamma_{T0}-1}} \tag{A.108}$$

$$\Rightarrow \frac{\partial \mathcal{E}_0}{\partial L_{T0}} > 0. \tag{A.109}$$

Therefore, since $L_{T0}^{IP} > L_{T0}^{CE}$

$$C_{T0}^{IP} < C_{T0}^{CE}, \tag{A.110}$$

$$\mathcal{E}_0^{IP} > \mathcal{E}_0^{CE}. \tag{A.111}$$

By definition of the current account balance

$$CA_0 = L_{T0}^{\alpha+\gamma_{T0}} - C_{T0} + (R^* - 1)F_0^*, \tag{A.112}$$

$$\Rightarrow CA_0^{IP} > CA_0^{CE}. \tag{A.113}$$

As shown above, given F_0^*, for both the IP and CE

$$F_1^* = R^* F_0^* + A_0 L_{T0}^{\alpha+\gamma_{T0}} - C_{T0}, \tag{A.114}$$

$$\Rightarrow F_1^{*IP} > F_1^{*CE}. \tag{A.115}$$

A.6. Proof of Proposition 6

Section A.4 showed that under Assumption 2 the optimal exchange rate industrial policy depends only on the tradable block of the model for any arbitrary path of γ_{Nt}.

Nontradable production and consumption are independent of the optimal policy, which can be seen from equation (A.38) and nontradable goods market clearing.

In this case, the modified Euler equation for the optimal exchange rate industrial policy takes the form

$$\left(\frac{\omega}{C_{Tt}}\right) = \beta R^* \frac{\theta(L_{Tt+1}, \gamma_{Tt+1})}{\theta(L_{Tt}, \gamma_{Tt})} \left(\frac{\omega}{C_{Tt+1}}\right), \tag{A.116}$$

which does not depend on γ_{Nt}.

Therefore, the result directly follows from the proof of Proposition 3.

A.7. Proof of Proposition 6

With time-invariant sectoral production externalities, $\gamma_{Tt} = \gamma_T$ and $\gamma_{Nt} = \gamma_N$ for all $t \geq 0$, the modified Euler equation for the optimal exchange rate industrial policy takes the form

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R^* \frac{\theta(\mathbf{x}_{t+1}, \gamma_T, \gamma_N)}{\theta(\mathbf{x}_t, \gamma_T, \gamma_N)} \left(\frac{\omega}{C_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{A.117}$$

where $\mathbf{x}_t \equiv \{C_t, C_{Tt}, C_{Nt}, L_t, L_{Tt}, L_{Nt}, A_t\}$.

The laissez-faire competitive equilibrium Euler equation is

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R^* \left(\frac{\omega}{C_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}. \tag{A.118}$$

The other conditions are identical for the optimal XR-IP and laissez-faire competitive equilibrium.

Given $\beta R^* = 1$ and A_t is constant, the laissez-faire competitive equilibrium allocation is time-invariant. Similarly, the allocation for the optimal exchange rate industrial policy must be time-invariant such that $\theta(\mathbf{x}_t, \gamma_T, \gamma_N) = \theta(\mathbf{x}_{t+1}, \gamma_T, \gamma_N)$ and, therefore, coincides with the laissez-faire equilibrium.

A.8. Proof of Proposition 7

We first describe the model variant in which households can save or borrow in foreign currency and the government can impose a capital control tax.

Households. Households can save or borrow in foreign currency at R^* and the government imposes a time-varying capital control tax τ_t. The household budget constraint expressed in domestic currency is given by

$$P_{Tt}C_{Tt} + P_{Nt}C_{Nt} + \frac{1}{(1+\tau_t)}\mathcal{E}_t B^*_{t+1} = W_t L_t + \Pi_t + T_t + \mathcal{E}_t R^* B^*_t, \tag{A.119}$$

where B^*_{t+1} are the foreign currency bonds purchased in t that mature in $t+1$ and R^* is the foreign currency interest rate. The other elements of the household problem are as in the baseline model.

The household's problem is to choose allocations $\{C_t, C_{Tt}, C_{Nt}, L_t, B^*_{t+1}\}_{t=0}^{\infty}$ that maximize utility (1), subject to the aggregation technology (2), the sequence of budget constraints (A.119), given a sequence of prices, profits and transfers, and an initial level of bonds B^*_0.

The first-order conditions that characterize the solution to the household's problem are

$$\left(\frac{1-\omega}{C_{Nt}}\right)^{\frac{1}{\eta}} = p_t \left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}}, \tag{A.120}$$

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} \frac{W_t}{P_{Tt}} = \phi L_t^{\nu}, \tag{A.121}$$

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R^*(1+\tau_t)\frac{P_{Tt}}{P_{Tt+1}}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}\left(\frac{\omega}{C_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}. \tag{A.122}$$

Firms. As in Section 2.

Government. The government budget balances each period with revenue from the capital control tax τ_t distributed lump-sum to the household

$$-\frac{\tau_t}{(1+\tau_t)}\mathcal{E}_t B^*_{t+1} = T_t. \tag{A.123}$$

Rest of the world. The domestic economy consumes c_{Tt} and produces $A_t L_{Tt}^{\alpha+\gamma_t}$ of the tradable good, and saves B^*_{t+1} abroad at the real interest rate R^*. The value in domestic currency must be equal, giving the balance of payments

$$C_{Tt} - A_t L_{Tt}^{\alpha+\gamma_t} = R^* B^*_t - B^*_{t+1}. \tag{A.124}$$

As in the baseline model, we assume the law of one price holds for tradable goods and normalize the foreign currency price of tradables, so that $P_{Tt} = \mathcal{E}_t$.

We now show the proposition for the model.

Competitive Equilibrium. The competitive equilibrium allocation $\{C_{Tt}, C_{Nt}, L_{Tt}, L_{Nt}, B^*_{t+1}\}_{t=0}^{\infty}$ is characterized by combining households' and firms' optimality conditions and market clear-

ing to give

$$\left(\frac{1-\omega}{\omega}\frac{C_{Tt}}{C_{Nt}}\right)^{\frac{1}{\eta}} = \frac{L_{Tt}^{\alpha+\gamma_{Tt}-1}}{L_{Nt}^{\alpha-1}}, \tag{A.125}$$

$$\frac{\phi\left(L_{Tt}+L_{Nt}\right)^{\nu}}{\left(\omega/C_{Tt}\right)^{\frac{1}{\eta}}C_t^{\frac{1}{\eta}-\sigma}} = \alpha A_t L_{Tt}^{\alpha+\gamma_{Tt}-1}, \tag{A.126}$$

$$\left(\frac{\omega}{C_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R^*(1+\tau_t)\left(\frac{\omega}{C_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{A.127}$$

$$C_{Nt} = A_t L_{Nt}^{\alpha}, \tag{A.128}$$

$$C_{Tt} - A_t L_{Tt}^{\alpha+\gamma_t} = R^* B_t^* - B_{t+1}^*. \tag{A.129}$$

By setting the sequence of capital control taxes

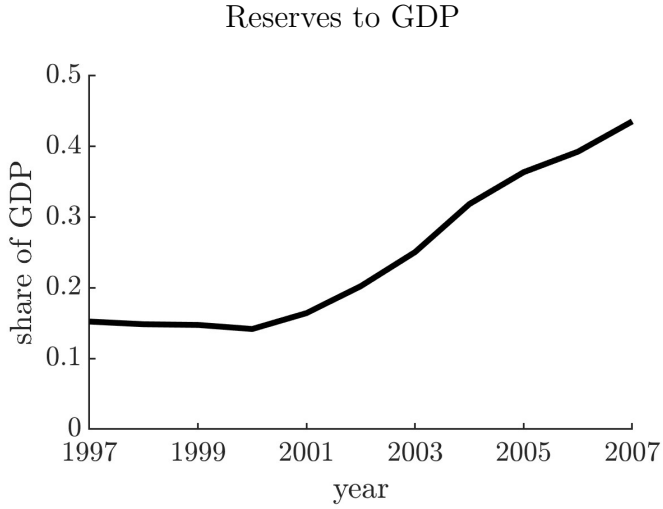
$$\tau_t = \frac{\theta(\mathbf{x}_{t+1}, \gamma_{Tt+1})}{\theta(\mathbf{x}_t, \gamma_{Tt})} - 1, \tag{A.130}$$

where $\mathbf{x}_t \equiv \{C_t^{IP}, C_{Tt}^{IP}, C_{Nt}^{IP}, L_t^{IP}, L_{Tt}^{IP}, L_{Nt}^{IP}, A_t\}$ is the optimal exchange rate industrial policy allocation, the competitive equilibrium conditions (A.125)–(A.129) are equivalent to the XR-IP and, therefore, attain the some allocation.

B. Empirical Appendix

B.1. China: Reserves holdings

Figure B1: China: Foreign Exchange Reserves



Notes: Reserves of foreign exchange and gold in current USD as a share of GDP in current USD. Data source: World Bank.

B.2. Country classification

Table B1: Country classification

Advanced	Emerging Markets
Australia	Argentina
Austria	Brazil
Belgium	Brunei Darussalam
Canada	Bulgaria
Denmark	Cambodia
Finland	Chile
France	China
Germany	Hong Kong
Greece	Colombia
Iceland	Costa Rica
Ireland	Croatia
Israel	Cyprus
Italy	Czech Republic
Japan	Estonia
Korea	Hungary
Luxembourg	India
Netherlands	Indonesia
New Zealand	Latvia
Norway	Lithuania
Portugal	Malaysia
Singapore	Malta
Spain	Mexico
Sweden	Philippines
Switzerland	Poland
United Kingdom	Romania
United States	Russian Federation
	Saudi Arabia
	Slovakia
	Slovenia
	South Africa
	Taiwan
	Thailand
	Tunisia
	Turkey
	Vietnam

Notes: Sample of countries used in the empirical analysis, as Bartelme *et al.* (2019).

B.3. Additional Empirical Detail

Data. Bilateral trade flows data are from the OECD's Inter-Country Input-Output tables, which provide bilateral trade among the 61 major economies in Table B1. These data report all bilateral flows, including domestic sales, in each sector we use to construct aggregate measures of expenditure and sales by country and sector as described in Section 5.1. We follow Bartelme *et al.* (2019) in focusing our empirical analysis on 15 manufacturing sectors, defined at a level similar to the 2-digit SIC and listed in Table B2, with baseline estimates for 2010. We report similar estimates in Table B3 for other available cross-section years: 1995, 2000, and 2005.

As in Bartelme *et al.* (2019), population $\widehat{L}_i$ is from the "POP" variable in the Penn World Tables version 9.0.

Estimation. The second and first stages corresponding to the IV estimator in Section 5.1 for country i sector k are

$$Y_{i,k} = \sum_{n\in\mathcal{I}} \delta_n \times \mathbb{1}_{n=i} + \sum_{n\in\mathcal{K}} \delta_n \times \mathbb{1}_{n=k} + \sum_{o\in\mathcal{H}}\sum_{n\in\mathcal{K}} \gamma_n^o \times (\mathbb{1}_{o=i} \times \mathbb{1}_{n=k} \times \ln L_{i,n}) + \varepsilon_{i,k} \tag{B1}$$

$$(\mathbb{1}_{o=i} \times \mathbb{1}_{n=k} \times \ln L_{i,n}) = \sum_{m\in\mathcal{I}} \widetilde{\delta}_{m,n} \times \mathbb{1}_{m=i} + \sum_{m\in\mathcal{K}} \widetilde{\delta}_{m,n} \times \mathbb{1}_{m=k} + \sum_{h\in\mathcal{H}}\sum_{m\in\mathcal{K}} \widetilde{\gamma}_{m,n}^h \times (\mathbb{1}_{h=i} \times \mathbb{1}_{m=k} \times \ln \widehat{L}_{i,m}) + \widetilde{\varepsilon}_{i,k}^{n,o} \text{ for all } n \in \mathcal{K},\, o \in \mathcal{H} \tag{B2}$$

where $\mathcal{I}$ are countries, $\mathcal{K}$ are sectors, $\mathcal{H}$ are $\{adv, em\}$, $\mathbb{1}_{n=i}$ for $n \in \mathcal{I}$ are country-specific dummy variables, $\mathbb{1}_{n=k}$ for $n \in \mathcal{K}$ are sector-specific dummy variables, and $\mathbb{1}_{n=h}$ for $n \in \mathcal{H}$ are advanced and emerging-market dummy variables (i.e., whether country h is an advanced or emerging-market economy, listed in Table B1).

B.4. Additional Empirical Results

Table B2: Tradable Sector Externalities (γ_{Tk})

Sector	All (1)	Advanced (2)	EMs (3)
Food, Beverages and Tobacco	0.22	0.11	0.26
	(0.02)	(0.05)	(0.04)
Textiles	0.12	0.03	0.17
	(0.01)	(0.03)	(0.04)
Wood Products	0.13	0.13	0.19
	(0.02)	(0.03)	(0.03)
Paper Products	0.15	0.07	0.21
	(0.01)	(0.05)	(0.04)
Coke/Petroleum Products	0.09	-0.04	0.12
	(0.01)	(0.03)	(0.03)
Chemicals	0.24	0.19	0.34
	(0.02)	(0.04)	(0.05)
Rubber and Plastics	0.42	0.22	0.69
	(0.04)	(0.12)	(0.08)
Mineral Products	0.17	0.08	0.25
	(0.01)	(0.03)	(0.03)
Basic Metals	0.09	-0.01	0.17
	(0.01)	(0.04)	(0.03)
Fabricated Metals	0.12	0.01	0.16
	(0.02)	(0.04)	(0.04)
Machinery and Equipment	0.24	0.19	0.32
	(0.02)	(0.04)	(0.04)
Computers and Electronics	0.08	-0.02	0.14
	(0.01)	(0.03)	(0.04)
Electrical Machinery, NEC	0.08	-0.04	0.13
	(0.01)	(0.04)	(0.04)
Motor Vehicles	0.18	0.16	0.22
	(0.01)	(0.04)	(0.04)
Other Transport Equipment	0.18	0.15	0.30
	(0.02)	(0.04)	(0.04)
Average	0.19	0.08	0.24
N Observations	915	390	525

Notes: Column (1) presents IV estimates of γ_{Tk} for 2010 from the entire sample in Bartelme *et al.* (2019). Column (2) contains estimates for advanced economies, and column (3) contains the estimates for emerging-market economies, all for the γ_{Tk} coefficients using the IV estimator from equations (21) and (**??**). Robust standard errors, clustered at country-sector level, are provided in parentheses.

Table B3: Tradable Sector Externalities (γ_{Tk}) over Time

	1995		2000		2005		2010	
Sector	Adv	EMs	Adv	EMs	Adv	EMs	Adv	EMs
Food, Beverages & Tobacco	0.01	0.20	0.02	0.23	0.08	0.25	0.11	0.26
	(0.05)	(0.04)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)
Textiles	-0.06	0.18	-0.05	0.18	0.01	0.18	0.03	0.17
	(0.05)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)
Wood Products	0.03	0.13	0.04	0.15	0.05	0.18	0.13	0.19
	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Paper Products	-0.07	0.18	-0.04	0.19	0.00	0.22	0.07	0.21
	(0.04)	(0.03)	(0.05)	(0.03)	(0.04)	(0.04)	(0.05)	(0.04)
Coke/Petroleum Products	-0.09	0.10	-0.10	0.11	-0.06	0.14	-0.04	0.12
	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Chemicals	0.09	0.28	0.11	0.29	0.16	0.34	0.19	0.34
	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)
Rubber and Plastics	0.00	0.56	0.05	0.68	0.13	0.75	0.22	0.69
	(0.11)	(0.09)	(0.13)	(0.08)	(0.12)	(0.12)	(0.12)	(0.08)
Mineral Products	-0.02	0.14	0.00	0.20	0.05	0.22	0.08	0.25
	(0.04)	(0.04)	(0.05)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)
Basic Metals	-0.12	0.11	-0.12	0.14	-0.04	0.16	-0.01	0.17
	(0.05)	(0.03)	(0.06)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)
Fabricated Metals	-0.09	0.15	-0.08	0.17	-0.02	0.20	0.01	0.16
	(0.04)	(0.03)	(0.05)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)
Machinery and Equipment	0.09	0.30	0.11	0.29	0.16	0.30	0.19	0.32
	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)
Computers and Electronics	-0.07	0.11	-0.09	0.12	-0.03	0.15	-0.02	0.14
	(0.03)	(0.02)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)
Electrical Machinery, NEC	-0.13	0.10	-0.13	0.13	-0.07	0.14	-0.04	0.13
	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)
Motor Vehicles	0.09	0.18	0.11	0.2	0.15	0.24	0.16	0.22
	(0.02)	(0.04)	(0.03)	(0.04)	(0.03)	(0.05)	(0.02)	(0.04)
Other Transport Equipment	0.02	0.22	0.05	0.24	0.12	0.27	0.15	0.30
	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)
Average	-0.02	0.20	-0.01	0.22	0.05	0.25	0.08	0.24
N Observations	390	525	390	525	390	525	390	525

Notes: This table shows IV estimates of γ_{Tk} at 5-year intervals from 1995 to 2010 for advanced and emerging-market economies from equations (21) and (**??**) Robust standard errors, clustered at country-sector level, are provided in parentheses.

B.5. Computational detail

B.5.1. Steady state

First best. The steady state of the model (dropping t subscripts and denoting $\gamma_T = \gamma$) for the first best is characterized by

$$\left(\frac{\omega}{c_T}\right)^{\frac{1}{\eta}} = \frac{\alpha}{(\alpha+\gamma)} \frac{c_N^{\frac{\alpha-1}{\alpha}}}{L_T^{\alpha+\gamma-1}} \left(\frac{1-\omega}{c_N}\right)^{\frac{1}{\eta}}, \tag{B3}$$

$$\left(\frac{\omega}{c_T}\right)^{\frac{1}{\eta}} C^{\frac{1}{\eta}-\sigma} = \phi \frac{(L_T + c_N^{\frac{1}{\alpha}})^{\nu}}{(\alpha+\gamma) L_T^{\alpha+\gamma-1}}, \tag{B4}$$

$$c_T - L_T^{\alpha+\gamma} = F^* \left(1 - \frac{1}{R^*}\right), \tag{B5}$$

which depends on the level of steady-state foreign currency bonds F^*.

We can solve for the steady state by solving for c_N in terms of c_T and L_T

$$c_N^{\frac{1}{\alpha}+\frac{1}{\eta}-1} = \frac{\alpha}{(\alpha+\gamma)} \left(\frac{1-\omega}{\omega}\right)^{\frac{1}{\eta}} c_T^{\frac{1}{\eta}} L_T^{1-\alpha-\gamma}, \tag{B6}$$

$$c_N = \left[\frac{\alpha}{(\alpha+\gamma)} \left(\frac{1-\omega}{\omega}\right)^{\frac{1}{\eta}} c_T^{\frac{1}{\eta}} L_T^{1-\alpha-\gamma}\right]^{\frac{\alpha\eta}{\eta+\alpha-\eta\alpha}}, \tag{B7}$$

and for L_T

$$L_T = \left[c_T - F^* \left(1 - \frac{1}{R^*}\right)\right]^{\frac{1}{\alpha+\gamma}}, \tag{B8}$$

and substituting these into the following to get a nonlinear equation for c_T:

$$\left(\frac{\omega}{c_T}\right)^{\frac{1}{\eta}} C^{\frac{1}{\eta}-\sigma} = \phi \frac{(L_T + c_N^{\frac{1}{\alpha}})^{\nu}}{(\alpha+\gamma) L_T^{\alpha+\gamma-1}}. \tag{B9}$$

CE and XR-IP. The steady state of the model for both the competitive equilibrium benchmark and XR-IP is characterized by

$$\left(\frac{\omega}{c_T}\right)^{\frac{1}{\eta}} = \mathcal{E}\left(\frac{1-\omega}{c_N}\right)^{\frac{1}{\eta}}, \tag{B10}$$

$$\left(\frac{\omega}{c_T}\right)^{\frac{1}{\eta}} C^{\frac{1}{\eta}-\sigma} = \phi\frac{(L_T + c_N^{\frac{1}{\alpha}})^{\nu}}{\alpha L_T^{\alpha+\gamma-1}}, \tag{B11}$$

$$\mathcal{E} = \frac{c_N^{\frac{\alpha-1}{\alpha}}}{L_T^{\alpha+\gamma-1}}, \tag{B12}$$

$$c_T - L_T^{\alpha+\gamma} = F^*\left(1 - \frac{1}{R^*}\right). \tag{B13}$$

We can solve for the steady state by substituting $\mathcal{E}$ and solving for c_N in terms of c_T and L_T

$$c_N = \left[\left(\frac{1-\omega}{\omega}\right)^{\frac{1}{\eta}} c_T^{\frac{1}{\eta}} L_T^{1-\alpha-\gamma}\right]^{\frac{\alpha\eta}{\eta+\alpha-\eta\alpha}}, \tag{B14}$$

and for L_T

$$L_T = \left[c_T - F^*\left(1 - \frac{1}{R^*}\right)\right]^{\frac{1}{\alpha+\gamma}}, \tag{B15}$$

and substituting these to get a non-linear equation for c_T

$$\left(\frac{\omega}{c_T}\right)^{\frac{1}{\eta}} C^{\frac{1}{\eta}-\sigma} = \phi\frac{(L_T + c_N^{\frac{1}{\alpha}})^{\nu}}{\alpha L_T^{\alpha+\gamma-1}}. \tag{B16}$$

B.5.2. Solving infinite horizon transition dynamics

We estimate the transition between the initial $t = 0$ and final $t = T$ steady states and solve for the path of all variables when an unanticipated decrease in the level of the labor externality in the infinite-horizon model hits at $t = 1$.

Solving Competitive Equilibrium. We know from the equilibrium conditions that the nominal exchange rate is given by

$$\mathcal{E}_t = \frac{c_{Nt}^{\frac{\alpha-1}{\alpha}}}{L_{Tt}^{\alpha+\gamma_t-1}}. \tag{B17}$$

For the competitive equilibrium benchmark, the household Euler equation is given by

$$\left(\frac{\omega}{c_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R_t^* \left(\frac{\omega}{c_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}. \tag{B18}$$

We can use the HH expenditure-switching condition to substitute out c_{Nt}

$$c_{Nt} = \left[\left(\frac{1-\omega}{\omega}\right)^{\frac{1}{\eta}} c_{Tt}^{\frac{1}{\eta}} L_{Tt}^{1-\alpha-\gamma_t}\right]^{\frac{\alpha\eta}{\eta+\alpha-\eta\alpha}}. \tag{B19}$$

Therefore, given an allocation at $t+1$, we can solve for c_{Tt} and L_{Tt} from the two equations

$$\left(\frac{\omega}{c_{Tt}}\right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} = \beta R_t^* \left(\frac{\omega}{c_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{B20}$$

$$\phi \frac{(L_{Tt} + c_{Nt}^{\frac{1}{\alpha}})^{\nu}}{\alpha L_{Tt}^{\alpha+\gamma_t-1}} = \beta R_t^* \left(\frac{\omega}{c_{Tt+1}}\right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}. \tag{B21}$$

We have two equations (B21) and (B20) for L_{Tt} and c_{Tt} in terms of variables at $t+1$.

Note that the balance of payments constraint is

$$c_{Tt} - L_{Tt}^{\alpha+\gamma_t} = F_t^* - \frac{F_{t+1}^*}{R_t^*}. \tag{B22}$$

Substituting in for c_{Nt} from (B19) into (B21)

$$c_{Nt} = Y_t \equiv \left\{ \left[\frac{\alpha L_{Tt}^{\alpha+\gamma_t-1}}{\phi} \beta R_t^* \left(\frac{\omega}{c_{Tt+1}} \right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma} \right]^{\frac{1}{\nu}} - L_{Tt} \right\}^{\alpha}, \tag{B23}$$

$$c_{Tt} = X_t^{\eta},\ X_t \equiv \left[\left(\frac{\omega}{1-\omega} \right)^{\frac{1}{\eta}} L_{Tt}^{-(1-\alpha-\gamma_t)} Y_t^{\frac{\eta+\alpha-\eta\alpha}{\alpha\eta}} \right]. \tag{B24}$$

Substituting in for c_{Tt} from (B24) into (B20)

$$\omega^{\frac{1}{\eta}} X_t^{-1} \left(\left[\omega^{\frac{1}{\eta}} (X_t)^{\eta-1} + (1-\omega)^{\frac{1}{\eta}} (Y_t)^{1-\frac{1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \right)^{\frac{1}{\eta}-\sigma} = \beta R_t^* \left(\frac{\omega}{c_{Tt+1}} \right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{B25}$$

which gives a nonlinear equation for L_{Tt} in terms of $t+1$ variables.

Algorithm.

We solve for the competitive equilibrium transition dynamics using the following steps:

1. Guess a new steady-state foreign currency bond holdings $\widetilde{F}_T^*$, and solve for the allocation at T given this guess.

2. Given this new steady state at T, solve backward from $t = T-1, ..., 1$ for $c_{Tt}, c_{Ft}, L_{Tt}, \mathcal{E}_t$ at each t solving for L_{Tt} using (B25), and then compute the other variables.

3. Solve forward from $t = 1, ..., T$ given the initial steady-state foreign currency bond holdings F_1^* and competitive equilibrium allocation from step 2 for the implied new steady-state assets $\widehat{F}_T^*$ using the balance of payments (B22).

4. Update the guess $\widetilde{F}_T^*$ using some dampening and iterate until convergence. After convergence we confirm that the goods market-clearing condition, household expenditure switching condition, MRS = MRT condition, and household Euler equation are satisfied.

Solving First Best. For the first best, we follow the same steps as above but with the first-best expression for c_{Nt}:

$$c_{Nt} = \left[\frac{\alpha}{(\alpha+\gamma_t)} \left(\frac{1-\omega}{\omega} \right)^{\frac{1}{\eta}} c_{Tt}^{\frac{1}{\eta}} L_{Tt}^{1-\alpha-\gamma} \right]^{\frac{\alpha\eta}{\eta+\alpha-\eta\alpha}}, \tag{B26}$$

and the first-best MRS = MRT condition:

$$\phi \frac{(L_{Tt} + c_{Nt}^{\frac{1}{\alpha}})^{\nu}}{(\alpha + \gamma_t) L_{Tt}^{\alpha+\gamma_t-1}} = \beta R_t^* \left(\frac{\omega}{c_{Tt+1}} \right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}. \tag{B27}$$

The other equations are the same as for the competitive equilibrium benchmark.

Substituting for c_{Nt} from (B26) into (B27),

$$c_{Nt} = Y_t \equiv \left\{ \left[\frac{(\alpha + \gamma_t) L_{Tt}^{\alpha+\gamma_t-1}}{\phi} \beta R_t^* \left(\frac{\omega}{c_{Tt+1}} \right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma} \right]^{\frac{1}{\nu}} - L_{Tt} \right\}^{\alpha}, \tag{B28}$$

$$c_{Tt} = X_t^{\eta},\ X_t \equiv \left[\frac{(\alpha + \gamma_t)}{\alpha} \left(\frac{\omega}{1-\omega} \right)^{\frac{1}{\eta}} L_{Tt}^{-(1-\alpha-\gamma_t)} Y_t^{\frac{\eta+\alpha-\eta\alpha}{\alpha\eta}} \right]. \tag{B29}$$

Substituting in for c_{Tt} from (B24) into (B20)

$$\omega^{\frac{1}{\eta}} X_t^{-1} \left(\left[\omega^{\frac{1}{\eta}} (X_t)^{\eta-1} + (1-\omega)^{\frac{1}{\eta}} (Y_t)^{1-\frac{1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \right)^{\frac{1}{\eta}-\sigma} = \beta R_t^* \left(\frac{\omega}{c_{Tt+1}} \right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma}, \tag{B30}$$

which gives a nonlinear equation for L_{Tt} in terms of $t+1$ variables, so we can solve using the same algorithm as for the competitive equilibrium.

Solving XR-IP. For the XR-IP, we follow the same steps as the competitive equilibrium but with the planner's intertemporal optimality condition

$$\left(\frac{\omega}{c_{Tt}} \right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} \theta_t = \beta R_t^* \left(\frac{\omega}{c_{Tt+1}} \right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma} \theta_{t+1}, \tag{B31}$$

where Appendix A.3 provides the derivation and expression for the wedge terms θ_t, θ_{t+1}.

Therefore, the planner's equations to solve for c_{Tt} and L_{Tt} are

$$\left(\frac{\omega}{c_{Tt}} \right)^{\frac{1}{\eta}} C_t^{\frac{1}{\eta}-\sigma} \theta_t = \beta R_t^* \left(\frac{\omega}{c_{Tt+1}} \right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma} \theta_{t+1}, \tag{B32}$$

$$\phi \frac{(L_{Tt} + c_{Nt}^{\frac{1}{\alpha}})^{\nu}}{\alpha L_{Tt}^{\alpha+\gamma_t-1}} \theta_t = \beta R_t^* \left(\frac{\omega}{c_{Tt+1}} \right)^{\frac{1}{\eta}} C_{t+1}^{\frac{1}{\eta}-\sigma} \theta_{t+1}. \tag{B33}$$

Substituting for c_{Nt} from (B19) into (B32) and (B33) gives two nonlinear equations for c_{Tt} and L_{Tt}.

We alter step 2 of the algorithm to jointly solve for c_{Tt} and L_{Tt} at each t:

2. Given this new steady state at T, solve backward from $t = T-1, ..., 1$ for $c_{Tt}, c_{Ft}, L_{Tt}, \mathcal{E}_t$ at each t by guessing and iterating for c_{Tt}, L_{Tt} using (B32) and (B33):

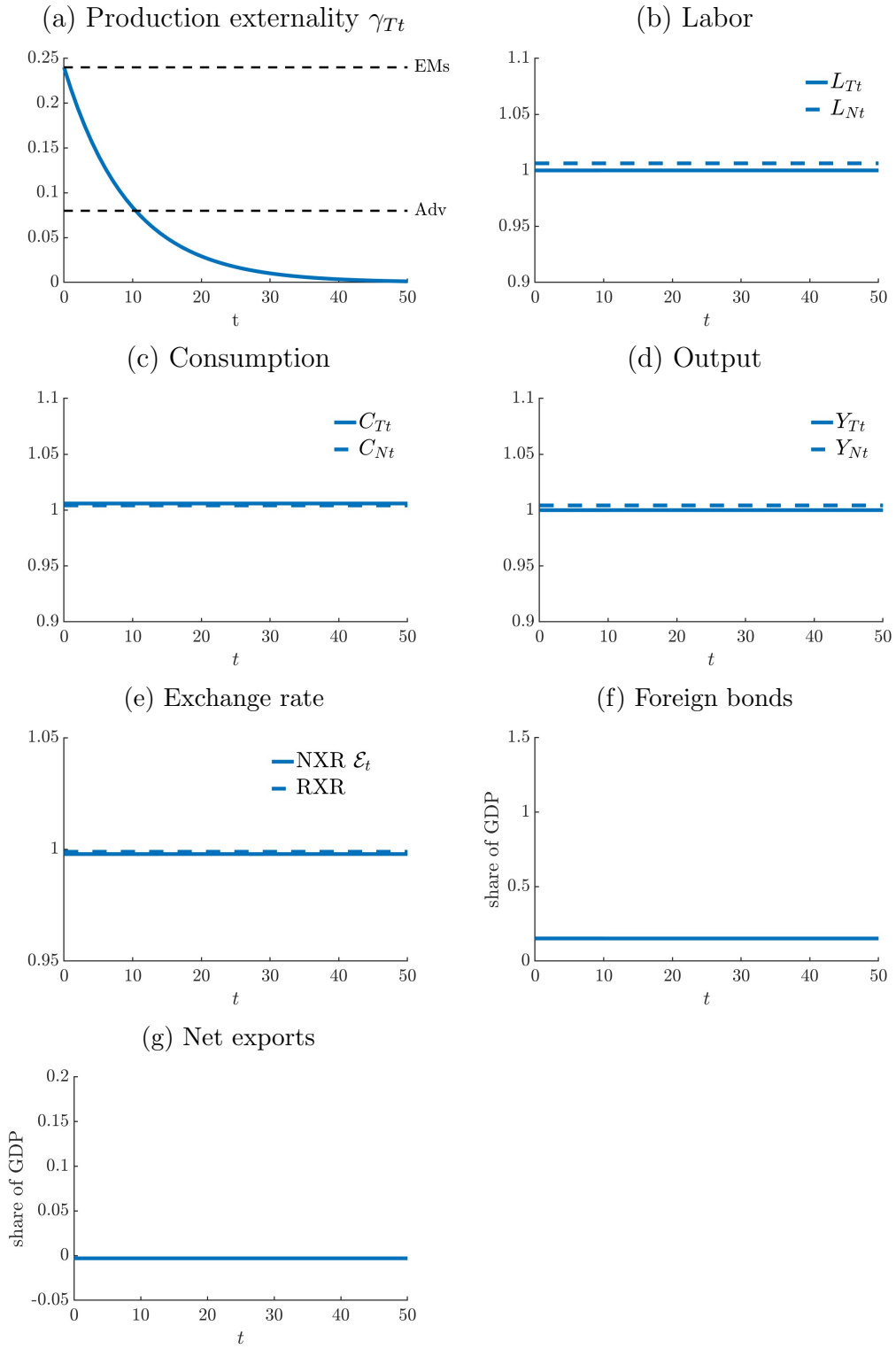
   a. Guess $\widetilde{c}_{Tt}$ and given this guess, solve for $\widetilde{L}_{Tt}$ from (B33).

   b. Given $\widetilde{L}_{Tt}$, solve for the implied $\widehat{c}_{Tt}$.

   c. Update guess for $\widetilde{c}_{Tt}$ using some dampening and iterate until convergence.

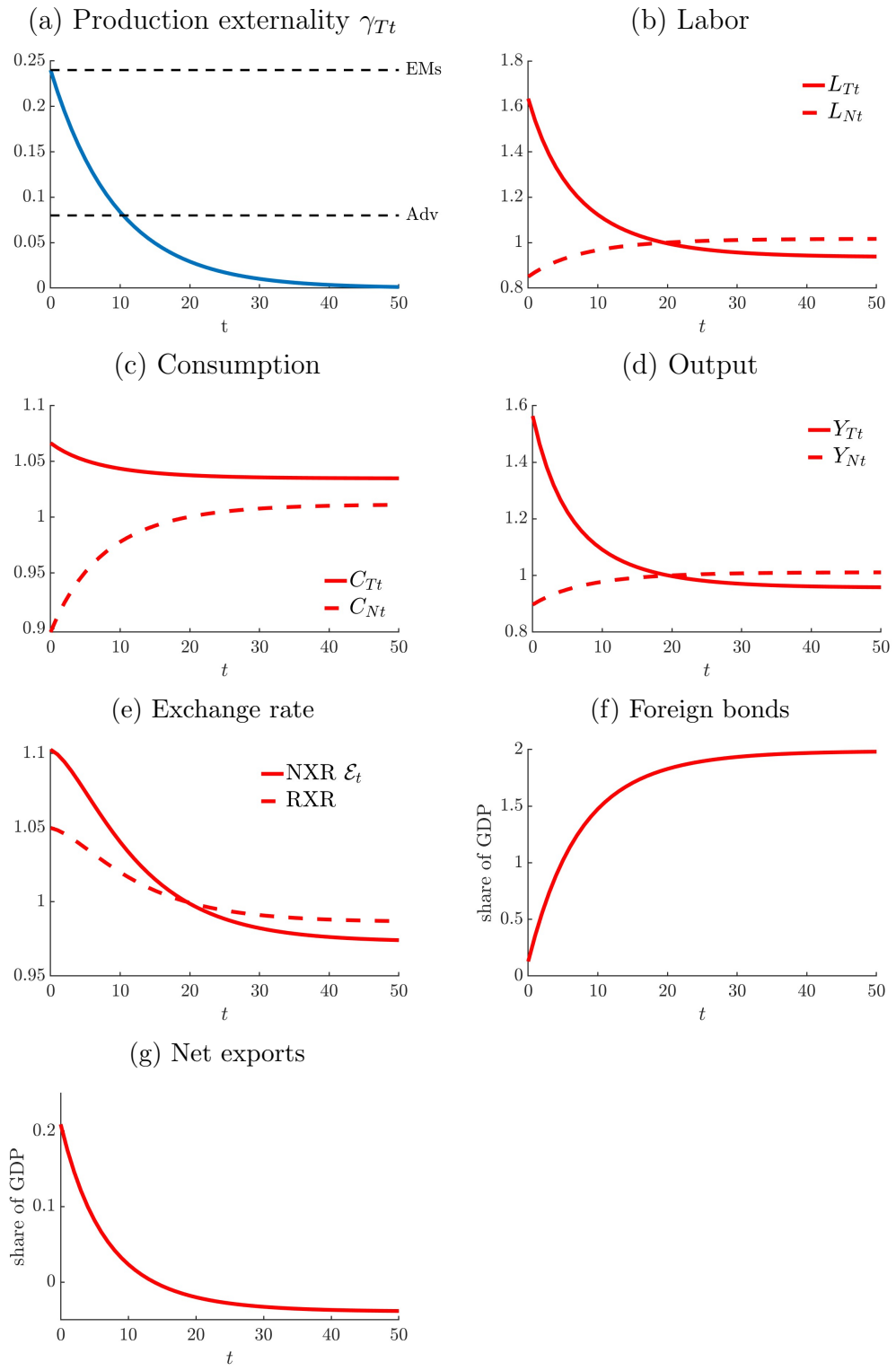
B.6. Quantitative Results – Additional Detail

Figure B2: Transition – Competitive Equilibrium



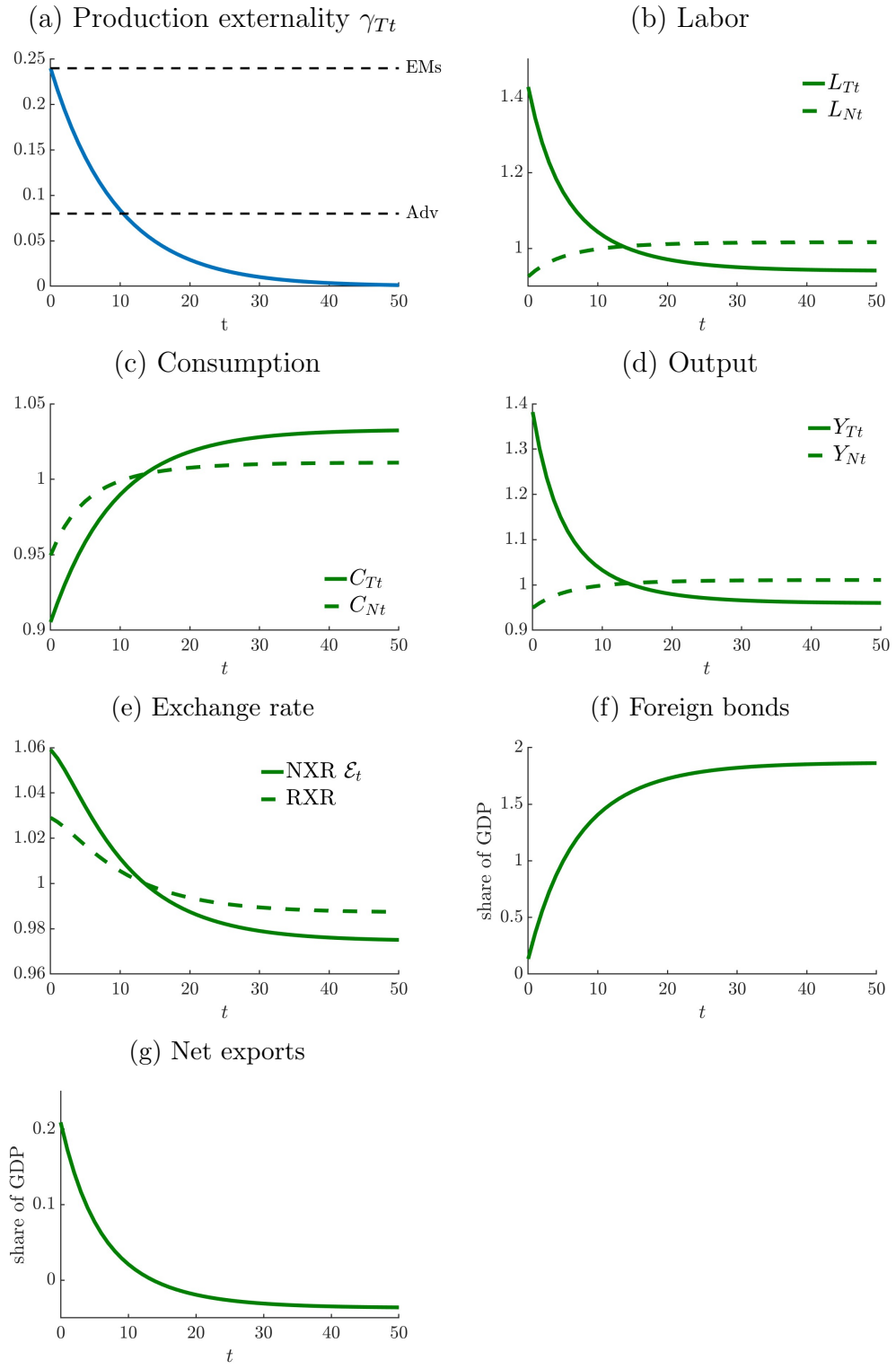
Notes: This figure shows transition dynamics for the model from the initial steady state calibrated for China in 1997, following an unanticipated decline in the production externality γ_{Tt} shown in Panel (a).

Figure B3: Transition – First Best



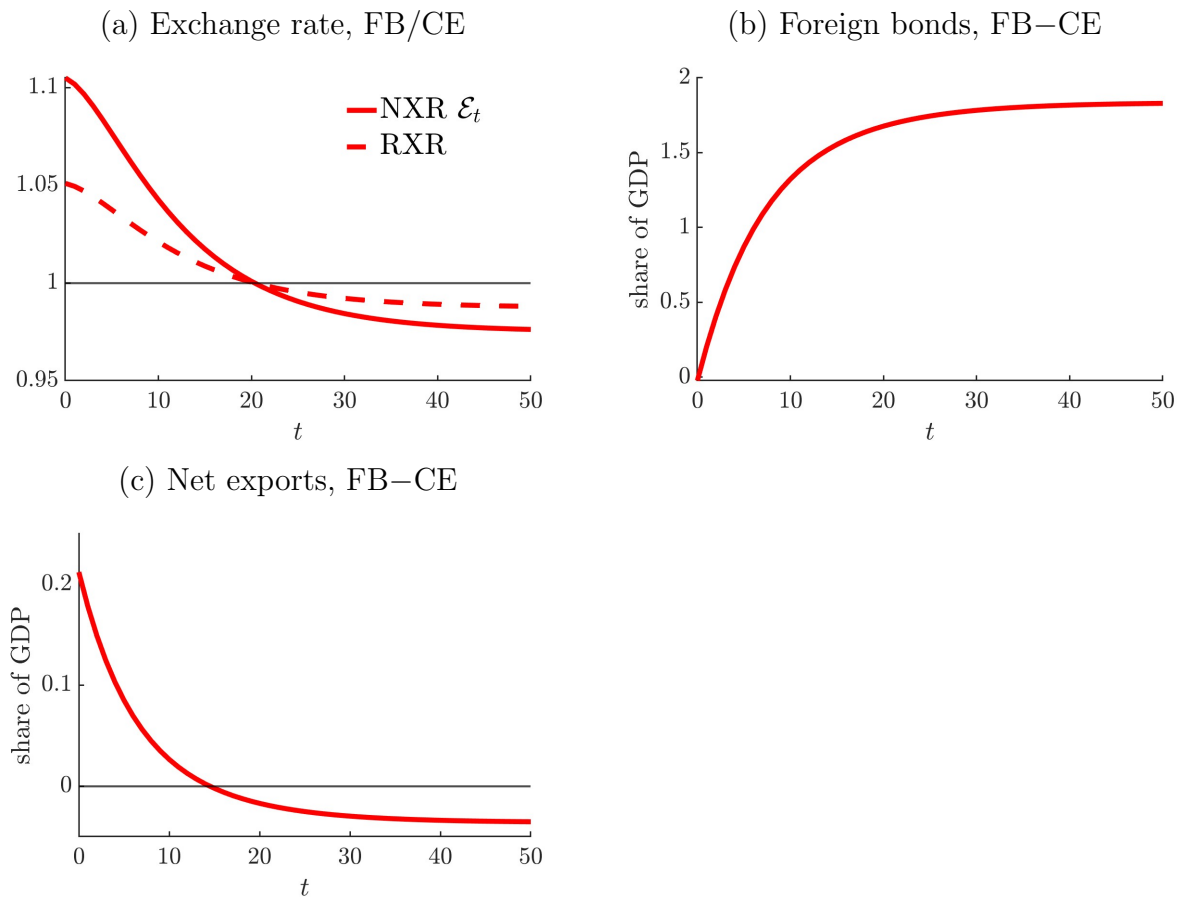
Notes: This figure shows transition dynamics for the model from the initial steady state calibrated for China in 1997, following an unanticipated decline in the production externality γ_{Tt} shown in Panel (a).

Figure B4: Transition – Optimal Exchange Rate Industrial Policy (XR-IP)



Notes: This figure shows transition dynamics for the model from the initial steady state calibrated for China in 1997, following an unanticipated decline in the production externality γ_{Tt} shown in Panel (a).

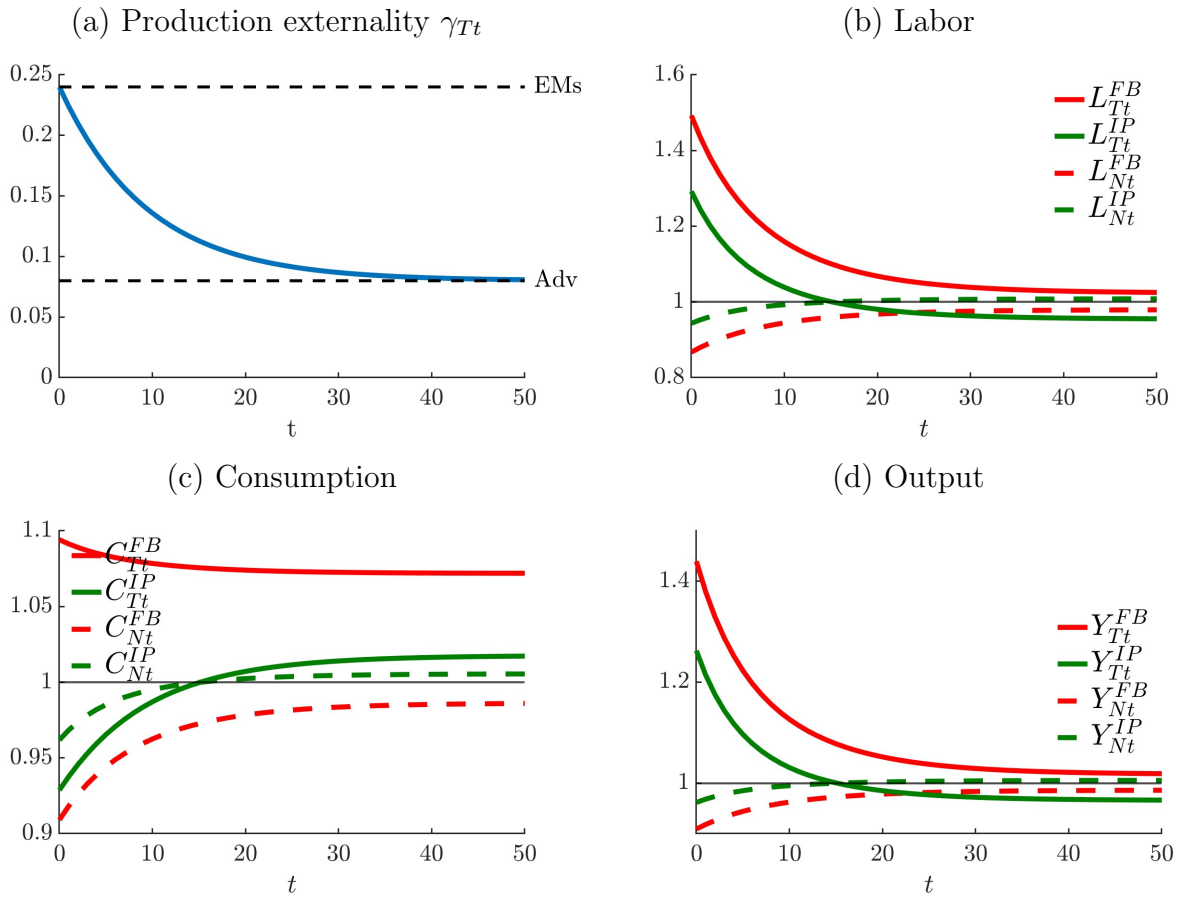
Figure B5: Transition – First Best relative to Competitive Equilibrium



Notes: This figure shows transition dynamics for the model from the initial steady state calibrated for China in 1997, following an unanticipated decline in the production externality γ_{Tt} shown in Figure 3 Panel (a). Variables are for the first best relative to the laissez-faire competitive equilibrium. Figures B2, B3, and B4 provide the variables in levels for each case.

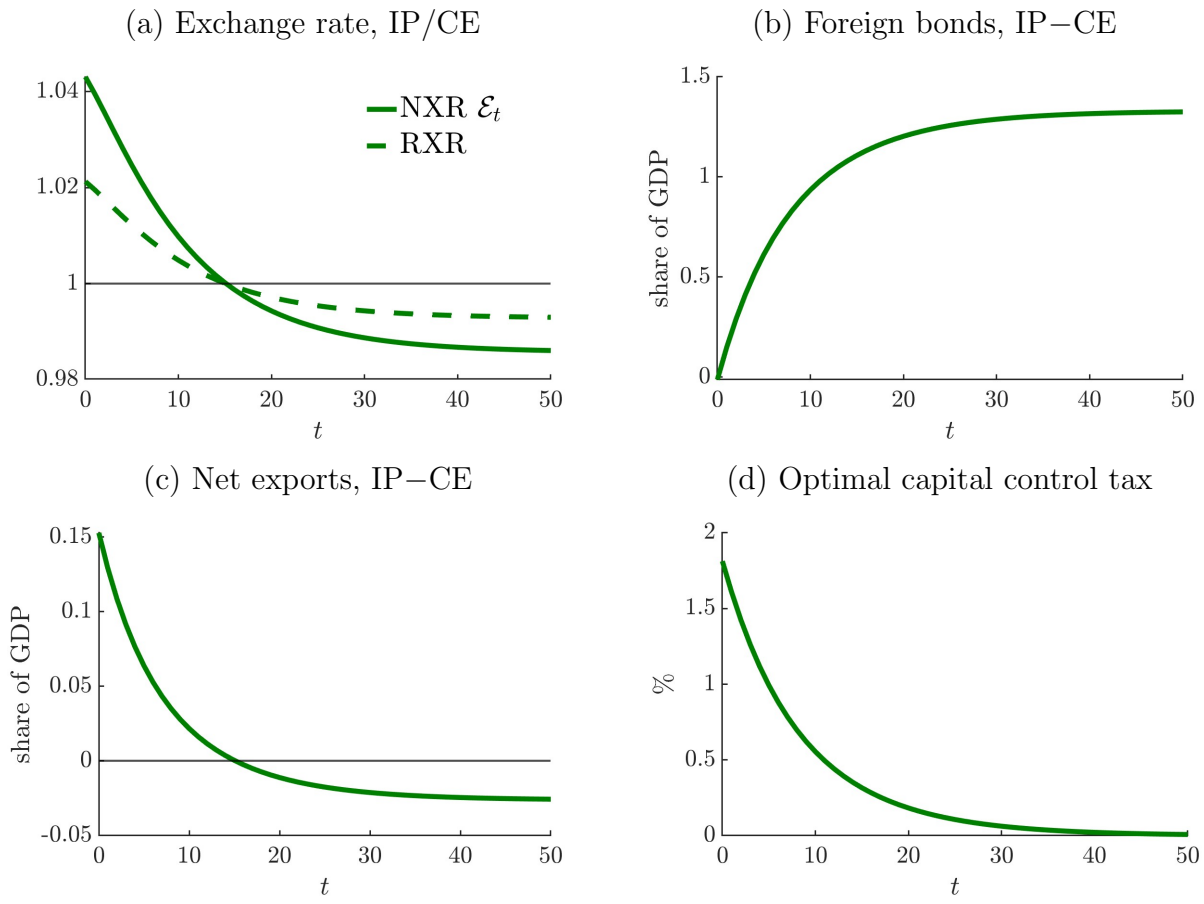
B.7. Quantitative Results – Alternate Production Externality Path

Figure B6: Alternate Transition – First Best and XR-IP Relative to the Competitive Equilibrium



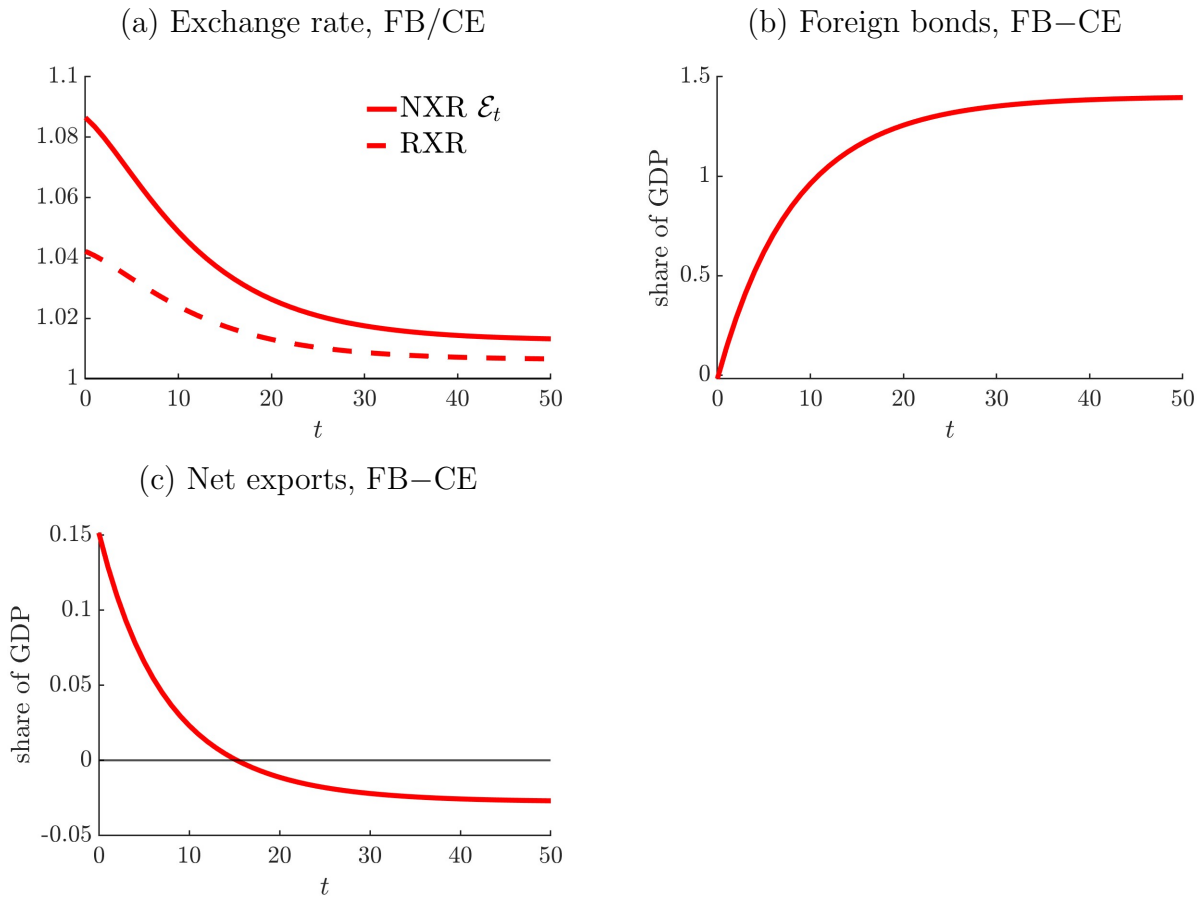
Notes: This figure shows transition dynamics for the model from the initial steady state calibrated for China in 1997, following an unanticipated decline in the production externality γ_{Tt} shown in Panel (a). The variables in Panels (b)-(d) are relative to the laissez-faire competitive equilibrium, with the first best shown by "FB" and optimal XR-IP by "IP."

Figure B7: Alternate Transition – Optimal XR-IP relative to the Competitive Equilibrium



Notes: This figure shows transition dynamics for the model from the initial steady state calibrated for China in 1997, following an unanticipated decline in the production externality γ_{Tt} shown in Figure B6 Panel (a). The variables in Panels (a)-(c) are for the optimal XR-IP relative to the laissez-faire competitive equilibrium. Panel (d) shows the optimal capital control tax, which implements the XR-IP allocation.

Figure B8: Alternate Transition – First Best relative to the Competitive Equilibrium



Notes: This figure shows transition dynamics for the model from the initial steady state calibrated for China in 1997, following an unanticipated decline in the production externality γ_{Tt} shown in Figure B6 Panel (a). Variables are for the first best relative to the laissez-faire competitive equilibrium.

B.8. Consumption-equivalent welfare

To compare consumption welfare for the first best (FB) vs. laissez-faire competitive equilibrium (CE), and similarly for XR-IP vs. CE, we take the allocation

$$W_{s:S}^{FB} = \sum_{t=s}^{S} \beta^{s-t} \left[\frac{(C_t^{FB})^{1-\sigma}}{1-\sigma} - \phi \frac{(L_t^{FB})^{1+\nu}}{1+\nu} \right], \tag{B34}$$

$$W_{s:S}^{CE} = \sum_{t=s}^{S} \beta^{s-t} \left[\frac{(C_t^{CE})^{1-\sigma}}{1-\sigma} - \phi \frac{(L_t^{CE})^{1+\nu}}{1+\nu} \right], \tag{B35}$$

and calculate the fraction Λ increase per period consumption in the CE to equate welfare in the FB

$$\sum_{t=s}^{S} \beta^{s-t} \left[\frac{((1+\Lambda)C_t^{CE})^{1-\sigma}}{1-\sigma} - \phi \frac{(L_t^{CE})^{1+\nu}}{1+\nu} \right] = \sum_{t=s}^{S} \beta^{s-t} \left[\frac{(C_t^{FB})^{1-\sigma}}{1-\sigma} - \phi \frac{(L_t^{FB})^{1+\nu}}{1+\nu} \right] \tag{B36}$$

$$\sum_{t=s}^{S} \beta^{s-t} \frac{(\Lambda C_t^{CE})^{1-\sigma}}{1-\sigma} = W_{s:S}^{FB} - W_{s:S}^{CE} \tag{B37}$$

$$\Lambda \sum_{t=s}^{S} \beta^{s-t} \frac{(C_t^{CE})^{1-\sigma}}{1-\sigma} = W_{s:S}^{FB} - W_{s:S}^{CE} \tag{B38}$$

$$\Lambda = \frac{(W_{s:S}^{FB} - W_{s:S}^{CE})}{C_{s:S}^{CE}} \tag{B39}$$

where

$$C_{s:S}^{CE} \equiv \sum_{t=s}^{S} \beta^{s-t} \frac{(C_t^{CE})^{1-\sigma}}{1-\sigma}. \tag{B40}$$

B.9. Welfare Effects of XR-IP – Alternate Parameters

Table B4: Effects of XR-IP relative to the Competitive Equilibrium – Varying Parameters

	XR-IP / CE, %Δ 10-yr avg.		
	Baseline: $\sigma = 2$, $\eta = 0.8$	CRRA coeff $\sigma = 3$	TNT elast $\eta = 0.5$
a. Output			
Agg.	7.2	7.3	7.7
T	16.5	16.5	17.9
NT	-2.5	-1.5	-3.1
b. Consumption			
Agg.	-4.0	-2.9	-4.2
T	-5.5	-4.2	-5.2
NT	-2.5	-1.5	-3.1
c. Welfare (incl transition)			
Cons. equiv.	0.17	0.31	0.18

Notes: This table shows the average for the first 10 years of the transition for the optimal XR-IP relative to the laissez-faire competitive equilibrium for the baseline calibration and when varying one parameter at a time.