Property Rights, Expropriations, and Business Cycles in China

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Abstract

Real business cycles in China are different than in many other countries, including consumption being more volatile than output and uncorrelated with investment. To study whether Chinese institutions can account for these features, we augment the standard real business cycle model by private and state-owned enterprises facing time-to-build constraints, expropriations, and government expenditures. We introduce shocks to each of these activities and estimate our model with Bayesian techniques. The model matches the salient data moments quite closely, with expropriations playing a central role. In particular, shocks to expropriations account for over 70% of consumption and output volatility, and over 60% of private investment volatility. To assess whether our estimated expropriations are empirically plausible, we show that: *(i)* the model-generated expropriation series is positively correlated with a commonly used measure of property rights; *(ii)* the explanatory power of expropriations drops considerably after 2012, coinciding with the government's anti-corruption campaign; and *(iii)* a placebo test estimating the model for the U.S. finds expropriations to be about one eighth of those in China, and to account for only a small share of the U.S. aggregate fluctuations.

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1 Introduction

Real business cycles in China follow different patterns compared to many other countries. Notably, consumption is more volatile than output, and displays a lack of correlation with investment and output. China's institutional structure, with a large government presence and relatively weak property rights, is potentially an important factor affecting macroeconomic fluctuations. Many Chinese enterprises are state-owned, where the decision making processes is quite different from those in the private sector (Song et al., 2011). Moreover, expropriations tend to be common and take many forms, such as selectively enforcing taxes to surprised business owners (Blustein, 2019), or setting mark-ups for land to be privately leased as a function of expected profits (Ding and Lichtenberg, 2011). In this paper, we introduce these features into a standard real business cycle (RBC) model to understand their role in shaping the business cycle dynamics.

While activities by state-owned enterprises (SOEs) are relatively straightforward to model by focusing on readily available theories and data, expropriations are not. Datasets on expropriations are rare, predominantly based on surveys, and available mostly at annual frequency, which presents problems for quantitative business cycle work. We tackle this by building a model with micro-founded expropriations. We exploit the fact that expropriations affect the dynamics of national account variables, such as output, consumption, and investment, differently than productivity or other shocks. This allows us to estimate the parameters related to expropriations with Bayesian techniques.

To this end, we extend the standard RBC model in four ways. Building on Rubini (2019), we first consider private-owned enterprises (POEs) with decreasing returns to scale technology, and politicians that expropriate firms. Expropriations lower the present value of a firm's future profit stream, depressing investment and increasing consumption. This lowers the correlation between the two series, and increases the volatility of consumption relative to output.

Expropriations arise endogenously, that is, more valuable firms are more "enticing" to expropriate. We model this by assuming expropriations require the use of productive resources. Empirically, many of these require labor. For example, if a surprise tax is to be collected, the government requires administrative resources.[1] In addition, expropriations depend on a stochastic process determining

[1]Alternatively, we could use capital, or other resources in direct competition with private firms to make the decision

expropriation efficiency, which represents the degree of property rights protection. Shocks to expropriation efficiency add a layer of uncertainty to expropriation, which Campos et al. (1999) find to be a central determinant of investment when property rights protection is weak.

Second, we introduce SOEs that differ from POEs along several dimensions. Following Song et al. (2011), SOEs are more capital intensive. In addition, they are not subject to expropriations since profits already accrue to the government. Goods produced by SOEs are combined with goods produced by POEs via a constant elasticity of substitution (CES) aggregator to form a final good.

Third, both POEs and SOEs face time-to-build technologies as in Kydland and Prescott (1982). This prevents investment from being too volatile, especially in the SOE sector.

Fourth, we consider exogenous shocks to government expenditures. When going to the data, we bundle government expenditures together with net exports, which allows us to account for the large fluctuations in both variables and makes the model more consistent with the data.

Our estimated baseline model accounts reasonably well for several unique moments of the Chinese economy. It generates (i) more volatile consumption than output; (ii) a close-to-zero correlation between consumption and private investment; (iii) a SOE investment that is more volatile than private investment; (iv) a negative correlation between consumption and SOE investment; and (v) a weak correlation between private and SOE investment—features that the standard RBC model cannot replicate.

A key result of this paper is the importance of expropriations. The variance decomposition shows that shocks to expropriation efficiency play the main role in generating macroeconomic volatility in China. These shocks account for over 70% of the volatility in consumption and output, and over 60% of private investment volatility.

To evaluate the empirical validity of our model-estimated expropriation series, we conduct three exercises. First, we use a Kalman filter to extract a smoothed time series of expropriations from our model. We then compare this smoothed series with a relatively standard measure of property rights enforcement, the Political Risk (PR) index of the International Country Risk Guide, used extensively in the literature (Knack and Keefer, 1995; Mauro, 1995; Hall and Jones, 1999; Acemoglu et al., 2003; Angelopoulos et al., 2011). We find that the correlation between the two series is positive, equal to

endogenous. The assumption of using labor is in line with the evidence in China presented in Section 2.

0.57.

Second, we investigate the role of expropriations after 2012, when President Xi Jinping rose to power with reducing corruption as his priority. To do this, we estimate the model before and after 2012, using the same set of prior distributions. We find that expropriations are still the main driver of macroeconomic volatility in the earlier period, but no longer in the latter one, during which they account for less than 10% of the volatility in consumption and output, and for less than 15% of the volatility in private investment, consistent with the evidence of the anti-corruption campaign's effectiveness provided by Hao et al. (2020) and Tao (2020). In the post-2012 period, private TFP shocks become the main driver of aggregate volatility.

Lastly, we estimate our model using U.S. data. Given the strong institutional framework in the U.S., this exercise serves as a placebo test. As such, finding a similar role of expropriations to that in China would be discouraging. This is, however, not the case. Expropriations in the U.S. are small, almost one eighth of those in China, and account for a minor fraction of aggregate fluctuations. Moreover, introducing expropriations in the U.S. does not considerably affect the fit of the model compared to the standard RBC model.

This paper is closely related to Angelopoulos et al. (2011), who study the effects of weak property rights protection on business cycle fluctuations in Mexico. The main difference between our setup and theirs is that expropriations are exogenous in their model. We endogenize expropriations for three reasons. First, there is empirical evidence supporting the fact that a firm's value affects the incentives to expropriate in China. For example, Ding and Lichtenberg (2011) document that the price the government charges for the lease of land to private firms depends greatly on the expected profits of the lessee. Second, the parameters in Angelopoulos et al. (2011) cannot be identified with statistical methods, since TFP and expropriation efficiency shocks are isomorphic: they have qualitatively identical effects on macroeconomic variables. Third, our framework allows us to rebate the proceeds of expropriations back to the households, thereby abstracting from any income effect.[2]

Our paper contributes to a large strand of literature that explores real business cycle properties in developing countries. For example, Neumeyer and Perri (2005) and Uribe and Yue (2006) show

[2]The assumption that the proceeds of expropriations are rebated to households also highlights a main difference between our framework and the literature on investment wedges or investment specific technology shocks such as Chari et al. (2007); Chakraborty and Otsu (2013); Cho and Doblas-Madrid (2013) and Dogan (2019).

that interest rate shocks in developing countries amplify the business cycle; and García-Cicco et al. (2010) show that financial constraints are particularly well-suited to study countries like Mexico and Argentina. Li et al. (2008) and Wang and You (2012) find that while interest rates or financial constraints may be high for some firms, they are not for those with government connections. Song et al. (2011) also argue that the large trade surplus in China is the result of high savings, which makes the case for economy-wide financial constraints hard to defend.[3]

Other studies that examine business cycle properties in developed and developing economies include Aguiar and Gopinath (2007), who introduce productivity trend shocks and find that the trend is much more volatile in developing countries. Restrepo-Echavarria (2014) and Horvath (2018) study the role of the informal economy and find that its size, when mismeasured, amplifies macroeconomic volatility. Chen et al. (2018) find similar effects of home production, and Dogan (2019) of investment specific technologies. Our paper adds to this literature by examining the impact of institutions on aggregate fluctuations in the world's two largest economies. In particular, we show that introducing expropriations not only allows us to account for excess volatility of consumption, but also for other moments unique to China such as the lack of correlation between consumption and investment, and the low comovement between private and SOE investments.

The rest of the paper is organized as follows. Section 2 describes China's institutional framework and property rights protection. Section 3 outlines the model. Bayesian prior and posterior analysis of the parameter values and equilibrium solutions are discussed in Section 4. Section 5 presents the main results. Section 6 conducts three external validation exercises of our model. Section 7 assesses the contribution of different model features. Section 8 concludes.

2 Expropriations in China

While the presence of SOEs has been studied extensively, the modeling of expropriations has been largely overlooked. This section documents that expropriations in China are prevalent, random, depend on firm values, and require the use of resources. Section 3 takes these characteristics into account

[3] In particular, García-Cicco et al. (2010) extract information about financial frictions from trade deficits in Argentina and Mexico. The same method applied to China would result in virtually no frictions, since the trade balance is always positive during our sample period.

to model expropriations.

Expropriations are prevalent. The quality of China's institutions is ranked relatively low according to several indicators (e.g. International Country Risk Guide, International Property Rights Index, the Corruption Perception Index, the World Bank Business Environment and Enterprise Performance Survey). For example, the Property Rights Alliance produces an index of property rights that ranges from 1 to 10, 10 being the strongest enforcement of property rights. In 2017, China scored 5.7, well below the U.S.' score of 8.1.[4]

China's institutional structure is suited for corruption and expropriation, as the public sector controls access to key resources such as land, natural resources, and bank loans. Ding and Lichtenberg (2011), Barboza (2012), and Fang et al. (2019), among others, provide empirical evidence whereby private firms seek close ties with politicians in exchange for economic favors, such as expediting the process of obtaining business operation licenses or permits for expanding existing businesses, reaping tax benefits, and gaining easier access to bank loans, land, and favorable government policies.[5] In addition, the regionally decentralized system, where the central government controls the political issues and the provincial governments are responsible for the economies within their jurisdiction, creates agency problems. Deininger et al. (2019) show how an experiment conducted by the central government to de-regularize the transfer of private property in the Chengdu prefecture to boost productivity led to large increases in expropriations by Chengdu regulators. Local politicians saw an opportunity for rent-seeking in the central government's decision to de-regularize, partly offsetting the benefits of such policy. Finally, Cai et al. (2013) argue that the government's procurement mechanism, a two stage auction, incentivizes corruption: in the first stage, bidders bribe politicians to keep the numbers of competitors low, allowing them to bid under more favorable conditions in the second stage.

Expropriations are random. The uncertain nature of expropriation is highlighted by the various forms it can take, including cash, gifts, entertainment, or a share of firms' stocks and technology.[6]

[4]The high level of corruption in China has been the focus of several recent studies (Svensson, 2005; Li et al., 2008; Cai et al., 2011; Xu, 2011; Wang and You, 2012; Hung et al., 2017; Wei et al., 2017).

[5]As an example, the New York Times' article "Billions Hidden Riches from Family of Chinese Leader" illustrates how jewelry firms gained access to the Chinese retail market by establishing close ties with relatives of China's former Prime Minister Wen Jiabao, who oversees the regulation of firms' entry and exit of that market. https://www.nytimes.com/2012/10/26/business/global/family-of-wen-jiabao-holds-a-hidden-fortune-in-china.html.

[6]The following New York Times article describes how Deutsche Bank engages in these practices: "Inside a

Blustein (2019) argues that municipal governments selectively choose to collect taxes that are unpublished, surprising firms with unexpected tax payments. Fang et al. (2019) show that bureaucratic buyers in China receive an average discount in unit price from real estate developers in the housing market that ranges from 0.69% to 3.72% depending on the empirical model specification.

Expropriations depend on firm values. Cai et al. (2011) illustrate that a firm's value typically determines the amount of payments expropriated. The larger the firm's size, the greater the expropriation payments. Ding and Lichtenberg (2011) describe a large spike of property prices when the central government converts agricultural land to urban use. In particular, the more profitable the businesses interested in leasing the land, the higher the mark-up over acquisition cost.

Expropriations require productive resources. Expropriations are generally carried out through intermediaries ("Zhongjianren" in Chinese), who invest in resources, primarily workers, to build close ties to all levels of the governments in their region ("Guanxi" in Chinese). The intermediaries often establish large networks, and hire workers to seek economic benefits for private firms, and in return, demand payments, similar to lobbying in the U.S. Stevenson (2019) illustrates how Deutsche Bank hired Chinese special consultants with access to politicians, as well as dozens of relatives of the Chinese government officials, to gain access to the Chinese market.

3 The Model

We extend the standard RBC model in four ways. First, there are POEs and SOEs, facing different technology and capital intensity, whose intermediate goods are aggregated into a final good. Second, the model includes delays in the formation of capital for both POEs and SOEs. Third, we introduce politicians, who expropriate a fraction of private firms' values and are subject to expropriation efficiency shocks. Fourth, we introduce government spending shocks to account for the presence of the government, trade surplus, and fluctuations in these variables in China. This assumption ensures that our model estimation is consistent with national accounts data.

Brazen Scheme to Woo China: Gifts, Golf and a $4,254 Wine" (https://www.nytimes.com/2019/10/14/business/deutsche-bank-china.html).

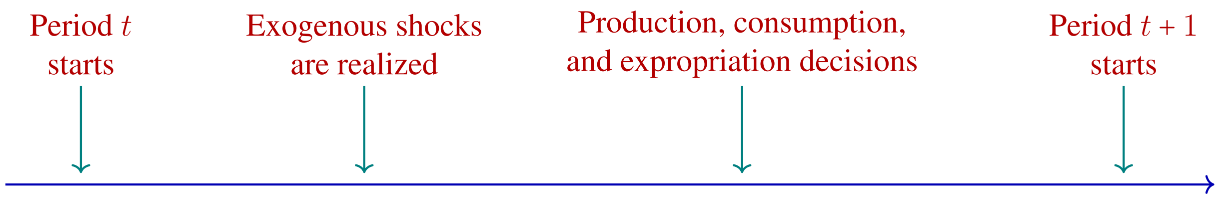

Figure 1: Timing of events

3.1 Timing of Events

The timing of events is illustrated in Figure 1. At the beginning of each period t, shocks to the economy are revealed. These include: (i) shocks to POEs' productivity, z_p; (ii) shocks to SOEs' productivity, z_g; (iii) shocks to the efficiency of expropriations, x; and (iv) shocks to government spending, g. At the end of the period t, politicians and firms make their hiring and investment decisions, and households decide on their consumption and savings.

3.2 Households

There is a representative household maximizing the following expected utility

$$E_t \sum_{t=0}^{\infty} \beta^t u(c_t) \tag{1}$$

subject to the budget constraint

$$c_t + q_t b_{t+1} + \tau_t = w_t + b_t + \pi_t. \tag{2}$$

The utility function assumes the logarithmic form, i.e., $u(c_t) = \log(c_t)$.[7] E_t denotes the expectations operator at time t, $\beta \in (0,1)$ is the household's subjective discount factor, $c_t \geq 0$ is consumption, $w_t \geq 0$ is the real wage, b_{t+1} is bonds purchased by households at price $q_t \geq 0$, π_t is rebated profits from politicians ($\pi_{x,t}$) and private firms ($\pi_{p,t}$), and τ_t is lump-sum taxes. The price of consumption goods is the numeraire, normalized to one.

[7]Note that labor does not enter the utility function. The reason for this is that most changes in employment during this time respond to government policies driving labor out of farms and into urban centers. Yao and Zhu (2020) argue that, as a result, labor is hardly correlated with output in China. Since our model is not designed to capture these changes, we assume the supply of labor is perfectly inelastic.

The optimality conditions for consumption and bond purchases give the standard Euler equation

$$q_t = E_t\left[\frac{\beta u'(c_{t+1})}{u'(c_t)}\right]. \tag{3}$$

3.3 Production

The production in the economy builds on Song et al. (2011). POEs and SOEs produce intermediate goods, $y_{p,t}$ and $y_{g,t}$, which are then combined into a final good, y_t, using the CES aggregator as follows

$$y_t = \left(\psi y_{g,t}^{\frac{\nu-1}{\nu}} + y_{p,t}^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}}, \tag{4}$$

where $\nu > 0$ denotes the elasticity of substitution between the intermediate goods and $\psi > 0$ determines the relative weight of SOE production. A representative firm produces the final good by solving the following static problem every period:

$$\max y_t - p_{g,t}y_{g,t} - p_{p,t}y_{p,t}, \tag{5}$$

where $p_{g,t}$ is the price of the SOE produced good at time t and $p_{p,t}$ is the analogous price for POEs. The first order conditions yield the following relationships between goods' prices and quantities:

$$\frac{y_{g,t}}{y_{p,t}} = \left(\psi\frac{p_{p,t}}{p_{g,t}}\right)^{\nu}, \tag{6}$$

$$1 = [\psi^{\nu}p_{g,t}^{1-\nu} + p_{p,t}^{1-\nu}]^{\frac{1}{1-\nu}}. \tag{7}$$

3.3.1 Private Firms

The private sector consists of a unit measure of identical firms with production function

$$y_{p,t} = e^{z_{p,t}}(k_{p,t}^{\alpha}h_{p,t}^{1-\alpha})^{\theta}, \tag{8}$$

with θ and $\alpha \in (0,1)$, $h_{p,t}$ is labor, $k_{p,t}$ is capital, and $z_{p,t}$ denotes POEs' productivity. Each period, the firm combines labor and capital to produce $y_{p,t}$ units of output. The capital share is $\alpha\theta$, where θ is a scale factor, capturing the degree of decreasing returns to scale to production. We choose this specification, as opposed to constant returns, so that firms in equilibrium generate positive profits, allowing us to model expropriations. $z_{p,t}$ follows a standard first-order autoregressive (AR(1)) process:

$$z_{p,t+1} = \rho_{z_p} z_{p,t} + \epsilon^{z_p}_{t+1}, \quad \epsilon^{z_p}_{t+1} \sim \mathcal{N}(0, \sigma^2_{z_p}), \tag{9}$$

where $\rho_{z_p} \in (0,1)$ is the autocorrelation coefficient and $\epsilon^{z_p}_{t+1}$ is an independently and identically distributed (i.i.d.) shock.[8]

Firms accumulate capital through investment, which is in units of the final good. Capital takes J periods to build, in the spirit of Kydland and Prescott (1982), so that if a project starts in period t, it becomes productive capital in period $t+J$. Each project requires a percentage $\phi_j \geq 0$ of the expense to be incurred in stage j, where $\sum_{j=1}^{J} \phi_j = 1$. Let $d^j_{p,t}$ be the investment incurred j periods before being realized. This implies that $d^j_{p,t+1} = d^{j+1}_{p,t}$ for $j = 1, 2, ..., J-1$. The law of motion for capital, given a depreciation rate $\delta \in [0,1]$, is

$$k_{p,t+1} = (1-\delta) k_{p,t} + d^1_{p,t}. \tag{10}$$

Total investment is the accumulation of investment in all stages, so that

$$i_{p,t} = \sum_{j=1}^{J} \phi_j d^j_{p,t}. \tag{11}$$

Private firms are subject to expropriations. Let $S_t \in [0,1]$ denote aggregate expropriations, i.e., the fraction of a firm's value expropriated in period t. POEs maximize expected profits every period taking as given expropriations and the prices in the economy, which depend on the state variables. We summarize all economy-wide state variables using the vector $M_t = (S_t, D^j_{p,t}, D^j_{g,t}, K_{p,t}, K_{g,t}, z_{p,t}, z_{g,t}, x_t, g_t)$ for $j = 1, \ldots, J-1$, where upper case letters denote the aggregate state variables corresponding to the lower case individual state variables. $D^j_{g,t}$ and $K^j_{g,t}$ denote SOEs' counterparts to $D^j_{p,t}$ and $K^j_{p,t}$, described in detail in section 3.3.2. The POE value function is:

$$\begin{aligned} V_p(k_{p,t}, d^1_{p,t}, \ldots, d^{J-1}_{p,t}, M_t) = \max_{d^J_{p,t}, h_{p,t}} \Bigg[& p_{p,t}(M_t) e^{z_{p,t}} (k^{\alpha}_{p,t} h^{1-\alpha}_{p,t})^{\theta} - w(M_t) h_{p.t} - \sum_{j=1}^{J} \phi_j d^j_{p,t} + \\ & E_t Q(M_t, M_{t+1})(1 - S(M_{t+1})) V_p(k_{p,t+1}, d^1_{p,t+1}, \ldots, d^{J-1}_{p,t+1}, M_{t+1}) \Bigg] \end{aligned} \tag{12}$$

$$\text{subject to} \quad k_{p,t+1} = (1-\delta) k_{p,t} + d^1_{p,t}, d^j_{p,t+1} = d^{j+1}_{p,t}. \tag{13}$$

[8]Notice that while each firm operates a decreasing returns to scale technology, the private sector displays aggregate constant returns to scale technology: doubling the mass of firms, workers, and capital doubles output.

Equation (12) shows that the role of expropriations for firm's behavior is similar to the market discount rate: an expected increase in expropriations leads the firm to discount the future more heavily, which lowers the present value of future profits. Since private firms are owned by the household, they discount future profits using the household's stochastic discount factor, $Q(M_t, M_{t+1}) \equiv \beta u'(c(M_{t+1}))/u'(c(M_t)) = \beta c(M_t)/c(M_{t+1})$, where $c(M_t)$ is the optimal decision rule for consumption given aggregate state M_t.

Notice that $V_{p,t}$ denotes the value function *before* expropriations, implying that firms are maximizing a value that includes payments to politicians. Alternatively, one could define the firm's value net of expropriation as $\hat{V}_{p,t} = V_{p,t}(1 - S_t)$. Maximizing $\hat{V}_{p,t}$ would, however, yield the same solution as maximizing $V_{p,t}$ since for private firms S_t is exogenous and known at time t. Thus, we do not introduce additional notation to denote the value net of expropriations.

The first order conditions of firm's maximization problem determine the amount of labor and capital used in the production:[9]

$$w_t = \theta(1-\alpha)p_{p,t}e^{z_{p,t}}(k_{p,t})^{\theta\alpha}(h_{p,t})^{\theta(1-\alpha)-1}, \tag{14}$$

$$E_t\left\{\underbrace{\phi_J + \sum_{i=1}^{J-1}\phi_{J-i}\left(\prod_{j=1}^{i}Q_{t+j}(1-S_{t+j})\right)}_{\text{Present value of marginal cost of investment}}\right\} = E_t\left\{\underbrace{(1-\delta)\sum_{i=1}^{J}\phi_{J+1-i}\left(\prod_{j=1}^{i}Q_{t+j}(1-S_{t+j})\right)}_{\text{Present value of undepreciated capital}}\right.$$
$$\left. + \underbrace{\left(\prod_{j=1}^{J}Q_{t+j}(1-S_{t+j})\right)\left(\theta\alpha p_{p,t+J}e^{z_{p,t+J}}k_{p,t+J}^{\alpha\theta-1}h_{p,t+J}^{\theta(1-\alpha)}\right)}_{\text{Present value of marginal productivity of capital}}\right\}, \tag{15}$$

where a price with a sub-index t is the value of that price function in period t, e.g., $w_t = w(M_t)$. While equation (14) is standard and sets the marginal productivity of labor equal to its marginal cost, equation (15) needs some explaining. The left hand side of (15) represents the cost of investment, which consists of the cost of obtaining one unit of capital J periods from today. Each period a fraction ϕ_j must be spent. Using $Q_{t+1}(1 - S_{t+1})$ as the effective discount rate, the left hand side denotes the present value of investing in an additional unit of capital. The return, on the right hand

[9] We provide details on the derivation of equation (15) in Appendix E.

side, has two components. First, it includes the present value of marginal productivity of capital J periods from today, taking into account that some of it will be expropriated (in each of the following J periods). Second, the undepreciated capital has a value $(1-\delta)$. This is accrued in J time periods, which assumes that firms can recoup a fraction $(1-\delta)$ of their investments in every stage.

3.3.2 State-Owned Firms

Following Song et al. (2011), SOEs only use capital in their technology and operate with a stand-in firm with constant returns to scale.[10] These firms are owned by the government, so they do not rebate their profits to the household and do not share the household's discount rate. This implies deciding on an exogenous discount rate for SOEs. We assume no discounting for simplicity.[11] Notwithstanding, assuming a discount rate equal to β produces very similar results, as shown in Appendix B.2. Given the government ownership, SOEs are not subject to expropriations.

The SOE production function is given by

$$y_{g,t} = e^{z_{g,t}} A k_{g,t}, \tag{16}$$

where $A > 0$ is a constant, and $z_{g,t}$ is a SOE-specific total factor productivity (TFP), following an AR(1) process:

$$z_{g,t+1} = \rho_{z_g} z_{g,t} + \epsilon^{z_g}_{t+1}, \quad \epsilon^{z_g}_{t+1} \sim \mathcal{N}(0, \sigma^2_{z_g}) \tag{17}$$

where $\rho_{z_g} \in (0,1)$ is the autocorrelation coefficient and $\epsilon^{z_g}_{t+1}$ is an i.i.d. shock.

SOEs' capital evolves in an analogous way to private capital. Specifically, let $d^j_{g,t}$ denote SOE stage-j investment, then $d^j_{g,t+1} = d^{j+1}_{g,t}$, and total SOE investment is $i_{g,t} = \sum_{j=1}^{J} \phi_j d^j_{g,t}$. The law of motion for SOE's capital stock is

$$k_{g,t+1} = (1-\delta) k_{g,t} + d^1_{g,t}. \tag{18}$$

[10] Song et al. (2011) show that the share of SOEs has declined dramatically in Chinese labor-intensive industries, while remaining high in capital-intensive industries. We thereby assume all SOEs are capital intensive.

[11] Appendix E shows that SOE profits are zero in steady state, and fluctuate around zero outside the steady state, implying the SOE value function is bounded.

SOEs solve the following profit-maximizing problem:

$$V_g(k_{gt}, d^1_{g,t}, \ldots, d^{J-1}_{g,t}, M_t) = \max_{d^J_{g,t}} \quad p_g(M_t) A e^{z_{g,t}} k_{g,t} - \sum_{j=1}^{J} \phi_j d^j_{g,t} + E_t V_g(k_{g,t+1}, d^1_{g,t+1}, \ldots, d^{J-1}_{g,t+1}, M_{t+1}) \tag{19}$$

$$s.t. \;\; k_{g,t+1} = (1-\delta) k_{g,t} + d^1_{g,t}, d^j_{g,t+1} = d^{j+1}_{g,t}. \tag{20}$$

The first order condition is

$$E_t p_{g,t+J} A e^{z_{g,t+J}} + 1 - \delta = 1. \tag{21}$$

SOEs equalize the marginal cost of investment, equal to 1 due to no discounting and no expropriations, to marginal productivity of capital plus the value of the undepreciated capital, $1-\delta$. This leaves marginal productivity of capital equal to the depreciation rate.

3.4 Expropriations

There is a measure one of politicians that each period hire workers to expropriate a fraction s_t of a private firm's value. We assume that politicians do not internalize the fact that their actions may affect firm's behavior. To make that clear, we use lower case s_t to denote the expropriation determined by politicians and upper case S_t to denote the expropriation faced by the firm. Since all politicians are identical, in equilibrium $s_t = S_t$ for all t. All proceeds from expropriation are rebated lump sum to the consumer to abstract from income effects and focus on the distortion introduced.

The politicians' expropriation technology is

$$s_t = e^{x_t} h^{\eta}_{g,t}, \quad \eta \in (0,1) \tag{22}$$

where x_t captures the efficiency of expropriation, $h_{g,t}$ is labor used for expropriation, and $1/\eta$ is the elasticity of the cost of extortion. x_t follows a stationary AR(1) process:

$$x_{t+1} = (1-\rho_x)\bar{x} + \rho_x x_t + \epsilon^x_{t+1}, \quad \epsilon^x_{t+1} \sim \mathcal{N}(0, \sigma^2_x) \tag{23}$$

where $\bar{x}$ is the unconditional mean of x_{t+1}, $\rho_x \in (0,1)$ is the autocorrelation coefficient, and ϵ^x_{t+1} is an i.i.d. shock. Note that the larger the $\bar{x}$, the weaker the property rights protection.

Every period, politicians solve:

$$\pi_{x,t} = \max_{s_t, h_{g,t}} s_t V_{p,t} - w_t h_{g,t} \quad \text{subject to} \quad s_t = e^{x_t} h_{g,t}^{\eta}, \tag{24}$$

where $\pi_{x,t}$ denotes expropriation profits and $V_{p,t} \equiv V_p(k_{p,t}, d_{p,t}^1, \ldots, d_{p,t}^{J-1}, M_t)$.

The first order condition determines the optimal s_t given by

$$s_t = e^{\frac{x_t}{1-\eta}} \left(\frac{\eta V_{p,t}}{w_t} \right)^{\frac{\eta}{1-\eta}}. \tag{25}$$

This condition shows that expropriations depend positively on the firm's value and expropriation efficiency. An increase in the wage rate, on the other hand, reduces expropriation, because it increases the cost of labor.

3.5 The Government

Every period, the government spends g_t, which follows an AR(1) process given by

$$\log g_{t+1} = (1 - \rho_g) \log \bar{g} + \rho_g \log g_t + \epsilon_{t+1}^g, \quad \epsilon_{t+1}^g \sim \mathcal{N}(0, \sigma_g^2) \tag{26}$$

where $\rho_g \in (0, 1)$ is the autocorrelation coefficient, $\bar{g}$ is the unconditional mean, and ϵ_{t+1}^g is an i.i.d. government spending shock. These expenditures are used for unproductive activities.[12]

The government balances its budget each period following

$$g_t = \tau_t + \pi_{g,t}, \tag{27}$$

where $\pi_{g,t}$ denotes the profits from SOEs.

[12] Alternatively, one could assume these expenditures are used to increase consumer welfare. There are two problems with this. First, empirically we map g to government expenditures plus net exports. Net exports should not increase welfare. Second, this would require determining the elasticity of substitution between g and c. If this is zero, the results do not change, for example, if the within period utility function is $u(c, g) = log(c) + g$. In Appendix B.2 we consider the case where (part of) g is a perfect substitute to c. The results remain largely unaffected.

3.6 Feasibility

Feasibility conditions yield for all t:

$$c_t + i_{p,t} + i_{g,t} + g_t = y_t \tag{28}$$

$$h_{p,t} + h_{g,t} = 1 \tag{29}$$

$$b_t = 0. \tag{30}$$

Equation (28) denotes goods market clearing: it states that aggregate consumption plus private investment, SOE investment, and government spending equal aggregate output. Equation (29) is the labor market clearing condition: there is a total of one unit of labor that can be employed in production and expropriation. Equation (30) is the bonds market clearing condition, where bonds are in zero net supply.

4 Taking the Model to the Data

We employ Bayesian methods to estimate the model using Chinese quarterly data, except for a few standard structural parameters, which are calibrated. The Bayesian approach is especially useful in our case, because it allows us to identify a number of key structural parameters that cannot be observed directly.

4.1 Data

Our estimation uses the following quarterly data series for the Chinese economy for the 1995Q1–2017Q4 period: output, consumption, total investment, investment by SOEs, investment by POEs, and wage. Data come from Chang et al. (2016), who apply various econometric methods to construct data comparable to the ones used in the U.S. The choice of our data series and sample window is driven by data availability. All variables are seasonally adjusted and in real per capita terms. The data series are detrended using the HP filter with a smoothing parameter equal to 1,600.[13] Appendix A.1 provides a full description of the data, and of the solution and estimation methods.

[13] Sakarya and De Jong (2020) argue that the use of the HP filter is justified when data series are integrated of up to order 2, which is the case in our analysis based on the Augmented Dickey-Fuller and Phillips-Perron tests.

4.2 Calibrated Parameters

We calibrate several standard structural parameters based on the existing literature. Table 1 summarizes the calibrated parameter values. The household's subjective discount factor (β) is set to 0.99. This value implies an average annual real interest rate of about 2.72%, given the inflation rate. The rate of capital depreciation for POEs and SOEs (δ) is 0.03, in line with Bai et al. (2006)'s estimate for the Chinese economy. Consistent with Chen and Wen (2017), we set the degree of decreasing returns to scale (θ) to 0.92. We fix α to 0.47, which implies a share of labor in the production function ($\theta(1-\alpha)$) of 0.49, as in Song et al. (2011). Following Chang et al. (2016), the elasticity of substitution between POEs and SOEs (ν) is set to 2. The share of SOE output in the final output production (ψ) and the scale parameter in the production function of SOEs (A) jointly determine the steady state ratio of POE investment to SOE investment. In fact, since only the product of ψ and A matters, the parameters cannot be identified independently. We normalize $A = 0.001$ and set $\psi = 1.23$ so that the investment ratio in our model equals 2.93 as in the data. The number of stages it takes to complete an investment project, J, is set to 2 for both POEs and SOEs to target the POE and SOE investment to output volatility. While we do not exactly match these numbers, setting $J = 2$ provides the best fit. As in Kydland and Prescott (1982) we assume $\phi_1 = \phi_2 = 1/2$. Table 1 summarizes our calibration strategy.

A key parameter that cannot be identified statistically or calibrated (due to lack of empirical evidence) is the share of labor in expropriation, η. We set $\eta = 1/3$, implying that one third of the proceeds from expropriations goes to workers. We show in Appendix B.3 that the main results are robust to alternative η values.

4.3 Bayesian Estimation

The remaining structural parameters are estimated with Bayesian methods. We choose the priors either by following the existing literature or by setting them to be relatively dispersed. Table 2 reports the prior and posterior distributions of the estimated parameters.

The novel, and perhaps the most interesting, parameters are related to the process governing expropriations: the unconditional mean of expropriation efficiency ($\bar{x}$), and the persistence and volatility

Description	Parameter	Target	Values
Subjective discount factor	β	Annual real interest rate of 2.7%	0.990
Capital depreciation rate	δ	Bai et al. (2006)	0.030
POE returns to scale	θ	Chen and Wen (2017)	0.920
POE capital share	α	POE labor share of 0.49	0.470
Elasticity of substitution	ν	Chang et al. (2016)	2.000
Size of SOEs relative to POEs	ψ	POE to SOE investment ratio of 2.93	1.230
Scale parameter in SOE production	A	Normalization	0.001
Time to build stages	J	Investment to output volatility for POEs (4.3) and SOEs (6.6)	2.000
Fraction of stage j investment	ϕ_j	Kydland and Prescott (1982)	0.500
Expropriation labor share	η	Not targeted (robustness in Appendix B.3)	0.333

Table 1: Calibrated parameters.

of expropriation efficiency (ρ_x and σ_x). The prior for $\bar{x}$ has a uniform distribution bounded between 0.0001 and 0.1, which implies that the prior mean and standard deviation of $\bar{x}$ are 0.05 and 0.0288, respectively. The persistence parameters for all shocks follow a beta prior distribution with mean 0.5 and standard deviation 0.1, in line with Smets and Wouters (2007). This distribution guarantees a positive value for the AR(1) coefficient. The priors for shocks' standard deviations follow an inverse gamma distribution, with the mean and the standard deviation set to 0.05 and infinity, respectively. Since there are more observables than the number of shocks in the model, we introduce, as in García-Cicco et al. (2010), measurement errors to some of the observables to achieve a proper model identification. The prior distributions for all measurement errors are uniform, bounded between 0.0001 and 0.1.

Table 2 presents the estimation results for our baseline model. For comparison purposes, we also report estimation results for a standard RBC model that features a representative constant returns to scale private firm and abstracts from expropriations, SOEs, time-to-build, and government spending shocks.[14] We report the posterior mean and the 5th and 95th percentiles of the posterior distributions obtained using the Metropolis-Hastings sampling algorithm. Results are based on running 2 chains, each with 250,000 draws. We discard the first 125,000 draws as a burn-in.[15]

The unconditional mean of expropriation efficiency ($\bar{x}$) has a posterior mean of 0.07, which,

[14]For the common parameters, we use identical priors and calibrated values in the RBC model as in the baseline model.

[15]Results are obtained using Dynare. Convergence diagnostics are done by comparing pooled and within Monte Carlo Markov Chain (MCMC) moments, which is based on the method proposed by Brooks and Gelman (1998). We also conduct the identification test using the method proposed by Iskrev (2010). Detailed results are available upon request.

Parameter description		Prior distribution	Posterior distribution	
			Standard RBC	Baseline model
Mean expropriation efficiency	$\bar{x}$	U(0.0500, 0.0288)	–	0.0714
			–	[0.0697, 0.0731]
Persistence: POE productivity	ρ_{z_p}	B(0.5000, 0.1000)	0.7120	0.6220
			[0.5935, 0.8272]	[0.5461, 0.6959]
Persistence: expropriation efficiency	ρ_x	B(0.5000, 0.1000)	–	0.9211
			–	[0.8852, 0.9544]
Persistence: SOE productivity	ρ_{z_g}	B(0.5000, 0.1000)	–	0.2043
			–	[0.1066, 0.3220]
Persistence: government spending	ρ_g	B(0.5000, 0.1000)	–	0.6968
			–	[0.5965, 0.7938]
Standard deviation: POE productivity	σ_{z_p}	IG(0.0500, ∞)	0.0061	0.0077
			[0.0065, 0.0090]	[0.0064, 0.0089]
Standard deviation: expropriation efficiency	σ_x	IG(0.0500, ∞)	–	0.0291
			–	[0.0219, 0.0371]
Standard deviation: SOE productivity	σ_{z_g}	IG(0.0500, ∞)	–	0.0213
			–	[0.0107, 0.0337]
Standard deviation: government spending	σ_g	IG(0.0500, ∞)	–	0.0396
			–	[0.0338, 0.0455]
Measurement errors				
investment	σ_I^{me}	U(0.0500, 0.0288)	0.0384	0.0076
			[0.0329, 0.0442]	[0.0065, 0.0088]
wage	σ_w^{me}	U(0.0500, 0.0288)	0.0271	0.0257
			[0.0232, 0.0313]	[0.0220, 0.0296]

Table 2: Prior and posterior distribution of estimated parameters for China. For the prior distribution, U represents uniform distribution, B represents beta distribution, IG represents inverse gamma distribution. The numbers in parentheses denote prior mean and standard deviation. For the posterior distribution, we report the mean, as well as the 5th and 95th percentiles in brackets.

according to equation (25) and given the value of other parameters and variables, implies that 3.87% of the firm's value is expropriated in steady state. The persistence of the expropriation efficiency process is 0.92, while the standard deviation is 0.03. To put these in context, we compare them to the estimates for the private productivity process that share the same priors. The posterior estimates of the productivity persistence and standard deviation are 0.62 and 0.008, respectively. Thus, the expropriation efficiency process is more persistent and more volatile than POE productivity. In other words, "surprises" in expropriations are more common than in TFP, and are more likely to last.

A noteworthy result is that the estimated values for the POE productivity process ρ_{z_p} and σ_{z_p} are fairly similar between the standard RBC and baseline models, suggesting that introducing expropriations does not really affect the productivity estimates. In fact, the 95% posterior credible intervals for ρ_{z_p} and σ_{z_p} under the baseline and standard RBC models overlap. Thus, the generated moments by our baseline model differ from those of the standard RBC model mainly because of the dynamics in the economy, not because of different underlying private TFP processes.

5 Results

We present our results as follows. Section 5.1 describes the differences between the standard RBC and baseline model in generating business cycle moments. Section 5.2 presents our main results showing that most of the business cycle fluctuations in China are driven by the expropriation efficiency shocks. Section 5.3 discusses the intuition behind the model's fit through the lens of impulse response functions.

5.1 Evaluation of Business Cycle Moments

To evaluate our model's performance in terms of its ability to reproduce business cycle properties of the Chinese economy, we compare the model-generated second moments with those of the data. We focus on five main macroeconomic variables: output (y), consumption (c), private investment (i_p), SOE investment (i_g), and wages (w). Table 3 reports the results.

The baseline model with expropriations outperforms the standard RBC model in most dimensions. In particular, a feature of the Chinese economy that is also present in many developing countries is more volatile consumption than output. The mechanism we propose complements existing studies that introduce financial constraints or stochastic productivity trends to explain the relatively high volatility of consumption in developing countries (Aguiar and Gopinath, 2007; Uribe and Yue, 2006). While financial constraints may also be important for many Chinese firms, the case for widespread financial constraints is hard to defend. First, SOEs do not seem to be financially constrained. Second, studies typically use information on trade deficits to estimate the degree of financial constraints, under the assumption that they are exacerbated by larger deficits. China has had trade surpluses during our sample period. With regards to stochastic trends, the lack of long-run national accounts data would render the estimation of the stochastic productivity trends in China uninformative, as highlighted by García-Cicco et al. (2010).[16]

[16] In addition, the main changes in trends in China are likely to have happened prior to 1995, when our data start. China started a process to regain access to the rest of the world in the 1980s. For example, the negotiations to enter the World Trade Organization started in 1986.

Moments	Data	Baseline	Standard RBC
$\sigma(c)/\sigma(y)$	1.672	1.285	0.491
$\sigma(i_p)/\sigma(y)$	4.281	4.760	2.413
$\sigma(i_g)/\sigma(y)$	6.603	5.385	–
$\sigma(w)/\sigma(y)$	3.009	0.800	1.000
$\rho(y, c)$	0.269	0.689	0.616
$\rho(y, i_p)$	0.149	0.629	0.954
$\rho(y, i_g)$	-0.105	0.181	–
$\rho(c, i_p)$	-0.001	0.052	0.352
$\rho(c, i_g)$	-0.359	-0.181	–
$\rho(i_p, i_g)$	0.256	0.173	–
$\rho(w, y)$	-0.180	0.743	1.000
$\rho(w, c)$	0.216	0.938	0.616
$\rho(w, i_p)$	-0.005	0.082	0.954
$\rho(w, i_g)$	0.169	-0.098	–
$\rho(y)$	0.829	0.917	0.796
$\rho(c)$	0.803	0.942	0.991
$\rho(i_p)$	0.615	0.842	0.729
$\rho(i_g)$	0.779	0.046	–
$\rho(w)$	0.737	0.889	0.796

Table 3: Moments: data, baseline, and standard RBC model. The standard deviations of real GDP from the data, baseline model, and the standard RBC model are 0.82, 2.40, and 2.15, respectively. $\sigma(x)$ denotes the standard deviation of x in percentages. $\rho(x)$ denotes the autocorrelation of x. $\rho(x, y)$ is the contemporaneous correlation between x and y.

A second feature that the standard RBC model fails to match is the lack of investment correlation with consumption and output. Other studies on China's business cycles also have difficulties replicating the lack of co-movement between the two variables (He et al., 2009; Chakraborty and Otsu, 2013). Our baseline model accounts for the weak correlation between consumption and POE investment and for the negative correlation between consumption and SOE investment. Moreover, the baseline model successfully generates low correlations between output and SOE investment, and between POE and SOE investment, all distinct business cycle features of the Chinese economy.

Our model, however, cannot replicate the low correlation between output and consumption, where our results are similar to those of the standard model. We fall short in accounting for the low correlation between output and private investment, although in this case the baseline model generates a correlation that is considerably closer to the data. Also, we do not improve over the standard RBC model in terms of autocorrelations and output volatility.[17] Lastly, both our model and the stan-

[17]We experimented with bringing the model-generated output volatility closer to its data counterpart by calibrating σ_z

	Private TFP shock	Expropriation shock	SOE TFP shock	Government spending shock
c_t	11.88	77.05	0.90	10.17
$i_{p,t}$	19.33	64.64	3.27	12.76
$i_{g,t}$	41.07	25.88	31.58	1.47
y_t	24.19	73.55	0.46	1.80

Table 4: Variance decomposition in percent. The table shows contribution of each shock to variations in consumption (c), POE investment (i_p), SOE investment (i_g), and output (y) under the baseline model.

dard RBC model perform poorly when accounting for the volatility and cyclicality of wages. This is in line with Boz et al. (2015), who show that models without labor market frictions have difficulties capturing the wage rate dynamics.

5.2 Variance Decomposition

The main result of this paper concerns the importance of expropriations in determining macroeconomic volatility. We show this by focusing on variance decompositions, which disaggregate the volatility of each model variable to the different exogenous shocks. Table 4 shows that the main contributor is the expropriation efficiency shocks, accounting for 77% of the volatility in consumption, 65% in POE investment, and 74% in output. The only exception is SOE investment, where the contribution of the expropriation shocks is relatively low, accounting for just over a quarter of its volatility. Private TFP shocks explain a relatively small fraction of aggregate volatility: 12% for consumption, 19% for private investment, and 24% for output. SOE TFP shocks are mostly relevant for SOE investment, accounting for 32% of its volatility. The contribution of government spending shocks is small. These results contrast numerous studies in the literature that attribute most of the macroeconomic volatility in emerging market economies to productivity shocks (García-Cicco et al., 2010; Chang and Fernández, 2013, among others).[18]

and then re-estimating the remaining parameters. This, however, changed the parameter values in a way that led to a very similar output volatility as in the baseline model.

[18]The large explanatory power of the expropriation shocks might indicate that our model is picking up something other than the changes in institutional weakness. Appendix D introduces a labor wedge to capture the impact of other distortions that are not explicitly modeled. The results remain largely unchanged.

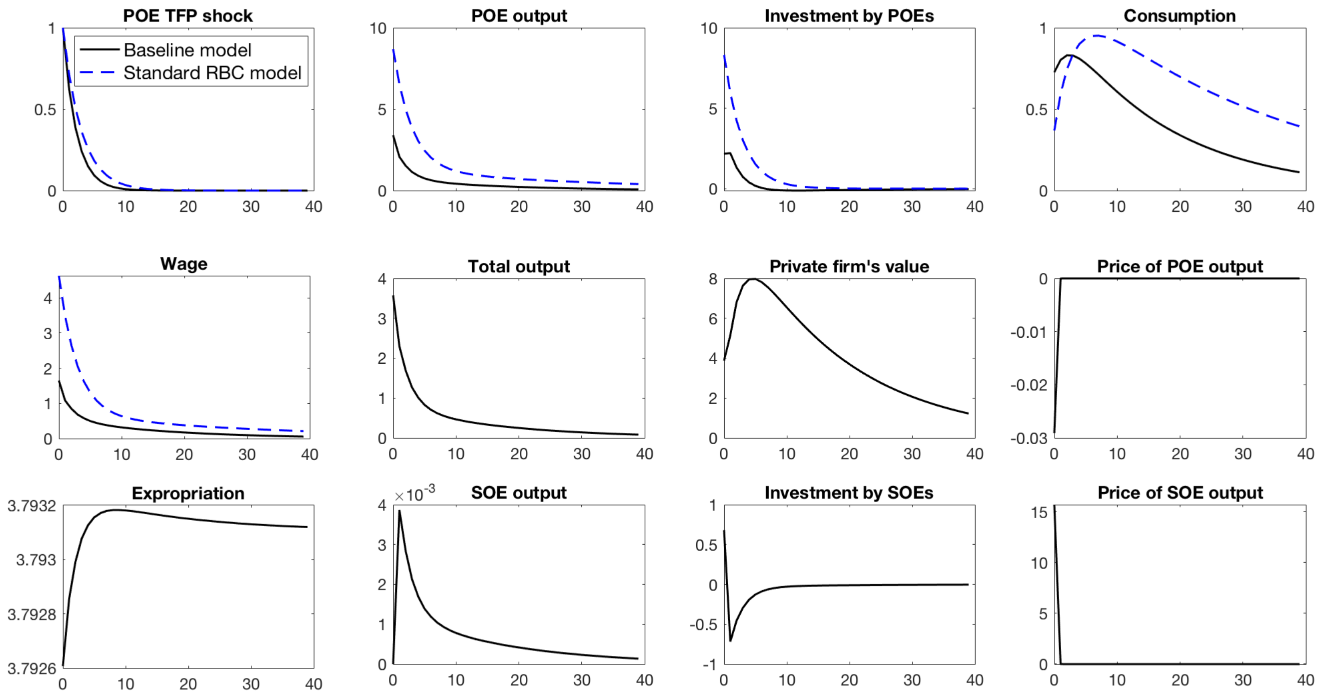

Figure 2: Impulse response to a one percent increase in productivity for POEs. The units on the y-axis are percentage deviations from steady state except expropriation, which is in actual percentage points. The x-axis shows time horizon in quarters.

5.3 Inspecting the Mechanism

This section describes the mechanism that leads our model to account for some of the business cycle features in China. We focus on the impulse responses to private TFP shocks, expropriation efficiency shocks, and SOE TFP shocks, since they are the main drivers of the fluctuations in the model variables. Specifically, Figure 2 displays the responses to a one percent increase in POE TFP, and Figure 3 and Figure 4 show the responses to a one percent increase in expropriation efficiency and SOE TFP. For comparison, in Figure 2 we also add a dashed blue line to denote the responses to an increase in the POE TFP shock in the standard RBC model.

The cyclicality of expropriations. Before delving into the reasons behind our model's fit of the data, it is worth describing some cyclical features of expropriations. In the model, expropriations are countercyclical, exhibiting a negative correlation of –0.66 with total output. Recall that in theory expropriations can be procyclical or countercyclical. An increase in POE TFP (z_p), by increasing private firm's value, increases the incentives to expropriate. It also, however, increases wages, which

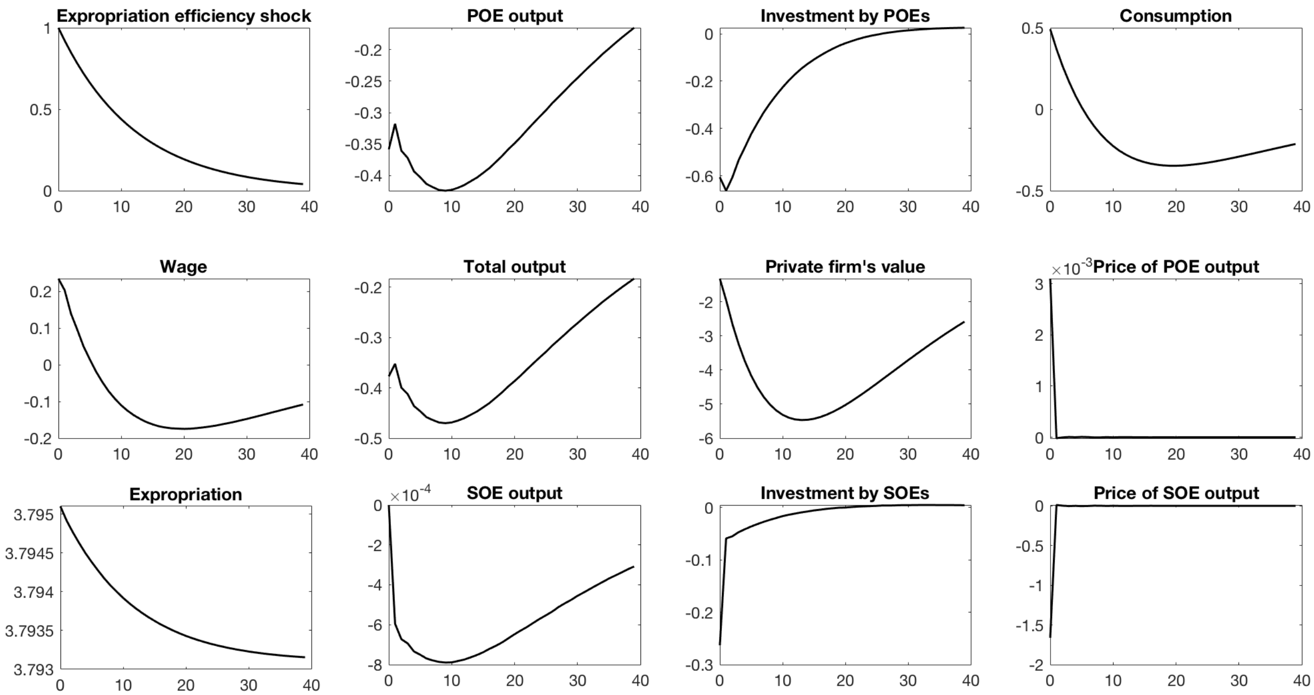

Figure 3: Impulse response to a one percent increase in expropriation efficiency. The units on the y-axis are percentage deviations from steady state except expropriation, which is in actual percentage points. The x-axis shows time horizon in quarters.

reduces the incentives. The negative correlation indicates that the second channel dominates, together with the fact that an increase in expropriation efficiency has a negative impact on investment and output in both sectors, especially for POEs.

Higher volatility of consumption than output. Expropriation efficiency shocks are the main contributor to the excess volatility of consumption. An increase in expropriation efficiency lowers private investment because of higher future expropriations, while increasing consumption. POE output drops because expropriations draw labor away from private production, but this decrease is limited, given that capital does not respond on impact. In addition, SOE output changes little because of its capital intensity. As a result, the change in total output is mild.

Lack of correlation between consumption and private investment. The close-to-zero correlation between consumption and POE investment in the model is mainly a result of two opposite channels. First, an increase in private TFP increases both consumption and private investment, as in the standard RBC model. Second, an increase in expropriations increases consumption at the expense of investment, as explained above. Note that the effects of the private TFP shock are weaker than in

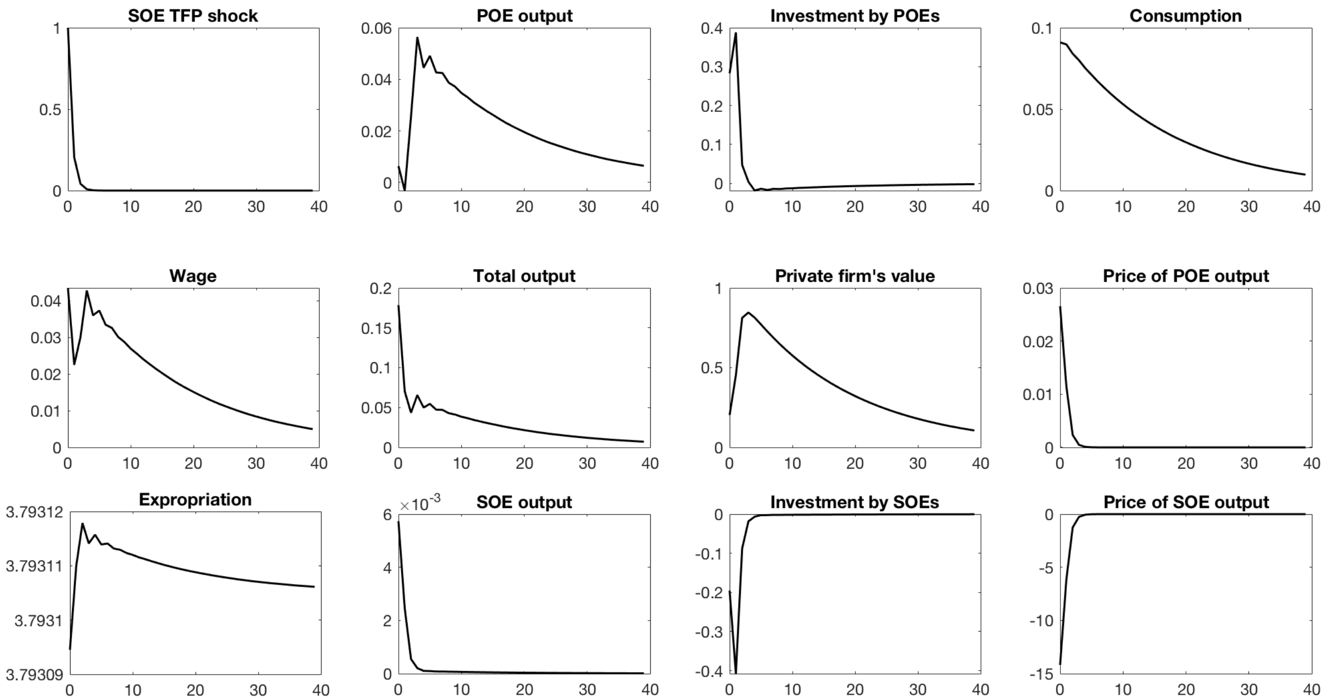

Figure 4: Impulse response to a one percent increase in SOE TFP. The units on the y-axis are percentage deviations from steady state except expropriation, which is in actual percentage points. The x-axis shows time horizon in quarters.

the standard RBC model. The initial response of consumption in the baseline model is about twice as much as that of the standard RBC model, while the reaction of private investment is less than one third. The relatively small increase in private investment is because firms anticipate that, once the wage drops, the rising value of POEs increases expropriations.

Mild correlation between output and POE investment. Our model performs better than the standard RBC model regarding the correlation between output and private investment, although it is still far from the value in the data. The reason for the partial success is that a positive private TFP shock incentivizes higher expropriations in the future, which translates into a smaller increase in investment. This is coupled with the fact that a positive shock to expropriation efficiency further breaks down the positive relationship between output and private investment, since this shock produces a negative comovement between consumption and private investment.

Negative correlation between consumption and SOE investment. A positive shock to SOE TFP (z_g) increases SOE output and reduces the price of the SOE good. The associated wealth effect raises the demand for POE goods, increasing private output and the price of POE goods, as well as aggregate consumption. This shock returns to its steady state relatively fast (since $\rho_{z_g} = 0.2$), and therefore so do the prices, according to equations (7) and (21). Since the elasticity of substitution between POE and SOE production is greater than one ($\nu > 1$), the ratio of SOE production to POE production must adjust faster than the corresponding price ratio, determined by equation (6). To achieve this, capital used in SOE production must fall, so investment in SOEs decreases, explaining the negative correlation.

Weak correlation between SOE and POE investment. POE and SOE investments respond differently to the two types of TFP shocks, which explains the weak correlation between them. As mentioned above, SOE TFP shocks produce a negative correlation between POE and SOE investment. A private TFP shock, on the other hand, raises private investment by increasing the marginal return on capital in equation (15). In turn, the wealth effect increases the demand for SOE output, and thereby boosts SOE investment, generating a positive correlation between private and SOE investment. This positive correlation dominates due to the expropriation efficiency shocks also leading to a positive comovement between POE and SOE investment, as larger expropriations discourage both types of investment.

Oscillating behavior in response to a SOE TFP shock. A distinct feature of these impulse responses to a SOE TFP shock is their oscillating behavior. Rouwenhorst (1991) shows this is typical for models with time to build. To understand why this happens, we focus mainly on POE output. A positive SOE TFP shock increases private output on impact, which falls slightly right after, and then increases considerably. The initial increase is due to the wealth effect, which also increases private investment. The subsequent fall in private output is driven by an increase in expropriations following the higher value of firms, drawing labor away from the POE sector. Investment turns into productive capital in two periods, which is when private output rises.

6 External Validation

Instead of being based on directly observed data, expropriations in our model are constructed from an identification process that results from matching model with data. In this sense, it is worth examining whether our estimates are "empirically plausible." This section performs three exercises to

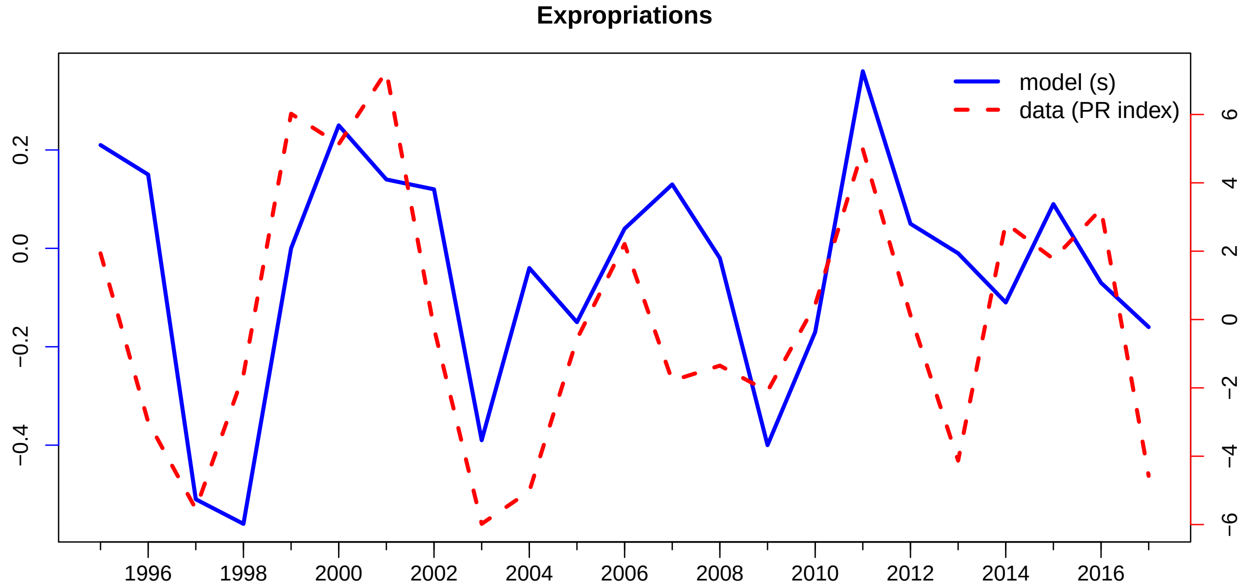

Figure 5: Comparison of model generated expropriations (s) with an empirical measure of expropriations—the cyclical component of the Political Risk index (PR index) from International Country Risk Guide.

this end. First, we produce a smoothed series of expropriations from the model and compare it with a commonly used empirical indicator of property rights. As discussed previously, this indicator has several drawbacks, but, if what our model captures is related to property rights, both series should exhibit similar dynamics. Second, we test our model by asking whether we can observe any changes in the importance of expropriations after 2012, when China's current President Xi Jinping rose to power, implementing a strong anti-corruption campaign. Third, we estimate the model for the U.S. as a placebo test, where expropriations should be much less prevalent given the strong protection of property rights.

6.1 Expropriations: Model versus Data

We use a Kalman filter to produce the smoothed model-generated quarterly time series of expropriations (s).[19] Using end-of-period values we convert it to the same annual frequency as its empirical counterpart. Intuitively, s captures fluctuations in expropriations over the business cycle.

Our empirical measure of expropriations is based on the Political Risk index (PR) provided by the International Country Risk Guide that has been used, among others, by Knack and Keefer (1995);

[19] We first use the command "`estimation`" in Dynare to apply Kalman filter. We then use the command "`shock_decomposition(parameter_set=posterior_mean)`" to extract the time series of s.

Mauro (1995); Hall and Jones (1999); Acemoglu et al. (2001, 2002, 2003); and Angelopoulos et al. (2011). This index assesses the country's political stability by aggregating 12 components such as corruption, democratic accountability, and investment profile. It ranges from 0 to 100, with larger numbers indicating lower political risk, and is available at annual frequency starting in 1984.

We work with $\widetilde{PR} \equiv \log(100 - PR)$, so that a low value indicates a low prevalence of expropriations, as implied by s in our model. We take logs of PR to focus on percentage changes.[20] We obtain a comparable measure of expropriations by HP-filtering $\widetilde{PR}$ with a standard annual smoothing parameter of 6.25, as in Angelopoulos et al. (2011).[21] Figure 5 plots the resulting cyclical component of $\widetilde{PR}$ (red dashed line) together with its model counterpart s (blue solid line). The correlation between the two series is 0.57, which we interpret as evidence that our model does a good job of capturing the salient fluctuations in expropriations over the business cycle.[22]

6.2 The 2012 Anti-Corruption Campaign

In 2012, Xi Jinping took office initiating one of the largest anti-corruption campaigns in Chinese history. Thus, an interesting question is whether our model can capture these changes. To this end, we split the data into two sub-sample periods: 1995Q1–2011Q4 and 2012Q1–2017Q4. We then re-estimate our baseline model using the same priors for both sub-samples. The posterior estimates for the unconditional mean of expropriation efficiency ($\bar{x}$) are 0.0715 and 0.0707, implying that in equilibrium 3.90% of the firm's values are expropriated in the pre-2012 period, while 3.85% of values are expropriated after that, which is not a significant change.[23]

However, the volatility and persistence of the expropriation process differ considerably across the two sub-samples. Our estimation shows that the expropriation process becomes less persistent and the volatility of expropriation efficiency shocks decreases by about 30% in the post-2012 period. This is important, because volatility is a key element of expropriations, since it determines the "surprise" nature of expropriations. To illustrate, if the volatility were zero, expropriations would simply turn into a corporate tax.

[20]Not taking logs of PR produces very similar results.

[21]We detrend $\widetilde{PR}$ because we cannot reject a unit-root null hypothesis based on the Augmented Dickey-Fuller and Phillips-Perron tests.

[22]We obtain very similar results when we compute the correlation between $\widetilde{PR}$ and the Kalman-filtered series for x_t.

[23]The complete sets of posterior estimates for both sub-sampling periods can be found in Appendix B.1.

	1995Q1 - 2011Q4				2012Q1 - 2017Q4			
	ϵ^{z_p}	ϵ^{x}	ϵ^{z_g}	ϵ^{g}	ϵ^{z_p}	ϵ^{x}	ϵ^{z_g}	ϵ^{g}
c_t	13.93	76.40	1.04	8.64	84.99	8.67	0.91	5.43
$i_{p,t}$	21.32	63.07	3.30	12.31	70.67	14.55	3.34	11.43
$i_{g,t}$	40.87	27.48	30.32	1.33	79.44	6.03	13.97	0.56
y_t	28.27	69.71	0.45	1.57	91.43	7.48	0.33	0.76

Table 5: Variance decomposition in percent: before and after 2012. ϵ^{z_p} denotes shock to private firm TFP, ϵ^{x} denotes expropriation efficiency shock, ϵ^{z_g} denotes shock to state-owned firm TFP, and ϵ^{g} denotes government spending shock.

Table 5 compares the variance decomposition of both sub-samples and illustrates the impact of the different estimates. While expropriation efficiency shocks are the most prominent determinants of aggregate volatility before 2012, they play a small role after that, accounting for less than 10% of consumption, SOE investment, and output variance, and for less than 15% of private investment variance. Private productivity shocks become the main driver of aggregate volatility.

This exercise thus finds that the anti-corruption campaign started in 2012 had large effects not on the amount extracted from private firms, but on its uncertainty. In other words, the rules have become clearer, even if the size of the payments to the government has not changed much.

6.3 Expropriations in the U.S. Economy

To estimate the model in the U.S., we first shut down the SOE sector, that is, we set $\psi = 0$. Next, we use the same quarterly data series for the U.S. economy over the 1995Q1 – 2017Q4 period, and use identical prior distributions as those for China. Appendix C provides a full description of the U.S. data, and discusses the choice of calibrated parameter values.

Table 6 reports the posterior estimates for the standard RBC model and our baseline model. The posterior estimate of $\bar{x}$ in the U.S. is 0.02, implying a steady state level of expropriations equal to 0.51% of the value of a firm, which is almost eight times smaller than in China. While the auto-correlation coefficient (ρ_x) is similar to the one in China, the volatility σ_x is greater in the U.S. than in China. However, the small magnitude of expropriations translates into expropriations playing a negligible role for business cycles. This is evident in Table 7, which shows that the fluctuations in the U.S. variables are mostly driven by the productivity shocks. Expropriation efficiency shocks explain less than 4% of the variance in consumption and output, and about 18% of the variance in private investment.

Parameter description		Prior distribution	Posterior distribution	
			Standard RBC	Baseline without SOEs
Mean expropriation efficiency	$\bar{x}$	U(0.0500, 0.0288)	–	0.0173
			–	[0.0164,0.0183]
Persistence: POE productivity	ρ_{z_p}	B(0.5000, 0.1000)	0.9783	0.9443
			[0.9669, 0.9882]	[0.9139, 0.9697]
Persistence: expropriation	ρ_x	B(0.5000, 0.1000)	–	0.8750
			–	[0.7996, 0.9442]
Persistence: government spending	ρ_g	B(0.5000, 0.1000)	–	0.5819
			–	[0.4246, 0.7389]
Standard deviation: POE productivity	σ_{z_p}	IG(0.0500, ∞)	0.0068	0.0069
			[0.0058, 0.0078]	[0.0059, 0.0080]
Standard deviation: expropriation	σ_x	IG(0.0500, ∞)	–	0.0665
			–	[0.0467, 0.0878]
Standard deviation: government spending	σ_g	IG(0.0500, ∞)	–	0.0206
			–	[0.0177, 0.0237]
Measurement errors				
wage	σ_w^{me}	U(0.0500, 0.0288)	0.0098	0.0107
			[0.0084, 0.0113]	[0.0091, 0.0125]

Table 6: Prior and posterior distribution of estimated parameters for the U.S. For the prior distribution, U represents uniform distribution, B represents beta distribution, IG represents inverse gamma distribution. The numbers in parentheses denote prior mean and standard deviation. For the posterior distribution, we report the mean, as well as the 5th and 95th percentiles in brackets.

	Private TFP shock	Expropriation shock	Government spending shock
c_t	95.46	3.52	1.02
$i_{p,t}$	73.29	17.87	8.84
y_t	96.14	3.76	0.10

Table 7: Variance decomposition in percent for the U.S. economy.

These results are in line with several cross-country surveys, which show a much stronger property rights protection in the U.S. than in China. One of the main drawbacks of such indices is that it is hard to compare the numbers beyond qualitative statements: they show that institutions are stronger in the U.S. than in China, but it is difficult to interpret how much stronger. Our results are superior in this sense: they show that, in terms of the value of a firm, expropriations in China are eight times larger than in the U.S.

Table 8 compares the second moments for the baseline model and data in the U.S., together with those generated by a standard RBC model. Our baseline model performs similarly to the standard one. The similar moments between the two U.S. models suggest that there is no harm in applying our model with expropriations to a country with relatively strong property rights.

Moments	Data	Baseline	Standard RBC
$\sigma(c)/\sigma(y)$	0.789	1.051	0.879
$\sigma(i_p)/\sigma(y)$	4.481	3.397	1.964
$\sigma(w)/\sigma(y)$	1.492	1.026	1.000
$\rho(y, c)$	0.874	0.927	0.975
$\rho(y, i_p)$	0.865	0.743	0.866
$\rho(c, i_p)$	0.761	0.476	0.732
$\rho(w, y)$	0.801	0.979	1.000
$\rho(w, c)$	0.816	0.955	0.906
$\rho(w, i_p)$	0.881	0.648	0.860
$\rho(y)$	0.869	0.963	0.983
$\rho(c)$	0.895	0.980	0.992
$\rho(i_p)$	0.936	0.870	0.951
$\rho(w)$	0.859	0.967	0.959

Table 8: Moments: data, standard RBC model, baseline model without SOEs for the U.S. The standard deviations of real GDP in the U.S. from the data, the baseline model, and the standard RBC model are 1.06, 2.72, and 3.96, respectively. $\sigma(x)$ denotes the standard deviation of x in percentage points. $\rho(x)$ denotes the autocorrelation of x. $\rho(x, y)$ is the contemporaneous correlation between x and y.

7 Contribution of Individual Channels

We examine four different variants of our model to evaluate the importance of individual channels. Specifically, we shut down the following channels one at a time: (i) expropriations; (ii) SOEs; (iii) time-to-build; and (iv) government spending shocks. We re-estimate each model using the same prior distributions and parameter calibrations as for the baseline model. We report the posterior estimates in Appendix B.1.

Table 9 presents the results. For comparison purposes, the first two columns reproduce the second moments from the data and the baseline model. The third column shows that the model without expropriations ("No exprop.") performs poorly in matching the second moments in the data. The predicted relative volatility of consumption to output is almost 3 times higher than the one in the data, and the relative volatility of POE investment to output is about half of the one in the data. This counterfactually high relative volatility of consumption is mainly driven by an increase in the persistence of the government spending process, when estimating the model without expropriations. When we shut down expropriations without re-estimating the model, the volatility of consumption relative to output decreases to 1.09, showing that all else equal expropriations amplify the relative

Moments	Data (1)	Baseline (2)	No exprop. (3)	No SOEs (4)	No TTB (5)	No G shock (6)
$\sigma(c)/\sigma(y)$	1.672	1.285	4.809	1.170	1.241	1.241
$\sigma(i_p)/\sigma(y)$	4.281	4.760	2.687	5.059	5.245	4.632
$\sigma(i_g)/\sigma(y)$	6.603	5.385	5.987	–	27.945	4.831
$\sigma(w)/\sigma(y)$	3.009	0.800	1.003	0.873	0.812	0.822
$\rho(y, c)$	0.269	0.689	0.808	0.720	0.672	0.674
$\rho(y, i_p)$	0.149	0.629	0.871	0.588	0.636	0.662
$\rho(y, i_g)$	-0.105	0.181	0.132	–	0.194	0.191
$\rho(c, i_p)$	-0.001	0.052	0.797	0.005	0.103	-0.060
$\rho(c, i_g)$	-0.359	-0.181	0.148	–	-0.053	-0.136
$\rho(i_p, i_g)$	0.256	0.173	-0.157	–	0.302	0.248
$\rho(w, y)$	-0.180	0.743	0.999	0.780	0.785	0.805
$\rho(w, c)$	0.216	0.938	0.808	0.930	0.896	0.932
$\rho(w, i_p)$	-0.005	0.082	0.869	0.073	0.191	0.160
$\rho(w, i_g)$	0.169	-0.098	0.141	–	0.089	-0.105
$\rho(y)$	0.829	0.917	0.906	0.936	0.883	0.894
$\rho(c)$	0.803	0.942	0.993	0.937	0.956	0.955
$\rho(i_p)$	0.615	0.842	0.875	0.841	0.728	0.870
$\rho(i_g)$	0.779	0.046	-0.068	–	-0.081	0.082
$\rho(w)$	0.737	0.889	0.903	0.922	0.872	0.878

Table 9: Moments: data, baseline model, model without expropriations ("No exprop."), model without SOEs ("No SOEs"), model without time-to-build investment technologies ("No TTB"), and model without government spending shocks ("No G shock").

consumption volatility. Overall, the results suggest that expropriations are an important feature for explaining the business cycles of the Chinese economy.

The fourth column ("No SOEs") shows the moments of a model with no SOEs, which are, in general, similar to our baseline model moments. Having SOEs improves the model's ability to predict the relative volatility of consumption to output, POE investment to output, and the procyclicality of consumption, but the model without SOEs performs comparably to our baseline model with respect to other moments.

In column five ("No TTB"), we shut down the time-to-build technology for capital for both POEs and SOEs. The results show that time-to-build is useful in bringing the relative volatility of investment closer to data, especially for SOEs. Without the delays in the formation of capital, the relative volatility of SOE investment to output is about 4 times higher than the one in the data.

The last column of Table 9 ("No G shock") shuts down the government expenditure shock by setting it to its steady state value. The results are fairly similar to our baseline model. The main difference is a lower relative volatility of SOE investment.

In Appendix B.2, we conduct additional exercises, that include government expenditures being rebated back to consumers in order to increase their utility, a process for expropriations that is completely exogenous, an endogenous discount rate for SOEs, and an exogenous SOE discount rate set to β. Overall, our baseline model outperforms all these alternative models, especially for the case of an endogenous discount rate for SOEs, in which the model produces poor results.[24]

8 Conclusion

In this paper we introduce China's institutional structure—expropriations, state-owned enterprises, government spending, and time-to-build investment technology—into a RBC model to study the business cycle properties of the Chinese economy. Expropriations affect macroeconomic variables differently than productivity and government spending shocks. This allows us to identify essential model parameters with Bayesian methods using readily available national accounts data.

Our model closely replicates several distinct features of the Chinese economy, which are difficult to account for with the standard RBC model. In particular, our model accounts for: (i) a volatility of consumption larger than that of output; (ii) a volatility of SOE investment larger than that of POE investment; (iii) a lack of correlation between consumption and private investment; (iv) a negative correlation between consumption and SOE investment; and (v) a weak correlation between private and SOE investment. Moreover, we find that the key driver of the Chinese business cycle dynamics is the risk of expropriation, accounting for a considerably larger fraction of macroeconomic volatility than other shocks in the model.

We conduct three exercises to validate our model. First, the model-generated expropriation series is positively correlated with a commonly used measure of property rights enforcement. Second, we show that the contribution of expropriations to aggregate fluctuations is substantially lower in the post-2012 period, when a major anti-corruption campaign was implemented by the Chinese President to increase the strength of property rights. Third, the role of expropriations in driving macroeconomic

[24]Note that this is an ad-hoc assumption. POEs use the same discount rate as households because they are owned by them. SOEs are, however, owned by the government.

volatility becomes negligible when we apply our model to the U.S., a country with strong property rights protection. The model performs very similarly to the standard RBC model in the U.S., suggesting that there may not be a need for such a model in countries with relatively strong institutions, but it also hints at the fact that there may be no cost associated with using it.

There is a great interest in understanding the effects of the strength of institutions on aggregate fluctuations. A problem, however, is that commonly used measures rely on surveys, which are subjective and may not be available at quarterly frequency or comparable across countries. In addition, the surveys' qualitative nature renders them often inappropriate for quantitative analysis. This study circumvents these problems by matching theory, data, and empirical estimation. We see our approach as a tool that can be applied to many questions involving property rights.

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Declaration of interest

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Appendix A Data Description and Estimation Methods

Appendix A.1 Data Description

Data series used in the estimation for China come from Chang et al. (2016) and are publicly available at the Federal Reserve Bank of Atlanta. We use quarterly data for the 1995Q1–2017Q4 period. Chang et al. (2016) provide detailed methodology of how these data series are constructed. We use the following time series:

- GDP (“NominalGDP”)
- household consumption expenditures (“NominalHHC”)
- private investment (“NominalNonSOEGFCF”+“NominalPrivGFCF”)
- investment by state-owned enterprises (“NominalSOEGFCF”)
- total business investment (“NominalNonSOEGFCF”+“NominalPrivGFCF”+“NominalSOEGFCF”)
- wage (“AvgNominalWage”)
- GDP price deflator (“GDPDeflator”)
- consumer price index (“CPI”)
- investment price index (“GFCFPriceindex”)
- population—economically active working-age individuals aged 16 to 60 (“pop”)

Data for GDP and average wage are converted to real values using the GDP deflator with 2010 as the base year. Consumption series is converted to real consumption using the CPI, while all investment series are converted to real values using the price index for gross fixed capital formation. All data series are expressed in per capita terms, and are transformed to natural logs by

$$obs_t = \log\left(\frac{Data_t}{population}\right), \tag{A.1}$$

where $Data_t$ is the seasonally adjusted data in real terms.

Note that we choose not to use data on employment. The reason is that employment transitioned from agricultural to manufacturing sector over the studied period. This transition did not follow any market-driven incentives. As shown by Chen and Wen (2017) and Chang et al. (2016), most of these changes were due to the government's strategic reforms, justifying our assumption of inelastic labor supply. Yao and Zhu (2020) point out that labor is hardly correlated with output in China, mainly because changes in employment are mostly related to centralized policies driving workers out of agricultural areas and into urban ones. Modeling such changes is beyond the scope of this paper.

Appendix A.2 Estimation Methods

The model is solved using perturbation methods around steady state as in Schmitt-Grohé and Uribe (2004). We use Bayesian methods for the parameter estimation similar to the one used by Smets and Wouters (2007). Specifically, let $p(\theta_{\mathcal{M}}|\mathcal{M})$ denote the density function of priors. The likelihood function describing the density of the observed data can then be written as

$$L(\theta_{\mathcal{M}}|Y_T, \mathcal{M}) \equiv p(Y_T|\theta_{\mathcal{M}}, \mathcal{M}), \tag{A.2}$$

where $\mathcal{M}$ denotes a specific model, $\theta_{\mathcal{M}}$ is the parameters of the model $\mathcal{M}$, $p(.)$ is the probability density function (pdf), and $Y_T = \{y_t\}_{t=1}^{T}$ is the data. Given the model $\mathcal{M}$ and the parameter vector $\theta_{\mathcal{M}}$, the joint posterior distribution of the parameter vector $\theta_{\mathcal{M}}$ for the model $\mathcal{M}$ is obtained by combining the likelihood function for Y_T and the prior distribution of $\theta_{\mathcal{M}}$,

$$p(\theta_{\mathcal{M}}|Y_T, \mathcal{M}) \propto L(\theta_{\mathcal{M}}|Y_T, \mathcal{M})p(\theta_{\mathcal{M}}|\mathcal{M}). \tag{A.3}$$

We estimate the likelihood function with Kalman filter, and then simulate the distribution of the parameter vector $\theta_{\mathcal{M}}$ using Monte-Carlo Markov Chain (MCMC) sampling algorithm. All estimations are done using Dynare.

Appendix B Alternative Model Specifications

This section describes additional exercises with the aim of providing robustness to our analysis. Appendix B.1 describes estimation details for the exercises presented in Sections 6.2 and 7. Appendix

Parameter description		Prior Distribution	1995–2011 Mean [5%, 95%]	2012–2017 Mean [5%, 95%]
Mean expropriation efficiency	$\bar{x}$	U(0.05, 0.0288)	0.0715 [0.0696, 0.0735]	0.0707 [0.0696, 0.0719]
Persistence: POE productivity	ρ_{z_p}	B(0.5, 0.1)	0.6016 [0.5122, 0.6906]	0.8019 [0.7136, 0.8878]
Persistence: expropriation	ρ_x	B(0.5, 0.1)	0.9019 [0.8599, 0.9420]	0.7499 [0.6616, 0.8376]
Persistence: SOE productivity	ρ_{z_g}	B(0.5, 0.1)	0.2315 [0.1172, 0.3507]	0.2044 [0.1133, 0.3058]
Persistence: G spending	ρ_g	B(0.5, 0.1)	0.6383 [0.5108, 0.7624]	0.5610 [0.4115, 0.7066]
Standard deviation: POE productivity	σ_{z_p}	IG(0.05, ∞)	0.0088 [0.0072, 0.0104]	0.0097 [0.0071, 0.0126]
Standard deviation: expropriation	σ_x	IG(0.05, ∞)	0.0357 [0.0258, 0.0468]	0.0249 [0.0156, 0.0351]
Standard deviation: SOE productivity	σ_{z_g}	IG(0.05, ∞)	0.0204 [0.0106, 0.0339]	0.0167 [0.0094, 0.0257]
Standard deviation: G spending	σ_g	IG(0.05, ∞)	0.0428 [0.0355, 0.0503]	0.0307 [0.0217, 0.0415]
Measurement errors				
investment	σ_I^{me}	U(0.05, 0.0288)	0.0088 [0.0072, 0.0104]	0.0013 [0.0009, 0.0017]
wage	σ_w^{me}	U(0.05, 0.0288)	0.0290 [0.0241, 0.0343]	0.0074 [0.0049, 0.0103]

Table B.1: Prior and posterior distribution of estimated parameters for the two sub-sample periods in China. U represents uniform distribution, B represents beta distribution, and IG represents inverse gamma distribution.

B.2 analyzes additional model specifications. Appendix B.3 conducts sensitivity analysis for the share parameter in the expropriation efficiency technology η.

Appendix B.1 Posterior Estimates

Table B.1 reports the prior and posterior distribution of the estimated parameters for the baseline model when we split the data into two sub-sampling periods: (i) 1995Q1–2011Q4, and (ii) 2012Q1 – 2017Q4.

Table B.2 reports the prior and posterior distribution of the estimated parameters for alternative models studied in Section 7, i.e., when we shut down individual model features one at a time. The prior distributions are set to the same ones as in our baseline model. In the model without SOEs, only four macroeconomic series are used for the estimation: GDP, consumption, private investment, and

Parameter	Prior	No exprop.	No SOEs	No TTB	No G shock
	Distribution	Mean	Mean	Mean	Mean
		[5%, 95%]	[5%, 95%]	[5%, 95%]	[5%, 95%]
$\bar{x}$	U(0.05, 0.0288)	–	0.0705	0.0710	0.0718
		–	[0.0683, 0.0726]	[0.0693, 0.0727]	[0.0694, 0.0742]
ρ_{z_p}	B(0.50, 0.10)	0.5592	0.7937	0.5959	0.4838
		[0.4410, 0.6750]	[0.6665, 0.9184]	[0.4715, 0.7156]	[0.3802, 0.5859]
ρ_x	B(0.50, 0.10)	–	0.9170	0.9181	0.9438
		–	[0.8766, 0.9543]	[0.8833, 0.9531]	[0.9126, 0.9730]
ρ_{z_g}	B(0.50, 0.10)	0.2749	–	0.7407	0.2683
		[0.1710, 0.3806]	–	[0.6554, 0.8243]	[0.1667, 0.3752]
ρ_g	B(0.50, 0.10)	0.9868	0.7504	0.7018	–
		[0.9800, 0.9930]	[0.6586, 0.8393]	[0.6074, 0.7899]	–
σ_{z_p}	IG(0.05, ∞)	0.0068	0.0071	0.0074	0.0108
		[0.0058, 0.0078]	[0.0060, 0.0083]	[0.0063, 0.0087]	[0.0091, 0.0125]
σ_x	IG(0.05, ∞)	–	0.0282	0.0225	0.0266
		–	[0.0214, 0.0355]	[0.0168, 0.0284]	[0.0200, 0.0336]
σ_{z_g}	IG(0.05, ∞)	0.0160	–	0.0063	0.0175
		[0.0103, 0.0229]	–	[0.0051, 0.0077]	[0.0110, 0.0253]
σ_g	IG(0.05, ∞)	0.0256	0.0386	0.0400	–
		[0.0209, 0.0307]	[0.0330, 0.0445]	[0.0343, 0.0462]	–
Measurement error					
σ_I^{me}	U(0.05, 0.0288)	0.0395	–	0.0077	0.0076
		[0.0337, 0.0455]	–	[0.0066, 0.0088]	[0.0065, 0.0087]
σ_w^{me}	U(0.05, 0.0288)	0.0272	0.0258	0.0265	0.0240
		[0.0233, 0.0313]	[0.0220, 0.0298]	[0.0226, 0.0305]	[0.0206, 0.0276]

Table B.2: Prior and posterior distributions of estimated parameters for alternative model specifications for the Chinese economy. $\bar{x}$ is unconditional mean of expropriation efficiency. ρ_{z_p} and σ_{z_p} are the persistence and standard deviation for TFP shock to POEs, respectively. ρ_x and σ_x are the persistence and standard deviation for expropriation efficiency shock, respectively. ρ_{z_g} and σ_{z_g} are the persistence and standard deviation for TFP shock to SOEs, respectively. ρ_g and σ_g are the persistence and standard deviation for government spending shock, respectively. σ_I^{me} is the measurement error for total investment, while σ_w^{me} is the measurement error for wage.

wage. Therefore, only one measurement error, for wage, is used to achieve identification. Overall, the posterior estimates pertaining to the expropriation efficiency process $(\bar{x}, \rho_x, \sigma_x)$ are similar across the alternative models, implying prevalent expropriations associated with persistent and volatile shocks to expropriation efficiency.

Appendix B.2 Extensions

We conduct the following extensions of our baseline model. We consider a model: (i) when part of the government expenditures is used to produce goods that increase the utility of households ("Public goods"); (ii) with exogenous expropriations ("Exogenous s"); (iii) with an endogenous discount rate for SOEs equal to the household's stochastic discount factor $Q(M_t, M_{t+1})$ ("SOE discount"); and (iv) with a constant discount rate equal to β for SOEs ("β discount"). For comparison purposes, we

Parameter	Prior Distribution	Public goods Mean [5%, 95%]	Exogenous s Mean [5%, 95%]	SOE discount Mean [5%, 95%]	β discount Mean [5%, 95%]
$\bar{x}$	U(0.05, 0.0288)	0.0718	–	0.0743	0.0712
		[0.0696, 0.0741]	–	[0.0690, 0.0803]	[0.0693, 0.0731]
ρ_{z_p}	B(0.50, 0.10)	0.6219	0.5254	0.9716	0.6364
		[0.5421, 0.6978]	[0.3948, 0.6472]	[0.9516, 0.9884]	[0.5557, 0.7123]
ρ_x	B(0.50, 0.10)	0.9307	0.6799	0.9725	0.9232
		[0.8953, 0.9648]	[0.5728, 0.7878]	[0.9507, 0.9901]	[0.8880, 0.9560]
ρ_{z_g}	B(0.50, 0.10)	0.2097	0.2599	0.8016	0.2107
		[0.1124, 0.3278]	[0.1613, 0.3660]	[0.7008, 0.9179]	[0.0810, 0.3268]
ρ_g	B(0.50, 0.10)	0.6224	0.7278	0.8719	0.7178
		[0.5155, 0.7235]	[0.6214, 0.8265]	[0.8281, 0.9121]	[0.6213, 0.8115]
σ_{z_p}	IG(0.05, ∞)	0.0078	0.0072	0.0068	0.0077
		[0.0066, 0.0099]	[0.0061, 0.0083]	[0.0058, 0.0078]	[0.0065, 0.0089]
σ_x	IG(0.05, ∞)	0.0260	0.1196	0.0156	0.0286
		[0.0193, 0.0331]	[0.0677, 0.1781]	[0.0127, 0.0185]	[0.0217, 0.0359]
σ_{z_g}	IG(0.05, ∞)	0.0207	0.0162	0.0466	0.0217
		[0.0106, 0.0331]	[0.0101, 0.0236]	[0.0338, 0.0596]	[0.0102, 0.0373]
σ_g	IG(0.05, ∞)	0.0400	0.0396	0.0378	0.0388
		[0.0342 0.0463]	[0.0340, 0.0455]	[0.0319, 0.0439]	[0.0331, 0.0446]
Measurement errors					
σ_I^{me}	U(0.05, 0.0288)	0.0076	0.0076	0.0115	0.0077
		[0.0065, 0.0087]	[0.0065, 0.0088]	[0.0099, 0.0133]	[0.0065, 0.0089]
σ_w^{me}	U(0.05, 0.0288)	0.0283	0.0272	0.0260	0.0259
		[0.0242, 0.0326]	[0.0233, 0.0314]	[0.0222, 0.0301]	[0.0221, 0.0229]

Table B.3: Prior and posterior distributions of estimated parameters for alternative model specifications for the Chinese economy. $\bar{x}$ is unconditional mean of expropriation efficiency. ρ_{z_p} and σ_{z_p} are the persistence and standard deviation for TFP shock to POEs. ρ_x and σ_x are the persistence and standard deviation for expropriation efficiency shocks. ρ_{z_g} and σ_{z_g} are the persistence and standard deviation for TFP shock to SOEs. ρ_g and σ_g are the persistence and standard deviation for government spending shock. σ_I^{me} is the measurement error for total investment, while σ_w^{me} is the measurement error for wage.

re-estimate each model with the same prior distributions and parameter calibrations as in the baseline model, and report the estimation results in Table B.3. The corresponding second moments are shown in Table B.4.

In our baseline model, government expenditures do not increase household utility. This section relaxes this assumption. To do so, one must first determine how these public goods enter the utility function. On one extreme, if utility is additive in public and private goods, the results of our analysis would remain unchanged. For example, if the within period utility function is $u(c, g) = \log(c) + g$. Here, we take the opposite extreme in which public goods are perfect substitutes with private goods.

Given that we proxy g in the model with the sum of government expenditures and net exports, we assume that only a fraction $\chi \in (0, 1)$ of goods g are perfect substitutes to consumption. This

Moments	Data (1)	Baseline (2)	Public goods (3)	Exogenous s (4)	SOE discount (5)	β discount (6)
$\sigma(c)/\sigma(y)$	1.672	1.285	1.367	1.629	1.197	1.245
$\sigma(i_p)/\sigma(y)$	4.281	4.760	4.581	6.571	3.523	4.745
$\sigma(i_g)/\sigma(y)$	6.603	5.385	5.221	9.304	26.182	5.593
$\sigma(w)/\sigma(y)$	3.009	0.800	0.775	1.009	0.915	0.799
$\rho(y,c)$	0.269	0.689	0.652	0.608	0.904	0.705
$\rho(y,i_p)$	0.149	0.629	0.639	0.402	0.532	0.636
$\rho(y,i_g)$	-0.105	0.181	0.185	0.124	0.059	0.177
$\rho(c,i_p)$	-0.001	0.052	-0.016	0.018	0.398	0.049
$\rho(c,i_g)$	-0.359	-0.181	-0.193	-0.102	-0.016	-0.150
$\rho(i_p,i_g)$	0.256	0.173	0.184	-0.025	-0.325	0.281
$\rho(w,y)$	-0.180	0.743	0.801	0.999	0.965	0.765
$\rho(w,c)$	0.216	0.938	0.893	0.605	0.956	0.938
$\rho(w,i_p)$	-0.005	0.082	0.122	0.397	0.404	0.098
$\rho(w,i_g)$	0.169	-0.098	-0.076	0.140	0.055	-0.082
$\rho(y)$	0.829	0.917	0.921	0.660	0.971	0.921
$\rho(c)$	0.803	0.942	0.911	0.749	0.919	0.944
$\rho(i_p)$	0.615	0.842	0.867	0.614	0.551	0.845
$\rho(i_g)$	0.779	0.046	0.053	-0.027	0.001	0.047
$\rho(w)$	0.737	0.889	0.796	0.893	0.959	0.892

Table B.4: Business cycle moments: data, baseline, and alternative model specifications.

addresses the fact that only government expenditures can constitute public goods, while net exports cannot. More specifically, the within period utility function becomes $u(c,g) = \log(c_t + \chi g_t)$, and we set $\chi = 2/3$ since this is the share of government expenditure in its sum with net exports.

The third column in Table B.4 ("Public goods") shows the second moments generated by this model. The moments are, in general, similar to the ones from our baseline model. However, supplying public goods to households slightly improves the relative volatility of consumption to output. The relative standard deviation of consumption to output is 1.367, a bit closer to the one in the data. Further, the correlations between consumption and investment in both sectors, and the autocorrelation of consumption, become more in line with the data. Thus, our assumption of "throwing government expenditures to the ocean" is a conservative one; a more serious analysis of the complementarity between public and private goods could further improve our results, but is beyond the scope of this paper.

The fourth column ("Exogenous s") sets $\eta = 0$, which makes the expropriation process exogenous. This is at odds with the evidence provided in Section 2, where we argue that the probability of a firm being expropriated depends positively on its value. An additional problem of this model is its inability in empirically identifying the unconditional mean of expropriation efficiency ($\bar{x}$), a key parameter in our baseline model. The Bayesian estimation cannot identify $\bar{x}$, so we set it such that in steady state expropriations are the same as in our baseline for comparison purposes. The reason for the lack of identification is because of the similar effects of a drop in private TFP and an increase in expropriation efficiency. In fact, in Angelopoulos et al. (2011), who assume an exogenous expropriation process, TFP and expropriations are isomorphic, preventing the identification via estimation. While we make different modeling assumptions that imply these are not perfectly isomorphic, the effects are similar enough to prevent the identification of $\bar{x}$.

This variant of the model fails to replicate the relative volatility of investment to output in both sectors, predicting volatilities that are much higher than their data counterparts. It also produces a wrong sign for the correlation between private and public investment. The model, however, does somewhat better in predicting the correlation between output and private investment.

In column five ("SOE discount"), we endogenize the discount factor for SOEs, and assume that SOEs, analogously to POEs, discount their future values using the household's stochastic discount factor $Q(M_t, M_{t+1})$. Note that this is still an ad hoc assumption. POEs need to use the same discount rate as households, because they are owned by them, but SOEs are owned by the government. Still, the exercise is a useful robustness check. This variant performs poorly in a number of dimensions, suggesting that an exogenous discount factor for SOEs is an important feature in matching the business cycle moments for China.

In the last experiment ("β discount"), we set the discount rate to β, instead of one, to evaluate the sensitivity of our baseline model's prediction with respect to SOE's discount rate. Table B.4's sixth column reports the results. The second moments predicted by this model are very similar to our baseline model, suggesting that our model's performance is not sensitive to the values of the discount rate used for the public sector firms.

Moments	Data (1)	Baseline (2)	η = 1/4 (3)	η = 2/3 (4)
$\sigma(c)/\sigma(y)$	1.672	1.285	1.334	1.137
$\sigma(i_p)/\sigma(y)$	4.281	4.760	5.013	4.071
$\sigma(i_g)/\sigma(y)$	6.603	5.385	5.501	5.263
$\sigma(w)/\sigma(y)$	3.009	0.800	0.836	0.742
$\rho(y,c)$	0.269	0.689	0.696	0.684
$\rho(y,i_p)$	0.149	0.629	0.586	0.749
$\rho(y,i_g)$	-0.105	0.181	0.176	0.190
$\rho(c,i_p)$	-0.001	0.052	0.018	0.168
$\rho(c,i_g)$	-0.359	-0.181	-0.175	-0.200
$\rho(i_p,i_g)$	0.256	0.173	0.178	0.138
$\rho(w,y)$	-0.180	0.743	0.848	0.225
$\rho(w,c)$	0.216	0.938	0.922	0.807
$\rho(w,i_p)$	-0.005	0.082	0.177	-0.317
$\rho(w,i_g)$	0.169	-0.098	-0.027	-0.341
$\rho(y)$	0.829	0.917	0.911	0.929
$\rho(c)$	0.803	0.942	0.934	0.969
$\rho(i_p)$	0.615	0.842	0.829	0.882
$\rho(i_g)$	0.779	0.046	0.048	0.029
$\rho(w)$	0.737	0.889	0.887	0.892

Table B.5: Business cycle moments: data, baseline, different values for η. For the baseline model, η = 1/3.

Appendix B.3 Sensitivity to η

Given the lack of empirical evidence for the parameter that governs the share of labor in the expropriation efficiency technology (η), we experiment with different values of η in this subsection. Table B.5 presents the results. Column 2 reports again our baseline results for convenience, and columns 3 and 4 present the second moments when η is set to 1/4 and 2/3, respectively. For comparison purposes, we keep all parameter values the same as the ones in the baseline specification except η. Overall, Table B.5 reveals that our main results are robust to alternative η values.

Appendix C Applying the Model to the U.S.

We calibrate a number of standard structural parameters to ensure that the implied steady state values of the model economy are consistent with the U.S. data. Table C.1 summarizes the calibrated parameter values. The discount factor for household (β) is set to 0.99, together with the annual inflation rate of 2%, to match an annualized 4% nominal risk-free interest rate. The rate of depreciation for capital

Description	Parameter	Target	Value
Subjective discount factor	β	Annual nominal interest rate of 4%	0.990
Capital depreciation rate	δ	Annual depreciation rate of 10%	0.025
POE capital share	α	Investment to GDP ratio of 13%	0.239
POE returns to scale	θ	Same as for China	0.920
Time to build stages	J	Same as for China	2.000
Fraction of stage j investment	ϕ_j	Same as for China	0.500
Expropriation labor share	$1/\eta$	Same as for China	0.333

Table C.1: Calibrated parameters for the U.S. economy.

stock (δ) is set to 0.025, a standard value in the literature when not considering residential investment, producing an annual depreciation rate of 10%. The share of capital in the production function (α) is calibrated to 0.239 to match the investment to GDP ratio of 0.13 for the U.S. economy during the sample period (excludes residential investment). Since there are no empirical estimates for the degree of decreasing returns to scale (θ), and the share of labor in the expropriation technology (η), we consider the same values as for the Chinese economy. Our quantitative results are robust to reasonable changes in these parameter values.

The data series used in the estimation for the U.S. economy come from the Federal Reserve Bank of St. Louis (FRED). For comparison purposes, we keep sample periods the same as in the Chinese case. Thus, the estimation uses quarterly data from 1995Q1 to 2017Q4. All data are seasonally adjusted and in real per capita terms with 2012 as base year. Four series for the U.S. economy are used: GDP (“GDP”), personal consumption expenditures (“PCE”), private non-residential fixed investment (“PNFI”), and wage (“A4102C1Q027SBEA”). We use comparable data series (except for the SOE investment series) and convert the nominal series into real terms in the same way as for China. Specifically, both GDP and wage are turned into real series by using the GDP deflator (“GDPDEF”). The consumption series is converted to real terms using PCE price index (“PCEPI”). The investment series is converted to real terms using the investment deflator (“GPDIdefl”). The population series used to transform the data in per capita terms is working age population aged 15 to 64 (“LFWA64TTUSM647S”).

Parameter description		Prior distribution	Posterior distribution
Mean expropriation efficiency	$\bar{x}$	U(0.0500, 0.0288)	0.0715
			[0.0694, 0.0736]
Persistence: POE productivity	ρ_{z_p}	B(0.5000, 0.1000)	0.6141
			[0.5451, 0.6923]
Persistence: expropriation efficiency	ρ_x	B(0.5000, 0.1000)	0.9211
			[0.8869, 0.9550]
Persistence: SOE productivity	ρ_{z_g}	B(0.5000, 0.1000)	0.2022
			[0.1116, 0.3056]
Persistence: government spending	ρ_g	B(0.5000, 0.1000)	0.7194
			[0.6224, 0.8139]
Persistence: labor wedge	ρ_{Δ_h}	B(0.5000, 0.1000)	0.7214
			[0.6225, 0.8156]
Standard deviation: POE productivity	σ_{z_p}	IG(0.0500, ∞)	0.0085
			[0.0072, 0.0098]
Standard deviation: expropriation efficiency	σ_x	IG(0.0500, ∞)	0.0288
			[0.0218, 0.0362]
Standard deviation: SOE productivity	σ_{z_g}	IG(0.0500, ∞)	0.0207
			[0.0111, 0.0324]
Standard deviation: government spending	σ_g	IG(0.0500, ∞)	0.0394
			[0.0337, 0.0454]
Standard deviation: labor wedge	σ_{Δ_h}	IG(0.0500, ∞)	0.0212
			[0.0182, 0.0244]
Measurement errors			
investment	σ_I^{me}	U(0.0500, 0.0288)	0.0076
			[0.0065, 0.0087]

Table D.1: Prior and posterior distribution of estimated parameters for the model with a labor wedge. $\bar{x}$ is unconditional mean of expropriation efficiency. ρ_{z_p} and σ_{z_p} are the persistence and standard deviation for TFP shock to POEs. ρ_x and σ_x are the persistence and standard deviation for expropriation efficiency shocks. ρ_{z_g} and σ_{z_g} are the persistence and standard deviation for TFP shock to SOEs. ρ_g and σ_g are the persistence and standard deviation for government spending shock. ρ_{Δ_h} and σ_{Δ_h} are the persistence and standard deviation for shock to labor wedge. σ_I^{me} is the measurement error for total investment.

Appendix D Introducing Wedges

The large explanatory power of the expropriation shocks for macroeconomic volatility in China might indicate that the shocks are capturing something other than changes in the institutional weakness. Chari et al. (2007) suggest a methodology to assess whether a friction may be of particular importance in a given market. More specifically, they suggest introducing exogenous parameters, called wedges, which distort the optimality conditions in the model. The larger the wedge, the larger the distortion that prevents the first order condition from holding. For example, Hsieh and Klenow (2009) employ wedges to assess frictions in China and India.

To this end, we extend our baseline model with a wedge to capture additional frictions in the data that are not explicitly modeled. The wedge in our setup, however, differs from those in the existing

Moments	Data	Baseline	Labor wedge
$\sigma(c)/\sigma(y)$	1.672	1.285	1.298
$\sigma(i_p)/\sigma(y)$	4.281	4.760	5.421
$\sigma(i_g)/\sigma(y)$	6.603	5.385	6.364
$\sigma(w)/\sigma(y)$	3.009	0.800	1.532
$\rho(y,c)$	0.269	0.689	0.599
$\rho(y,i_p)$	0.149	0.629	0.634
$\rho(y,i_g)$	-0.105	0.181	0.212
$\rho(c,i_p)$	-0.001	0.052	-0.013
$\rho(c,i_g)$	-0.359	-0.181	-0.201
$\rho(i_p,i_g)$	0.256	0.173	0.150
$\rho(w,y)$	-0.180	0.743	0.480
$\rho(w,c)$	0.216	0.938	0.537
$\rho(w,i_p)$	-0.005	0.082	0.128
$\rho(w,i_g)$	0.169	-0.098	0.025
$\rho(y)$	0.829	0.917	0.869
$\rho(c)$	0.803	0.942	0.939
$\rho(i_p)$	0.615	0.842	0.827
$\rho(i_g)$	0.779	0.046	-0.009
$\rho(w)$	0.737	0.889	0.781

Table D.2: Moments: data, baseline model, and model with a labor wedge. The standard deviations of real GDP from the data, baseline model, and the model with a labor wedge are 0.82, 2.40, and 2.15, respectively. $\sigma(x)$ denotes the standard deviation of x in percentages. $\rho(x)$ denotes the autocorrelation of x. $\rho(x,y)$ is the contemporaneous correlation between x and y.

literature, in the sense that it consists of exogenous random shocks. Hsieh and Klenow (2009) assume their wedges to be constant. Chari et al. (2007) allow for wedge uncertainty, but the wedges are identified such that the model's optimality conditions exactly match the data, and as such are not random shocks.

Introducing wedges into our model means that the parameters governing the wedge shock processes need to be identified and then estimated. Because of the way they enter the model, a capital or output wedge cannot be identified via estimation. This is because in our model an output wedge is isomorphic to a productivity shock, while a capital wedge would appear in the same equations as S_t, preventing its identification from the expropriation shock. Consequently, we introduce a labor wedge to our baseline model in this Appendix.

Premultiplying the wage rate w in the POE value function in equation (12) with a labor wedge,

Variance decomposition: Baseline model with a labor wedge					
	Private TFP	Expropriation	SOE TFP	Government spending	Labor wedge
c_t	13.54	72.74	0.80	11.07	1.85
$i_{p,t}$	22.16	60.02	2.87	12.23	2.72
$i_{g,t}$	44.44	22.97	26.47	1.35	4.76
y_t	27.12	67.51	0.40	1.84	3.12

Table D.3: Variance decomposition in percent. The table shows contribution of each shock to variations in consumption (c), POE investment (i_p), SOE investment (i_g), and output (y) for the model with a labor wedge.

$\Delta_{h,t}$, and dividing the corresponding equation (14) by equation (15), one obtains:

$$\frac{\Delta_{h,t} w_t}{E_t\left\{\phi_J + \sum_{i=1}^{J-1} \phi_{J-i}\left(\prod_{j=1}^{i} Q_{t+j}(1-S_{t+j})\right) - (1-\delta)\sum_{i=1}^{J} \phi_{J+1-i}\left(\prod_{j=1}^{i} Q_{t+j}(1-S_{t+j})\right)\right\}} = \frac{\theta(1-\alpha)p_{p,t}e^{z_{p,t}}(k_{p,t})^{\theta\alpha}(h_{p,t})^{\theta(1-\alpha)-1}}{E_t\left\{\left(\prod_{j=1}^{J} Q_{t+j}(1-S_{t+j})\right)\left(\theta\alpha p_{p,t+J}e^{z_{p,t+J}}k_{p,t+J}^{\alpha\theta-1}h_{p,t+J}^{\theta(1-\alpha)}\right)\right\}} \tag{D.1}$$

where $\Delta_{h,t}$ follows a standard AR(1) process. We then estimate the labor wedge process with Bayesian methods using the same prior distributions as for other shocks in our baseline model. Table D.1 reports the estimation results.[25]

Table D.2 compares the labor wedge model moments with the ones in the data, and the baseline model. The labor wedge model moments are similar to those in the baseline model. The main difference, perhaps, is that in the labor wedge model the wage rate becomes more volatile than output, as in the data. Table D.3 reports the variance decomposition for the model with a labor wedge, showing that the expropriation shocks are still the main driver of the business cycles, albeit their contribution somewhat decreases relative to the baseline model. More precisely, the expropriation shocks account for 73% of consumption volatility, 60% of private investment volatility, 23% of public investment volatility, and 68% of output volatility. Overall, we find that introducing this wedge does not considerably affect our main results.[26]

[25] Since we introduce a labor wedge, we remove the measurement error on wages, so that the system stays exactly identified.

[26] We have also experimented with introducing a labor wedge on both POEs and politicians. The results remain very similar and are available on request.

Appendix E Analytical Derivations

Appendix E.1 First Order Condition for Private Capital

This section provides the details for the derivation of the first order condition for POEs with respect to private capital, k_p.

For all t let $Q(M_t, M_{t+1}) \equiv Q_{t+1}, p_p(M_t) \equiv p_{p,t}, w(M_t) \equiv w_t$, and $S(M_t) \equiv S_t$. The POE value function is

$$V_p(k_{p,t}, d^1_{p,t}, d^2_{p,t}, \dots, d^{J-1}_{p,t}, M_t) = \max_{d^J_{p,t}, h_{p,t}} p_{p,t} e^{z_{p,t}} (k^{\alpha}_{p,t} h^{1-\alpha}_{p,t})^{\theta} - w_t h_{p,t} - \sum_{j=1}^{J} \phi_j d^j_{p,t} +$$
$$E_t Q_{t+1}(1 - S_{t+1}) V_p(k_{p,t+1}, d^1_{p,t+1}, d^2_{p,t+1}, \dots, d^{J-1}_{p,t+1}, M_{t+1})$$
$$\text{subject to } k_{p,t+1} = (1-\delta)k_{p,t} + d^1_{p,t}, d^j_{p,t+1} = d^{j+1}_{p,t}.$$

Using

$$d^j_{p,t} = k_{p,t+j} - (1-\delta)k_{p,t+j-1} \text{ for } j = 1, 2, \dots, J$$

the value function can be re-written as

$$V_p(k_{p,t}, k_{p,t+1} - (1-\delta)k_{p,t}, k_{p,t+2} - (1-\delta)k_{p,t+1}, \dots, k_{p,t+J-1} - (1-\delta)k_{p,t+J-2}, M_t) =$$
$$\max_{k_{p,t+J}, h_{p,t}} p_{p,t} e^{z_{p,t}} (k^{\alpha}_{p,t} h^{1-\alpha}_{p,t})^{\theta} - w_t h_{p,t} - \sum_{j=1}^{J} \phi_j (k_{p,t+j} - (1-\delta)k_{p,t+j-1}) +$$
$$E_t Q_{t+1}(1 - S_{t+1}) V_p((k_{p,t+1}, k_{p,t+2} - (1-\delta)k_{p,t+1}, k_{p,t+3} - (1-\delta)k_{p,t+2}, \dots, k_{p,t+J} - (1-\delta)k_{p,t+J-1}, M_{t+1})).$$

The first order condition with respect to $k_{p,t+J}$ yields

$$\phi_J = E_t Q_{t+1}(1 - S_{t+1}) \frac{\partial V_p(k_{p,t+1}, k_{p,t+2} - (1-\delta)k_{p,t+1}, \dots, k_{p,t+J} - (1-\delta)k_{p,t+J-1}, M_{t+1})}{\partial k_{p,t+J}}.$$

Notice that

$$
\begin{aligned}
&V_p(k_{p,t+1}, k_{p,t+2}-(1-\delta)k_{p,t+1},\dots,k_{p,t+J}-(1-\delta)k_{p,t+J-1},M_{t+1}) = \\
&\qquad \max_{k_{p,t+J+1},h_{p,t+1}} p_{p,t+1}e^{z_{p,t+1}}(k_{p,t+1}^{\alpha}h_{p,t+1}^{1-\alpha})^{\theta} - w_{t+1}h_{p,t+1} - \sum_{j=1}^{J}\phi_j(k_{p,t+j+1}-(1-\delta)k_{p,t+j}) + \\
&\qquad E_{t+1}Q_{t+2}(1-S_{t+2})V_p(k_{p,t+2},k_{p,t+3}-(1-\delta)k_{p,t+2},\dots,k_{p,t+J+1}-(1-\delta)k_{p,t+J},M_{t+2}).
\end{aligned}
$$

Using the envelope theorem,

$$
\begin{aligned}
&\frac{\partial V_p(k_{p,t+1}, k_{p,t+2}-(1-\delta)k_{p,t+1},\dots,k_{p,t+J}-(1-\delta)k_{p,t+J-1},M_{t+1})}{\partial k_{p,t+J}} = \\
&-\phi_{J-1}+(1-\delta)\phi_J + \\
&E_{t+1}Q_{t+2}(1-S_{t+2})\frac{\partial V_p(k_{p,t+2},k_{p,t+3}-(1-\delta)k_{p,t+2},\dots,k_{p,t+J+1}-(1-\delta)k_{p,t+J},M_{t+2})}{\partial k_{p,t+J}}.
\end{aligned}
$$

Combing the first order condition with respect to $k_{p,t+J}$ and the envelope theorem condition gives

$$
\begin{aligned}
&\phi_J = \\
&\quad E_tQ_{t+1}(1-S_{t+1})\left[-\phi_{J-1}+(1-\delta)\phi_J + \right.\\
&\quad \left. E_{t+1}Q_{t+2}(1-S_{t+2})\frac{\partial V_p(k_{p,t+2},k_{p,t+3}-(1-\delta)k_{p,t+2},\dots,k_{p,t+J+1}-(1-\delta)k_{p,t+J},M_{t+2})}{\partial k_{p,t+J}}\right].
\end{aligned}
$$

Iterating J times and applying the Law of Iterated Expectations,

$$
\begin{aligned}
&\phi_J = \\
&\quad -E_t\sum_{i=1}^{J-1}\phi_{J-i}\left(\prod_{j=1}^{i}Q_{t+j}(1-S_{t+j})\right) + \\
&\quad E_t(1-\delta)\sum_{i=1}^{J-1}\phi_{J+1-i}\left(\prod_{j=1}^{i}Q_{t+j}(1-S_{t+j})\right) + \\
&\quad E_t\prod_{j=1}^{J}Q_{t+j}(1-S_{t+j})\frac{\partial V_p(k_{p,t+J},k_{p,t+J+1}-(1-\delta)k_{p,t+J},\dots,k_{p,t+J-1+J}-(1-\delta)k_{p,t+J-1+J-1},M_{t+J})}{\partial k_{p,t+J}}
\end{aligned}
$$

where

$$
\begin{aligned}
&\frac{\partial V_p(k_{p,t+J},k_{p,t+J+1}-(1-\delta)k_{p,t+J},\dots,k_{p,t+J-1+J}-(1-\delta)k_{p,t+J-1+J-1},M_{t+J})}{\partial k_{p,t+J}} = \\
&(1-\delta)\phi_1 + \theta\alpha p_{p,t+J}e^{z_{p,t+J}}k_{p,t+J}^{\theta\alpha-1}h_{p,t+J}^{\theta(1-\alpha)}.
\end{aligned}
$$

Thus, the first order condition is

$$\phi_J + E_t \sum_{i=1}^{J-1} \phi_{J-i} \left(\prod_{j=1}^{i} Q_{t+j}(1 - S_{t+j}) \right) =$$
$$E_t(1-\delta) \sum_{i=1}^{J} \phi_{J+1-i} \left(\prod_{j=1}^{i} Q_{t+j}(1 - S_{t+j}) \right) + E_t \left(\prod_{j=1}^{J} Q_{t+j}(1 - S_{t+j}) \right) \theta\alpha p_{p,t+J} e^{z_{p,t+J}} k_{p,t+J}^{\theta\alpha-1} h_{p,t+J}^{\theta(1-\alpha)},$$

which is equation (15).

Appendix E.2 SOE Profits

Notice that the linear nature of the SOE production function means that per period profits of SOEs are zero in steady state. To see this, the optimality condition for SOEs in equation (21) implies that $p_g A e^{z_g} = \delta$, where variables without a time subscript denote their steady state counterparts. Using this relationship, steady state SOE per period profits are

$$p_g A e^{z_g} k_g - k_g + (1-\delta) k_g = \delta k_g - k_g + (1-\delta) k_g = 0.$$

Outside the steady state, profits fluctuate around zero.