Central Bank Independence and Inflation: Schumpeterian Theory and Evidence*

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Abstract

We first use a monetary Schumpeterian model to investigate how central bank independence (CBI) affects inflation. We find that we cannot predict a monotone relationship between CBI and inflation. When the elasticity of labor supply is high or the seigniorage is mainly used to finance entrepreneurs, a condition that is more likely in developed countries, CBI has a positive effect on inflation; in contrast, when labor supply is inelastic or the seigniorage is mainly used to finance non-productive government spending, a situation more commonly found in developing countries, CBI has a negative effect or no effect on inflation. Calibration shows the following. When the nominal interest rate increases from 8.3% (the sample mean) to the optimal value of 28.1%, the equilibrium rate of economic growth increases from the benchmark value of 1.8% to 1.99%, and the welfare gain is equivalent to a permanent increase in consumption of 1.02%. The growth and welfare effects increase with CBI. As an empirical test, we build panel data for 68 countries during 1998–2010 and find that the effect of CBI on inflation is positive and significant in developed countries, and it is insignificant (at the 5% level) in developing countries in both system generalized method of moments (GMM) and instrumental variable (IV) estimations. Our results remain robust to the consideration of financial crises, financial development, and other factors affecting inflation. Our empirical findings provide support for our theory.

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1 Introduction

The existing literature debates whether central bank independence (CBI) helps to reduce inflation (e.g., Alesina and Summers, 1993; Loungani and Sheets, 1997; Cukierman and Lippi, 1999; De Haan and Kooi, 2000; Hermes and Lensink, 2000; Berger et al., 2001; Cukierman et al., 2002; Neyapti, 2003; Jácome and Vázquez, 2005; Crowe and Meade, 2008; Klomp and De Haan, 2010; Dincer and Eichengreen, 2014).[1] In this paper we contribute by using a monetary Schumpeterian model to investigate how CBI impacts inflation. To our knowledge, this is the first study that analyzes how CBI impacts inflation in a growth-theoretic framework featuring R&D-driven innovation. Additionally, we build cross-country panel data during 1998–2010 to test our model. The motivation of our paper is as follows.

What is central bank independence? Usually, we would say, the central bank should be independent from fiscal authority. There are two good reasons for this. The first developed with the discovery and rejection of the Phillips curve: central banks should not adjust their monetary policy to systematically stabilize output and employment. They must be independent from the fiscal authority or elected government so that the government cannot force them to adjust their monetary policy and that the commitment of the central bank to low inflation rates is credible. The second reason is to prevent the monetization of public debt. A central bank that is independent cannot be pressured by the fiscal authority to partly finance its expenditures, thereby losing the ability to control inflation.

The role of CBI has not been studied in the R&D-driven growth-theoretic framework (e.g., Marquis and Reffett, 1994; Chu and Cozzi, 2014; He, 2015; Chu et al., 2015; Huang et al., 2015; Chu, Ning, and Zhu, 2017; Chu et al., 2017; He, 2018; Chu et al., 2018). To fill this gap, we incorporate CBI into a monetary Schumpeterian model. Doing so would help us to further understand the role of CBI in the making of monetary policy, which has important consequences for growth and welfare.

In this paper, we focus on the aforementioned second reason for CBI (i.e., we ignore the time-inconsistency problem): an independent central bank helps to prevent the fiscal authority from financing its expenditures with seigniorage revenue. The importance of the seigniorage revenue has been recently highlighted in monetary Schumpeterian growth models by He and Zou (2016). In He and Zou (2016), the allocation of the seigniorage revenue between entrepreneurs and the government has important consequences on growth. The seigniorage revenue allocated to entrepreneurs is like a subsidy to entrepreneurial innovation, which generates a positive seigniorage effect that absorbs labor into R&D. This in turn promotes growth. The seigniorage revenue allocated to the government draws labor away

[1] See Berger, De Haan and Eijffinger (2001) for a discussion on some of the early studies, and Klomp and De Haan (2010) for a meta-regression analysis of 59 studies. For instance, using 82 developing countries during 1980–1989, De Haan and Kooi (2000) find that CBI is related to inflation only if the high-inflation countries are included in the sample. Jácome and Vázquez (2005) use panel data from Latin America and the Caribbean and find no causal effect of CBI on inflation. Dincer and Eichengreen (2014) show that the level and variability of inflation are significantly affected by CBI.

from R&D and production to the government sector, which generates a negative government crowding-out effect that retards growth. Building on He and Zou (2016), we model the role of CBI by assuming that the allocation of the seigniorage revenue depends on CBI.

Specifically, we introduce money into a Schumpeterian quality-ladder model through the CIA (cash-in-advance) constraint on consumption. We first assume that the seigniorage revenue from steady inflation is allocated between households and entrepreneurs (other cases, such as seigniorage revenue being allocated between households and the government and a higher degree of CBI helping to prevent the fiscal authority from financing its expenditures with seigniorage revenue will also be investigated).[2] A higher degree of CBI would increase the share of the seigniorage revenue allocated to entrepreneurs. Our model predicts the following: We cannot predict a monotone relationship between CBI and inflation. In countries where the step-size of innovation is small, CBI has a positive effect on the nominal interest rate and, therefore, inflation. In contrast, in countries where the step-size of innovation is large, CBI has a negative effect on the nominal interest rate and, therefore, inflation. The economic intuition is as follows.

A higher nominal interest rate would yield larger seigniorage revenue. When a larger share of the seigniorage revenue is allocated to entrepreneurs, it increases the share of labor employed by entrepreneurs (i.e., R&D labor)—the *seigniorage effect* highlighted in He and Zou (2016). When the step-size of innovation is small, there is R&D overinvestment. In this case, the optimal interest rate would be smaller than ρ (the rate of time preference). When this happens, there would be negative seigniorage revenue, which means the entrepreneurs are taxed according to the low nominal interest rate. A resultant decrease in R&D labor would be welfare-improving when there is R&D overinvestment. When the step-size of innovation is large, there is R&D underinvestment. In this case, the optimal interest would be above ρ, yielding positive seigniorage revenue. The positive seigniorage revenue allocated to entrepreneurs would increase R&D labor, which is welfare-improving when there is R&D underinvestment.

An increase in the nominal interest rate has two opposing effects on welfare. On the one hand, it increases R&D labor and thereby the growth rate through the seigniorage effect. This would increase welfare. On the other hand, manufacturing labor decreases when R&D labor increases, leading to a decrease in welfare. We can view the seigniorage effect as the marginal benefit of an increase in the nominal interest rate. The marginal cost is proportional to the step-size of innovation. For a fixed marginal cost, the marginal benefit must remain unchanged. An increase in the degree of CBI increases the marginal benefit of an increase in the nominal interest rate. When the step-size of innovation is small, the optimal nominal interest rate has to increase: an increase in the nominal interest rate when it is below ρ

[2] Please see He and Zou (2016) for the importance of the seigniorage revenue and its allocation in real world situations. He and Zou (2016) also offer a survey of the related literature. Because of their discussion of it, we shall omit detailed references to the literature.

would increase the seigniorage, thereby decreasing the seigniorage effect. When the step-size of innovation is high, an increase in the degree of CBI would cause the optimal nominal interest rate to decrease; a decrease in the nominal interest rate when it is above ρ would decrease the seigniorage and, therefore, the seigniorage effect.

We then consider elastic labor supply. We find the following. The elasticity of labor supply determines the sign of the effect of CBI on inflation: when the elasticity is high, CBI is more likely to have a positive effect on the nominal interest rate and thereby inflation; when it is low, CBI is more likely to have a negative effect on the nominal interest rate.

We calibrate the model to estimate the growth and welfare effects. We find the following. When the nominal interest rate i increases from 8.3% (the sample mean, elaborated below) to the optimal value of 28.1%, the equilibrium rate of economic growth increases from the benchmark value of 1.8% to 1.99%, and the welfare gain is equivalent to a permanent increase in consumption of 1.02%. After that, any further increase in the nominal interest rate will decrease the social welfare. The growth and welfare effects are much larger with a larger value of CBI. Additionally, under elastic labor supply, the optimal nominal interest rate increases with the degree of CBI. We also calibrate the case of inelastic labor supply. Under inelastic labor supply, when the step-size of innovation is above a threshold, the optimal nominal interest rate is positive, which decreases with the degree of CBI.

Additionally, we investigate the case in which the seigniorage revenue is allocated between the government and entrepreneurs. We find that the allocation of the seigniorage revenue between the government and entrepreneurs determines the sign of the effect of CBI on inflation. When the majority of the seigniorage revenue is used to finance non-productive government spending, the Friedman rule is optimal and CBI has no effect on the nominal interest rate; when the seigniorage revenue is mainly channeled to subsidize business-promoting activities (i.e., the entrepreneurs), CBI has a positive effect on the nominal interest rate.

To summarize, our model focuses on the allocation of the seigniorage revenue that is affected by the degree of CBI in order to illustrate a novel channel through which CBI would have an impact on the determination of the optimal nominal interest rate and, therefore, the inflation rate. Despite of the different modelling assumptions, our common prediction is that, CBI is more likely to have a positive effect on the nominal interest rate in developed countries that are more likely to have a larger elasticity of labor supply and to feature that the seigniorage revenue is mainly channeled to subsidize business-promoting activities.

Our theory helps to explain the existing empirical debate on the effect of CBI on inflation. We then use cross-country panel data to investigate the causal effect of CBI on inflation. The existing empirical literature has only established a correlation between CBI and inflation. In this paper, we contribute by establishing a causal effect of CBI on inflation using dynamic cross-country panel data and the associated system GMM (generalized method of moments) estimation proposed by Blundell and Bond (1998).

Another reason why economists debate the effect of CBI on inflation is that there is no consensus on a perfect measure of CBI. There may be a large difference between the *de jure* and the *de facto* measures of CBI. There are studies using the turnover rate of the central bank governor as the measure of (*de facto*) CBI (e.g., Vuletin and Zhu, 2011). In this paper, we focus on establishing a causal relationship between the *de jure* measure of CBI and inflation. The *de jure* measure of CBI is the oldest and most widely used method in the literature. If we also compare results with the *de facto* measure of CBI, we would not be able to clearly identify where the causal effect of CBI on inflation originates. Therefore, in this paper, we focus on the *de jure* measure of CBI. However, as this measure of CBI may be related to the rule of law in a country, we also use static panel data and legal origins as instruments in instrumental variable (IV) regressions to check the robustness of our results. There, we find that our empirical findings match better with our theoretical prediction.

Specifically, we acquire consumer price index (CPI) inflation data provided by the International Financial Statistics (IFS) of the IMF (International Monetary Fund) and CBI data from Dincer and Eichengreen (2014), who report the data on CBI for about 100 countries during 1998–2014. We then access data on the control variables from the World Development Indicators (WDI) of the World Bank and the Penn World Table (hereafter PWT) 9.0 (Feenstra, Inklaar, & Timmer, 2015). Because Dincer and Eichengreen (2014) do not report the data on CBI for countries with the euro as their currency and some countries in Dincer and Eichengreen (2014) do not have data on employment (the *emp* series in PWT 9.0) and/or human capital (the *hc* series in PWT 9.0), we end up with 68 countries with complete data. That is, we have panel data for 68 countries during 1998–2010 (a balanced panel with 884 observations). Following the existing literature (e.g., Dincer & Eichengreen, 2014), we use the logarithm of (1+inflation) as the dependent variable. We find the following.

The effect of CBI on inflation is positive and significant at the 5% level in advanced countries, and it is insignificant at the 5% level in developing countries in system GMM regressions and IV estimation that uses legal origins as instruments. Our results remain robust after controlling for the income level of the countries and other factors that may affect inflation, such as financial development, current account surplus, and the level of government spending. Our sample involves two worldwide financial crises: the Asian Financial Crisis of 1997–1998 and the recent global financial crisis of 2008–2009. Our results remain robust after controlling for dummy variables that indicate the existence of financial crises. Our empirical findings provide support for our theory.

Our study contributes to the literature on CBI and its effect on inflation, government deficits, growth, and welfare (see e.g., Bade and Parkin, 1988; De Haan and Zelhorst, 1990; Grilli, Masciandaro, and Tabellini, 1991; Cukierman et al., 1992; Fischer, 1995; Hochreiter, Rovelli and Winckler, 1996; Sikken and De Haan, 1998, and references cited above). Our study also relates to the large body of literature on inflation dynamics and monetary policymaking under globalization (see e.g., Galí, 2010; Zhang, 2017).

The rest of the paper proceeds as follows. Section 2 presents the model. Section 3 describes the data. Section 4 displays the empirical evidence. Section 5 concludes.

2 A Monetary Schumpeterian Model

The model follows Chu and Cozzi (2014). For the sake of simplicity, in our model, there is a CIA on consumption only. In addition, we assume that some of the seigniorage revenue is lump-sum transferred to households while the rest of the seigniorage revenue is used to finance entrepreneurial activity.

2.1 The Households

At time t, the population size of each household is fixed at L. There is a unit continuum of identical households, which have a lifetime utility function

$$U = \int_0^\infty e^{-\rho t} \left[\ln (c_t) + \theta \ln (1 - l_t)\right] dt, \tag{1}$$

where c_t is per capita real consumption of final goods and l_t is per capita supply of labor at time t. $\rho > 0$ is the rate of time preference and $\theta \geq 0$ captures leisure preference. Each individual is endowed with one unit of labor. For the sake of simplicity, we assume that there is no population growth.

Each household maximizes its lifetime utility given in equation (1) subject to the asset-accumulation equation given by

$$\dot{a}_t + \dot{m}_t = r_t a_t + w_t l_t - c_t - \pi_t m_t + (1 - \beta)\, \tau_t, \tag{2}$$

where a_t is the real value of equity shares in monopolistic intermediate-goods firms owned by each member of households; r_t and w_t are the rate of real interest and the wage, respectively; m_t is the real money balance held by each person; and π_t is the inflation rate. We assume that the CIA constraint is given by $c_t \leq m_t$.

The literature traditionally assumes that seigniorage revenue is rebated as a lump-sum transfer to the household. In contrast, we follow He and Zou (2016) in assuming that each person only receives a lump-sum transfer of $(1 - \beta)$ share $(0 \leq \beta \leq 1)$ of the seigniorage revenue τ_t from the government (or pay a lump-sum tax if $\tau_t < 0$). We assume that the share β positively depends on the degree of CBI. A higher degree of CBI would enable the monetary authority to use the seigniorage revenue τ_t to subsidize productivity-enhancing activities. Here we differ from He and Zou (2016). He and Zou (2016) assume that the rest of the seigniorage revenue τ_t would be retained by the government, yielding a government crowding-out effect. However, such an effect will yield new predictions, and we will investigate that case in a separate section.

The no-arbitrage condition is $i_t = \pi_t + r_t$, where i_t is also the nominal interest rate. Using Hamiltonian, the optimality condition for consumption is

$$\frac{1}{c_t} = \mu_t \left(1 + i_t\right), \tag{3}$$

where μ_t the Hamiltonian co-state variable on (2). The optimal condition for labor supply is

$$\frac{\theta}{1 - l_t} = w_t \mu_t, \tag{4}$$

where the left-hand-side of equation (4) is the marginal disutility of labor, and the right-hand-side of equation (4) is marginal benefit of labor. Using (3), we rewrite the optimal condition for labor supply as

$$w_t \left(1 - l_t\right) = \theta c_t \left(1 + i_t\right). \tag{5}$$

The Euler equation is

$$-\frac{\dot{\mu}_t}{\mu_t} = r_t - \rho. \tag{6}$$

2.2 The Final-Goods Sector

The production function of the competitive final-goods firms is

$$y_t = \exp\left(\int_0^1 \ln x_t\left(j\right) dj\right), \tag{7}$$

where $x_t\left(j\right)$ denotes intermediate goods $j \in [0, 1]$. The final goods firms maximize their profit, taking the price of each intermediate good j, denoted $p_t\left(j\right)$, as given. The demand function for $x_t\left(j\right)$ is

$$x_t\left(j\right) = y_t / p_t\left(j\right). \tag{8}$$

2.3 The Intermediate-Goods Sector

There is a unit continuum of industries producing differentiated intermediate goods. Each industry is temporarily dominated by an industry leader until the arrival of the next innovation, and the owner of the new innovation becomes the next industry leader. The leader in industry j has the following production function:

$$x_t(j) = \gamma^{q_t(j)} L_{x,t}(j). \tag{9}$$

The parameter $\gamma > 1$ is the step size of a productivity improvement, and $q_t(j)$ is the number of productivity improvements that have occurred in industry j by time t. $L_{x,t}(j)$ is the production-labor in industry j. (9) adopts a cost-reducing view of vertical innovation. Given $\gamma^{q_t(j)}$, the marginal cost of production for the industry leader in industry j is $mc_t(j) =$

$w_t/\gamma^{q_t(j)}$. Standard Bertrand price competition leads to a profit-maximizing price $p_t(j)$ determined by a markup γ over the marginal cost. The amount of monopolistic profit is

$$\Pi_t(j) = \left(\frac{\gamma - 1}{\gamma}\right) p_t(j)\, x_t(j) = \left(\frac{\gamma - 1}{\gamma}\right) y_t. \tag{10}$$

The labor income from production is

$$w_t L_{x,t}(j) = \left(\frac{1}{\gamma}\right) p_t(j)\, x_t(j) = \left(\frac{1}{\gamma}\right) y_t. \tag{11}$$

2.4 The Labor Market

The fixed stock of aggregate labor supply L has two uses. First, some labor is used in producing intermediate goods. Second, some labor is used as research input. The labor market clearing condition is

$$L_{x,t} + L_{r,t} = l_t L, \tag{12}$$

where $L_{x,t}$ and $L_{r,t}$ are the total employment in manufacturing and R&D, respectively.

2.5 The Seigniorage Revenue

The monetary authority (i.e., the central bank together with the government) exogenously chooses the monetary growth rate $\dot{M}_t/M_t$, which is equivalent to the case in which the nominal interest rate is chosen as the policy instrument because $i_t = \dot{M}_t/M_t + \rho$. The derivation is as follows. In our model, we have $m_t = M_t/(P_t L)$, where P_t is the price of final-goods and $\dot{P}_t/P_t = \pi_t$. Therefore, without population growth, we have $\dot{m}_t/m_t = \dot{M}_t/M_t - \pi_t$. On the balanced growth path, c_t and m_t grow at the same rate g_t. Combining equations (3) and (6) yields $g_t = r_t - \rho$. We also have the Fisher equation $i_t = r_t + \pi_t$. Taken together, we have $\dot{M}_t/M_t - \pi_t = i_t - \pi_t - \rho$, which is just $i_t = \dot{M}_t/M_t + \rho$. Additionally, we have $i_t - \rho = \dot{M}_t/M_t = \dot{m}_t/m_t + \pi_t = g_t + \pi_t$.

The seigniorage revenue R_t is

$$R_t = \frac{\dot{M}_t}{P_t} = \left(\dot{m}_t + \pi_t m_t\right) L = \left(\frac{\dot{m}_t}{m_t} + \pi_t\right) \frac{m_t L}{y_t} y_t = (g_t + \pi_t)\, \phi_t y_t, \tag{13}$$

where we use the fact that on the balanced growth path m_t, c_t, and y_t all grow at the same rate; we define ϕ_t as the money-output ratio Lm_t/y_t, and ϕ_t will be pinned down later.

We also have $R_t = \dot{M}_t/P_t = \left(\dot{M}_t/M_t\right) m_t L$. Plugging $(g_t + \pi_t) = (i_t - \rho)$ in (13) yields $R_t = (i_t - \rho)\, \phi_t y_t$. Therefore, if $\dot{M}_t/M_t > 0$ (equivalent to $i_t > \rho$), then there will be positive seigniorage revenue; otherwise, the seigniorage revenue will be negative.

As assumed, households and the entrepreneurs get $(1-\beta)$ and β share of the seigniorage revenue, respectively, where β is exogenously pinned down by the bargaining between the central bank and the government. Moreover, β increases with the degree of CBI.

2.6 Research Arbitrage

Because entrepreneurs get β share of the seigniorage revenue, their profit will be the usual monopolistic profit from innovations (the Π_t in equation 10) plus the extra seigniorage revenue. Using equation (13), the profit of entrepreneurship, $\widehat{\Pi}_t$, becomes

$$\widehat{\Pi}_t = \Pi_t(j) + \beta \cdot R_t = \left(\frac{\gamma-1}{\gamma}\right) y_t + \beta\left(g_t + \pi_t\right)\phi_t y_t, \tag{14}$$

where the term $\beta\left(g_t + \pi_t\right)\phi_t y_t$ in (14) is the *positive seigniorage effect.*

As in Chu and Cozzi, we denote by $v_t(j)$ the value of the monopolistic firm in industry j. In a symmetric equilibrium, $v_t(j) = v_t$. The no-arbitrage condition for v_t is

$$r_t v_t = \widehat{\Pi}_t + \dot{v}_t - \lambda_t v_t. \tag{15}$$

Equation (15) says that the return of holding an innovation, $r_t v_t$, equals the sum of the flow profit of innovation, Π_t, and potential capital gain $(\dot{v}_t)$, less the expected capital loss, $\lambda_t v_t$, where λ_t is the arrival rate of the next innovation.

The zero-expected-profit condition of R&D firm $k \in [0,1]$ in each industry is

$$\lambda_t(k)\, v_t = w_t L_{r,t}(k), \tag{16}$$

where $L_{r,t}(k)$ is the amount of labor hired by R&D firm k, and $\lambda_t(k)$ (the firm-level innovation rate per unit time) is $\lambda_t(k) = \varphi\frac{L_{r,t}(k)}{L}$, where φ is a constant. This assumption eliminates the scale effects (see Chu and Cozzi, 2014; Laincz and Peretto, 2006). The aggregate arrival rate of innovation is

$$\lambda_t = \int_0^1 \lambda_t(k)\, dk = \varphi\frac{L_{r,t}(k)}{L} = \varphi l_{r,t}, \tag{17}$$

where $l_{r,t}$ is the share of population employed in R&D. Similarly, the share of population in production is $l_{x,t} = L_{x,t}/L$.

2.7 The General Equilibrium

The general equilibrium is a time path of prices $\{p_t(j), r_t, w_t, i_t, v_t\}$ and allocations $\{c_t, m_t, y_t, x_t(j), L_{x,t}(j), L_{r,t}(k)\}$, which satisfy the following conditions at each instant of time:

- households maximize utility taking prices $\{r_t, w_t, i_t\}$ as given;
- competitive final-goods firms maximize profit taking $\{p_t(j)\}$ as given;

- monopolistic intermediate-goods firms choose $\{L_{x,t}(j), p_t(j)\}$ to maximize profit taking $\{w_t\}$ as given;

- R&D firms choose $\{L_{r,t}(k)\}$ to maximize expected profit taking $\{w_t, i_t, v_t\}$ as given;

- the labor market clears (that is, $L_{x,t} + L_{r,t} = l_t L$);

- the final goods market clears (that is, $y_t = c_t L + \beta R_t$);

- the CIA constraint binds: $c_t = m_t$;

- the value of monopolistic firms adds up to the value of households' assets (i.e., $v_t = a_t L$).

2.8 Balanced Growth Path

In this paper we focus on the balanced growth path. On this path, the growth rate of aggregate technology (and thus the growth rate of allocation variables such as c_t, m_t, and y_t) grows at a constant rate. Plugging equation (9) into (7), we have

$$y_t = \exp\left(\int_0^1 q_t(j)\, dj \ln\gamma\right) L_x = \exp\left(\int_0^t \lambda_v dv \ln\gamma\right) L_x = Z_t L_x, \tag{18}$$

where $Z_t \equiv \exp\left(\int_0^t \lambda_v dv \ln\gamma\right)$ is the level of aggregate technology. The growth rate of Z_t is

$$g_z = \lambda_t \ln\gamma = \varphi l_{r,t} \ln\gamma, \tag{19}$$

which is linear in the share of labor employed by R&D firms, as in standard Schumpeterian growth models (see e.g., Chu and Cozzi, 2014). On the balanced growth path, equation (18) shows that y_t and Z_t must grow at the same rate: $g_y = g_z$, given no population growth. Per capita consumption is $c_t = y_t/L$, implying that c_t and Z_t must grow at the same rate: $g_c = g_z$. The binding CIA constraint means $g_c = \dot{m}_t/m_t$. Therefore, we have the balanced growth rate (the growth rate of per capita consumption or output) $g_t = g_z$, given in (19).

Now we show that the equilibrium labor allocation is stationary on a balanced growth path. Substituting the condition $\dot{v}_t/v_t = g = r - \rho$ into (15) and then using (16), we have $\lambda\widehat{\Pi}_t = (\rho + \lambda) w_t L_{r,t}$. Then using (11), (14), (17), and $(g_t + \pi_t) = (i - \rho)$, we have

$$[(\gamma - 1) + \beta\gamma (i - \rho) \phi] l_x = l_r + \rho/\varphi. \tag{20}$$

We have the final goods market clearing condition, $y_t = c_t L + \beta R_t = c_t L + \beta (i - \rho) \phi_t y_t$, using equation (13). Therefore, we have

$$c_t = [1 - \beta (i - \rho) \phi_t] y_t. \tag{21}$$

The binding CIA constraint is $c_t L = m_t L$, and we have $\phi_t = (m_t L)/y_t = (c_t L)/y_t$. Combining with (21) solves for the money-output ratio ϕ_t as

$$\phi_t = \frac{1}{1+\beta(i-\rho)}. \tag{22}$$

The labor market clearing condition is

$$l_r + l_x = l = 1 - \frac{\theta\gamma(1+i_t)}{1+\beta(i-\rho)} l_x. \tag{23}$$

Solving (20), (22), and (23) yields the equilibrium labor allocation as

$$\begin{aligned} l_r &= \frac{(\gamma-1)[1+\beta(i-\rho)]+\beta\gamma(i-\rho)}{\gamma[1+2\beta(i-\rho)+\theta(1+i)]}\left(1+\frac{\rho}{\varphi}\right)-\frac{\rho}{\varphi}, & (24)\\ l_x &= \frac{1+\beta(i-\rho)}{\gamma[1+2\beta(i-\rho)+\theta(1+i)]}\left(1+\frac{\rho}{\varphi}\right), & (25)\\ l &= \frac{1+2\beta(i-\rho)}{1+2\beta(i-\rho)+\theta(1+i)}\left(1+\frac{\rho}{\varphi}\right)-\frac{\rho}{\varphi}. & (26) \end{aligned}$$

Therefore, the equilibrium labor allocation is stationary on a balanced growth path with an exogenous chosen i.

2.9 Central Bank Independence and the Inflation Rate

In the following, we focus on second-best allocations. As discussed above, the monetary authority's policy instrument could be either the monetary growth rate $\dot{M}_t/M_t$ or the nominal interest rate i_t because $i_t = \dot{M}_t/M_t + \rho$, as derived above. Therefore, in this paper, we focus on the nominal interest rate as the policy instrument. To derive the optimal monetary policy (i.e., the optimal nominal interest rate), we impose balanced growth on (1) to obtain

$$U = \frac{1}{\rho}\left[\ln(Z_0\phi l_x) + \frac{g}{\rho} + \theta\ln(1-l)\right] = \frac{1}{\rho}\left[\ln(\phi l_x) + \frac{g}{\rho} + \theta\ln(1-l)\right], \tag{27}$$

where the last equality is obtained by normalizing Z_0 (the aggregate technology at time 0) to unity (following Chu and Cozzi, 2014).

2.9.1 Inelastic labor supply

With inelastic labor supply, we have $\theta = 0$. Now the equilibrium labor allocations become

$$\begin{aligned} l_r &= \frac{(\gamma-1)[1+\beta(i-\rho)]+\beta\gamma(i-\rho)}{\gamma[1+2\beta(i-\rho)]}\left(1+\frac{\rho}{\varphi}\right)-\frac{\rho}{\varphi}, & (28)\\ l_x &= \frac{1+\beta(i-\rho)}{\gamma[1+2\beta(i-\rho)]}\left(1+\frac{\rho}{\varphi}\right), & (29)\\ l &= 1. & (30) \end{aligned}$$

Proposition 1 *Under inelastic labor supply, when the step-size of innovation γ is small, a higher degree of CBI would increase the optimal nominal interest rate and thereby the inflation rate; when it is large, a higher degree of CBI would decrease the optimal nominal interest rate and thereby the inflation rate.*

Proof: Now plugging (22) and the equilibrium labor allocations in (28)-(30) into (27) and taking the derivative with respect to the nominal interest rate, we have

$$\frac{\partial U}{\partial i} = \frac{\beta}{\gamma \rho^2} \left[\frac{(1 + \varphi/\rho) \ln \gamma - 2\gamma \left[1 + 2\beta \left(i - \rho\right)\right]}{\left[1 + 2\beta \left(i - \rho\right)\right]^2} \right]. \tag{31}$$

The optimal nominal interest rate would be that solves $\frac{\partial U}{\partial i} = 0$, which gives the optimal interest rate as

$$i^* = \rho + \frac{(1 + \varphi/\rho) \ln \gamma - 2\gamma}{4\gamma\beta}, \text{ if } 2 < (1 + \varphi/\rho) \frac{\ln \gamma}{\gamma}, \tag{32}$$

$$i^* = \rho - \frac{2\gamma - (1 + \varphi/\rho) \ln \gamma}{4\gamma\beta}, \text{ if } 2 > (1 + \varphi/\rho) \frac{\ln \gamma}{\gamma}. \tag{33}$$

The optimal interest rate depends on the size of the structural parameters (e.g., β and γ). For instance, $(\ln \gamma)/\gamma$ is an increasing function of γ. Therefore, when γ is small, we have $(1 + \varphi/\rho) \frac{\ln \gamma}{\gamma} < 2$. In this case, the optimal interest rate would be the one given in (33), and we have $i^* < \rho$. In this case, the optimal interest rate could be negative and the Friedman rule will be optimal. When γ is large, we have $(1 + \varphi/\rho) \frac{\ln \gamma}{\gamma} > 2$. In this case, the optimal interest rate would be the one given in (32), and we have $i^* > \rho$.

According to (32), the optimal nominal interest rate decreases with β (the degree of CBI) when γ is large. By contrast, (33) indicates that the optimal interest rate increases with β when γ is small. Additionally, when the Friedman rule is optimal, initially an increase in β has no effect on the nominal interest rate. However, when β is above a threshold, its further increase will raise the optimal nominal interest rate.

Now we can derive how inflation rate would change with β. On the balanced growth path, we have $\pi = i^* - g(i^*) - \rho$. Given an increase in the nominal interest rate, we have $g'(i^*) < 1$. This is because

$$g'(i^*) = \frac{\varphi \ln \gamma}{\gamma} \frac{\beta}{\left[1 + 2\beta \left(i - \rho\right)\right]^2} \left(1 + \frac{\rho}{\varphi}\right), \tag{34}$$

which shows $g'(i^*) < 1$ with normal structural parameter space. Therefore, there is a positive relationship between the nominal interest rate and the inflation rate.

When γ is large, the optimal interest rate given in (32) indicates that it decreases with β. As a result, the inflation rate also decreases. That is, a higher degree of CBI decreases the optimal nominal interest rate, ending up decreasing the inflation rate. We would observe a negative relationship between CBI and the inflation rate.

When γ is small, the optimal interest rate given in (33) indicates that it increases with β. In other words, a higher degree of CBI increases the optimal nominal interest rate. In this case, given $\pi = i^* - g(i^*) - \rho$, the inflation rate would also increase. Therefore, in this case a higher degree of CBI would increase the inflation rate. Q.E.D.

The economic intuition behind Proposition 1 is as follows. We have introduced the assumption that a higher degree of CBI means a larger share of the seigniorage revenue would be used to subsidize productivity-enhancing activities. A higher nominal interest rate would yield larger seigniorage revenue. When a larger share of the seigniorage revenue is allocated to entrepreneurs, it would increase the share of labor employed by entrepreneurs (i.e., R&D labor l_r)—the seigniorage effect highlighted in He and Zou (2016). When the step-size of innovation is small, there is R&D overinvestment. In this case, the optimal interest rate would be smaller than ρ, according to (33). When this happens, there would be negative seigniorage revenue, which means the entrepreneurs are taxed by the low nominal interest rate. A resultant decrease in R&D labor l_r would be welfare-improving when there is R&D overinvestment. When the step-size of innovation is large, there is R&D underinvestment. In this case the optimal interest would be above ρ (according to (32)), yielding positive seigniorage revenue. The positive seigniorage revenue allocated to entrepreneurs would increase R&D labor, which is welfare-improving when there is R&D underinvestment.

According to (27), an increase in the nominal interest rate has two opposing effects on the welfare. On the one hand, it increases R&D labor l_r and thereby the growth rate g through the seigniorage effect. This would increase welfare. On the other hand, manufacturing labor l_x decreases when R&D labor increases, ultimately decreasing welfare. We can view the seigniorage effect as the marginal benefit of an increase in the nominal interest rate. According to the numerator in (31), the marginal cost is mainly related to the step-size of innovation. For optimality (i.e., maximizing welfare), given a fixed marginal cost, the marginal benefit has to remain unchanged. An increase in the degree of CBI increases the marginal benefit of an increase in the nominal interest rate. When the step-size of innovation is small, the optimal nominal interest rate must increase. An increase in the nominal interest rate, when it is below ρ, would increase the seigniorage and thereby decrease the seigniorage effect (considering the seigniorage revenue $R_t = (i - \rho)\, y_t$). When the step-size of innovation is high, the nominal interest rate is above ρ. An increase in the degree of CBI would cause the optimal nominal interest rate to decrease. A decrease in the nominal interest rate when it is above ρ would decrease the seigniorage and, therefore, the seigniorage effect.

2.9.2 Elastic labor supply

Elastic labor supply introduces an additional distortion of a positive nominal interest rate on welfare—the effect of a smaller market size. That is, a higher nominal interest rate decreases total labor supply via the consumption-leisure choice, ending up decreasing both R&D labor l_r and manufacturing labor l_x. We can show that Proposition 1 still holds with more restrictive parameter space (e.g., when θ is low enough). However, when θ is high enough, Proposition 1 does not hold. Instead, CBI has a positive effect on inflation even when the step-size of innovation is large (see the calibration results in section 2.11).

In summary, under inelastic labor supply, in countries where the step-size of innovation is small, CBI has a positive effect on inflation; however, in countries where the step-size of innovation is large, CBI has a negative effect on inflation. Under elastic labor supply, CBI has a positive effect on inflation even when the step-size of innovation is large.

2.10 Alternative Ways of Introducing CBI

There are other ways to model the role of CBI in the determination of the optimal nominal interest rate and, thus, the inflation rate. For instance, we assume that the entrepreneurs and the government get β and $(1-\beta)$ share of the seigniorage revenue, which is investigated in section 2.10.1. We can also assume that the households and the government get α and $(1-\alpha)$ share of the seigniorage revenue, which is discussed in section 2.10.2. In both cases, a higher degree of CBI would tie the grabbing hand of the government, leading to a larger share of the seigniorage revenue being allocated to entrepreneurs (i.e., a larger value of β) or households ((i.e., a larger value of α).

2.10.1 Seigniorage allocated between entrepreneurs and the government

In this section, we assume that the entrepreneurs and the government get β and $(1-\beta)$ share of the seigniorage revenue. With inelastic labor supply and a CIA on consumption, the labor market clearing condition is

$$l_r + l_x + l_g = 1, \tag{35}$$

where the share of labor employed in the government sector $l_g = L_g/L$ is determined by $w_t L_g = (1-\beta) R_t$. In this case, the money-output ratio ϕ_t is $\phi_t = \frac{1}{1+(i-\rho)}$. The equilibrium labor allocation is

$$l_r = \frac{(\gamma-1)[1+(i-\rho)] + \beta\gamma(i-\rho)}{\gamma[1+(i-\rho)] + \gamma(i-\rho)}\left(1+\frac{\rho}{\varphi}\right) - \frac{\rho}{\varphi}, \tag{36}$$

$$l_x = \frac{1+(i-\rho)}{\gamma[1+(i-\rho)] + \gamma(i-\rho)}\left(1+\frac{\rho}{\varphi}\right), \tag{37}$$

$$l_g = \frac{(1-\beta)\gamma(i-\rho)}{\gamma[1+(i-\rho)] + \gamma(i-\rho)}\left(1+\frac{\rho}{\varphi}\right). \tag{38}$$

Proposition 2 *When β is large (seigniorage revenue mainly goes to entrepreneurs), the optimal nominal interest rate is above zero (i.e., the Friedman rule is sub-optimal), which increases with β. By contrast, when β is small (seigniorage revenue is mainly used to finance non-productive government spending), the Friedman rule is optimal.*

Proof. Plugging equations (36)–(38) into (27) and taking the derivative with respect to the nominal interest rate, we have

$$sign\left(\frac{\partial U}{\partial i}\right) = sign\left\{\left(1+\frac{\varphi}{\rho}\right)(\ln\gamma)(1-\gamma+\beta\gamma) - 2\gamma\left[1+2(i-\rho)\right]\right\}. \tag{39}$$

Solving $\frac{\partial U}{\partial i} = 0$ yields the optimal interest rate as

$$i^* = \left(\rho - \frac{1}{2} + \frac{(1+\varphi/\rho)}{4}\frac{\ln\gamma}{\gamma}(1-\gamma+\beta\gamma)\right) \gtreqless 0. \tag{40}$$

According to equation (40), when β is small, it is possible that $i^* < 0$ and the Friedman rule may be optimal. When the Friedman rule is optimal, a small increase in the degree of CBI has no effect on the nominal interest rate. When β is large, the Friedman rule is sub-optimal (i.e., the optimal nominal interest rate is above zero). Taking the derivative of the optimal nominal interest rate in (40) with respect to β, we have

$$\frac{\partial i^*}{\partial \beta} = \frac{(1+\varphi/\rho)}{4}\ln\gamma > 0. \tag{41}$$

Equation (41) shows that the optimal interest rate increases with β. Q.E.D.

Therefore, when the seigniorage is more likely to be used to subsidize entrepreneurs, a condition that is more likely in developed countries with a high degree of CBI, CBI has a positive effect on the nominal interest rate. The assumption here differs from that in section 2.9.2. In section 2.9.2, the elasticity of labor supply determines the sign of the effect of CBI on inflation: when the elasticity is high, CBI is more likely to have a positive effect on the nominal interest rate and thereby inflation; when it is low, CBI is more likely to have a negative effect on the nominal interest rate. Here, the allocation of the seigniorage revenue between the government and entrepreneurs determines the sign of the effect of CBI on inflation. When the majority of the seigniorage revenue is used to finance non-productive government spending, the Friedman rule is optimal and CBI has no effect on the nominal interest rate; when the seigniorage revenue is mainly channeled to subsidize business-promoting activities, CBI has a positive effect on the nominal interest rate.

2.10.2 Seigniorage allocated between households and the government

Following He and Zou (2016), we assume that the seigniorage revenue retained by the government will hire away more labor (the *government crowding-out effect*). He and Zou (2016, p. 474) rationalize the assumption as follows: "The government uses the seigniorage revenue that it keeps for government expenditures. Unlike the usual assumption of treating government expenditures as government consumption of final goods, we assume that government expenditures require the use of labor for the production of nonproductive and nonutility-enhancing government goods and services."

In this case, with inelastic labor supply, both R&D labor and manufacturing labor are decreasing in the nominal interest rate. It can be shown that the Friedman rule would be optimal under the CIA constraint on consumption. There would be no room for CBI to affect the optimal nominal interest rate. However, if we follow Chu and Cozzi (2014) to assume that the CIA constraint applies to R&D investment instead of consumption (i.e., the CIA constraint becomes $b_t \leq m_t$, where b_t is the amount of money borrowed by entrepreneurs), then R&D overinvestment in equilibrium is a necessary and sufficient condition for Friedman rule to be suboptimal. When there exists R&D overinvestment, the optimal nominal interest rate would be positive. Moreover, it can be shown that the optimal nominal interest rate would also depend on the degree of CBI. In this case with inelastic labor supply, we have

$$(\gamma - 1)\, l_x = (1 + i)\,(l_r + \rho/\varphi)\,. \tag{42}$$

The labor market clearing condition is still $l_r + l_x + l_g = 1$, where l_g is determined by

$$l_g = (1 - \alpha)\,(g + \pi)\,\phi\gamma l_x = (1 - \alpha)\,(g + \pi)\,l_r, \tag{43}$$

where the second equality is derived as follows. Using the binding CIA constraint on R&D investment, we have $bL = mL = w_t L_r$. Using (11), we have $\phi = mL/y = l_r/\,(\gamma l_x)$.

Now the equilibrium labor allocation becomes

$$l_r = \frac{(\gamma - 1)\left[1 + \frac{\rho}{\varphi} + (1 - \alpha)\,(i - \rho)\,\frac{\rho}{\varphi}\right]}{\gamma + i + (\gamma - 1)\,(1 - \alpha)\,(i - \rho)} - \frac{\rho}{\varphi}, \tag{44}$$

$$l_x = \frac{(1 + i)\left[1 + \frac{\rho}{\varphi} + (1 - \alpha)\,(i - \rho)\,\frac{\rho}{\varphi}\right]}{\gamma + i + (\gamma - 1)\,(1 - \alpha)\,(i - \rho)}, \tag{45}$$

$$l_g = \frac{(1 - \alpha)\,(i - \rho)\left[(\gamma - 1) - (1 + i)\,\frac{\rho}{\varphi}\right]}{\gamma + i + (\gamma - 1)\,(1 - \alpha)\,(i - \rho)}. \tag{46}$$

Plugging the labor allocations into the utility function, it is easy to see that the optimal nominal interest rate depends on α (the degree of CBI).

Therefore, we can see that capturing the second argument (i.e., an independent central bank helps to prevent the fiscal authority from financing its expenditures with the seigniorage revenue) is not sufficient for CBI to affect the optimal nominal interest rate. This is because the Friedman rule would be optimal under the CIA constraint on consumption in this case. In this case, the optimal nominal interest rate that maximizes social welfare would depend on the CBI only when the CIA constraint also applies on R&D investment.

To summarize, our model focuses on the allocation of the seigniorage revenue that is affected by the degree of CBI in order to illustrate a novel channel through which CBI would have an impact on the determination of the optimal nominal interest rate and, therefore, the inflation rate. Although some readers may be not convinced that it is a good modeling choice to use the *seigniorage effect*, our prediction does not hinge on this choice. Additionally, despite of the different modelling assumptions, our common prediction is that, CBI is more likely to have a positive effect on the nominal interest rate in developed countries, because developed countries are more likely to have a larger elasticity of labor supply and to feature that the seigniorage revenue is mainly channeled to subsidize business-promoting activities.

In the following we empirically test the prediction of our model. However, the nominal interest rate is difficult to observe across countries. In contrast, data on the rate of inflation is widely accessible and reliable. Because the inflation rate is determined by the nominal interest rate through the Fisher equation, we test the effect of CBI on the inflation rate to check the validity of our theory and further evaluate the importance/magnitude of the channel that we emphasize.

Before the regression analysis in Section 3, we would like to calibrate the model and simulate the quantitative effects of CBI and inflation on growth and social welfare to further increase the empirical appeals of the paper.

2.11 Quantitative Analysis

In this calibration analysis, we focus on the developed/advanced countries. Additionally, we focus on the elastic labor supply case in Section 2.9.2 (the other cases in Section 2.10 can also be calibrated, but we omit them to save space).

Our model has the following set of structural parameters $\{\rho, \gamma, \varphi, \theta, \beta\}$. We follow Chu, Ning, and Zhu (2017) to set the discount rate ρ to a conventional value of 0.04 and the step size of innovation γ to 1.05. We need three conditions to pin down the values of $\{\varphi, \theta, \beta\}$. The first condition is the long-run GDP per capita growth of 1.8% in advanced countries (see e.g., Mehra and Prescott, 1985). The second condition is the standard moment of $l = 0.3$, following Chu and Cozzi (2014). We need another condition. In Section 3, we will regress CBI on the inflation rate to test the predictions of our model. We can use regressions to recover $\frac{\partial i}{\partial CBI}$, but the computation is too messy. As an alternative, we use regressions to recover $\frac{\partial g}{\partial CBI}$, where the growth rate g is $g = (\varphi \ln \gamma)\, l_r$, where l_r is given in (24). We use the PWT 9.0 to construct the growth rate as the growth rate of annual real GDP per employment (see Section 3.5 for details), denoted $growth$. Then we regress the growth rate on CBI, controlling for conditional convergence, the other important variables, and fixed time effects (see Section 3 for details). The IV regression results (see Section 4.2 for the details of the IV regression, including using the legal origins as instruments for CBI) for developed countries are as follows:

$$growth_t = 0.0165 \times CBI_t + (Controls)_t + T_t + \varepsilon_t, \tag{47}$$

where $Controls$ are the other explanatory variables (explained in Section 3), and T_t stands for the year fixed effects. Therefore, we take the predicted value of 0.0165 for $\frac{\partial g}{\partial CBI}$. Now we pin down the values of $\{\varphi, \theta, \beta\}$ by solving the following three equations:

$$g = (\varphi \ln \gamma)\, l_r = 0.018, \tag{48}$$

$$l = 0.3, \tag{49}$$

$$\frac{\partial g}{\partial \beta} = \frac{\partial g}{\partial CBI} = 0.0165, \tag{50}$$

where l_r in (48) is given in (24); l in (49) is given in (26).

It is worth discussing that we have taken a short-cut here concerning (50). The reason is that β is a proxy for CBI (or vice versa), but they are not the same thing. We have $\frac{\partial g}{\partial CBI} = \frac{\partial g}{\partial \beta}\frac{\partial \beta}{\partial CBI}$. If we have $\frac{\partial \beta}{\partial CBI}$, we can recover $\frac{\partial g}{\partial \beta} = \frac{\partial g}{\partial CBI} / \frac{\partial \beta}{\partial CBI}$. However, we do not have the necessary data on the share of the seigniorage revenue allocated to entrepreneurs across countries (i.e., we do not have $\frac{\partial \beta}{\partial CBI}$). Therefore, we have used the implicit assumption $\frac{\partial \beta}{\partial CBI} = 1$ in (50). Nevertheless, in the following, we will take different values of $\frac{\partial \beta}{\partial CBI}$ and thereby $\frac{\partial g}{\partial \beta}$ to re-evaluate the growth and welfare effects.

We also have $i = 0.083$, which is our calculated sample value because $i = \pi + r = \pi + \rho + g$ (our sample mean of inflation rate is 2.51% for developed countries). Solving equations (48)–(50) yields the values of $\{\varphi, \theta, \beta\}$ to be $\{25.92, 2.16, 0.116\}$. To summarize, we pin down the parameter values $\{\rho, \gamma, \varphi, \theta, \beta\}$ as $\{0.04, 1.05, 25.92, 2.16, 0.116\}$.

According to the calibration results in columns 1.1 and 1.2 of Table 1, when the step-size of innovation γ is below 1.01, the Friedman rule is optimal. When i decreases from the benchmark value of 8.3% to 0, the equilibrium rate of economic growth decreases from the benchmark value of 0.06% to 0.003%, and the welfare gain ΔU is equivalent to a permanent increase in consumption of 0.28%. Columns 1.3-1.6 of Table 1 illustrate that the optimal nominal interest rate is positive when the step-size of innovation γ is larger than 1.01, and the Friedman rule is suboptimal. Additionally, the optimal nominal interest rate increases with the step-size of innovation γ. Columns 1.5 and 1.6 report the calibration results for $\gamma = 1.05$. When i increases from the benchmark value of 8.3% to the optimal value of 102.2%, the equilibrium rate of economic growth increases from the benchmark value of 1.80% to 3.57%, and the welfare gain ΔU is equivalent to a permanent increase in consumption of 18.56%. After that, any further increase in the nominal interest rate will decrease the social welfare. Additionally, comparing the results in column 1.4 to those in column 1.6 of Table 1 shows that the optimal nominal interest rate increases with β under elastic labor supply.

Table 1: Calibration Results

	Column number					
	1.1	1.2	1.3	1.4	1.5	1.6
	$\{\rho, \varphi, \theta, \beta\} = \{0.04, 25.92, 2.16, 0.116\}$					
	$\gamma \leq 1.01$		$\gamma = 1.04$		$\gamma = 1.05$	
i	8.3%	0	8.3%	81.3%	8.3%	102.2%
g	0.08%	0.003%	1.17%	1.41%	1.80%	3.57%
ΔU	n/a	0.28%	n/a	11.78%	n/a	18.56%

Note: i is the nominal interest rate. g is per capita growth rate.

ΔU is the welfare gain (equivalent to a permanent increase in consumption).

As discussed, it is meaningful for us to take different values of $\frac{\partial \beta}{\partial CBI}$ and thereby $\frac{\partial g}{\partial \beta}$ to re-evaluate the growth and welfare effects. We find that when $\frac{\partial \beta}{\partial CBI}$ is below about 0.9, there will be no solutions. Therefore, we take the following three values of $\frac{\partial \beta}{\partial CBI}$: 0.9, 0.95, and 1.05. The calibration results are presented in Table 2. One can observe that the growth and welfare effects significantly depend on the value of $\frac{\partial \beta}{\partial CBI}$ and, therefore, β. A higher value of $\frac{\partial \beta}{\partial CBI}$ yields a larger value of calibrated β, which increases the growth and welfare effects when i increases from the benchmark value of 8.3% to the optimal value. Comparing the results in Table 1 and Table 2, we deem the growth and welfare effects in columns 2.3 and 2.4 to be more realistic.

Table 2: Calibration Results

	Column number					
	2.1	2.2	2.3	2.4	2.5	2.6
	$\{\rho, \gamma\} = \{0.04, 1.05\}$					
	$\frac{\partial \beta}{\partial CBI} = 0.9$		$\frac{\partial \beta}{\partial CBI} = 0.95$		$\frac{\partial \beta}{\partial CBI} = 1.05$	
	$\{\varphi, \theta, \beta\} =$					
	$\{28.46, 2.14, 0.0014\}$		$\{27.12, 2.15, 0.059\}$		$\{23.85, 2.18, 0.230\}$	
i	8.3%	0	8.3%	28.1%	8.3%	201.8%
g	1.80%	1.91%	1.80%	1.99%	1.80%	6.98%
ΔU	n/a	2.98%	n/a	1.02%	n/a	82.52%

Note: i is the nominal interest rate. g is per capita growth rate.

ΔU is the welfare gain (equivalent to a permanent increase in consumption).

As discussed, Proposition 1 holds only when the elasticity of labor supply is low. It is meaningful for us to check the validity of Proposition 1. We also calibrate the case of $\theta = 0$ and $\beta = 0.059$ and report the results in Table 2. Under inelastic labor supply, when the step-size of innovation is above a threshold, the optimal nominal interest rate is positive, which decreases with β. The optimal nominal interest rates under inelastic labor supply in the counterfactual cases (in Table 2) are much higher than those under elastic labor supply (Table 1) because the negative market-size effect is absent. That is, a higher nominal interest rate will not decrease labor supply under inelastic labor supply, leaving more room for a higher nominal interest rate and thereby a larger seigniorage revenue in subsidizing entrepreneurs to raise growth and social welfare.

Table 3: Calibration Results

	Column number						
	2.1	2.3	2.4	2.5	2.6	2.7	2.8
	$\{\rho, \varphi\} = \{0.04, 25.92\}$ and $\theta = 0$						
	$\gamma \leq 1.003$		$\gamma = 1.0031$			$\gamma = 1.05$	
		$\beta = 0.059$	$\beta = 0.08$	$\beta = 0.12$	$\beta = 0.059$	$\beta = 0.08$	$\beta = 0.12$
i^*	0	5.1%	4.8%	4.5%	11935%	8803%	5870%

Note: i^* is the optimal nominal interest rate.

3 The Data

3.1 Empirical Specification

Before we construct the variables, we present the following empirical specification:

$$\pi_{it} = \beta_1 \pi_{i,t-1} + \beta_2 CBI_{i,t} + \beta_3 (Controls) + \theta_i + T_t + \varepsilon_{it}, \quad (51)$$

$$\log(1+\pi)_{it} = \beta_1 \log(1+\pi)_{i,t-1} + \beta_2 CBI_{i,t} + \beta_3 (Controls) + \theta_i + T_t + \varepsilon_{it}, \quad (52)$$

where π_{it} is the average annual rate of inflation at year t for country i, and CBI stands for the degree of CBI.[3] *Controls* are the other explanatory variables (explained below). θ_i and T_t stand for the country fixed effects and year fixed effects, respectively.

Existing studies have used several transformed measures of the inflation. For instance, some researchers have used the logarithm of (1+inflation rate) (see Dincer and Eichengreen, 2014). To be comparable with existing studies, we will use the logarithm of (1+inflation rate) as the dependent variable. Nevertheless, we will check the robustness of our results by using the change in CPI as the measure of inflation.

[3] It is also worth mentioning that in our empirical specification, we have used the current value of CBI. Nevertheless, our results remain robust when we used the lagged value of CBI to mitigate the simultaneity problem in the previous version of the paper.

There is no prior about whether we should control for the lagged dependent variable in the regressions. However, according to the Phillips curve, inflation would depend on its past value (one can explain this as adaptive expectation). Therefore, it is possible that changes in inflation rates are persistent over time. With the lagged dependent variable included, the dynamic panel data specification will allow us to use the most efficient system, GMM, proposed by Blundell and Bond (1998) to deal with the potential endogeneity of CBI and all the other independent variables, using internal instruments (i.e., the differences and lagged differences of the independent variables as instruments for the level equation; see elaboration in Roodman, 2006). Nevertheless, we have checked the robustness of our results by using the static specification and using legal origins as instruments.

To get more control variables to avoid the potential omitted variable bias, we follow the Phillips curve literature (see Zhang, Osborn, & Kim, 2008, for a study on the New Keynesian Phillips Curve). According to the Phillips curve, inflation would also depend on the output gap (the difference between output and its potential). At any point of time, potential output is assumed to be fixed; therefore, inflation would then depend on the factors impacting output. Thus, we control for output per capita (e.g., Dincer & Eichengreen, 2014). Output per capita is included because advanced and developed countries on average have lower levels of inflation. To mitigate its potential endogeneity problem, we use the lagged value of output per capita. That is, we control for $\ln\left(\frac{GDP}{emp}\right)_{t-1}$, the logarithm of real GDP per employment for the previous year. We also control for factors that may impact output. Specifically, we control for I/GDP and $Human$, the physical capital investment rate and human capital indicator, respectively. The control variable *labor* measures labor force growth. The level of government spending may also have an effect on the inflation rate, and we include the ratio of government spending to GDP ratio, denoted GOV/GDP, in the regression.

The existing literature also offer a standard set of variables that explain inflation differences across countries. These variables include trade openness and financial depth. Therefore, we further control for the share of current account surplus to GDP, denoted CA/GDP, and financial depth, denoted FD/GDP. There is no theoretical explanation for trade openness to impact the inflation rate. However, the current account status may have an impact on it. A country having a current account deficit may have experienced an economic downturn, raising people's expectation of inflation and, in this way, the real inflation rate.

3.2 The Data Sample

For most of the other control variables, we use the recent PWT 9.0. This provides the most complete and recent data for all the countries during 1950–2014. Considering our control variables, we exclude from our sample those countries that do not have data on employment (the *emp* series in PWT 9.0) and/or human capital (the *hc* series in PWT 9.0). This leaves us with 144 countries in the sample.

For the measure on CBI, we follow the recent study of Dincer and Eichengreen (2014). They do not report the data on CBI for countries with the euro as their currency. Furthermore, some countries in Dincer and Eichengreen (2014) do not have data on employment and/or human capital. Taken together, our final sample has 68 countries with complete data. See the Appendix A for the countries in our sample. Our sample consists of both developing and developed countries. Out of these, there are 12 countries identified as advanced—namely, Australia, Canada, the United Kingdom, Iceland, Israel, Japan, the Republic of Korea, Norway, New Zealand, Singapore, Sweden, and the United States.

Because the CBI sample in Dincer and Eichengreen (2014) covers 1998–2010, we use this same period when using the current values of CBI. Therefore, our final sample, consisting of 68 countries over 1998–2010, provides a balanced panel of 884 observations. Our final sample size may be smaller, depending on the missing observations of different variables.

3.3 Measuring the Inflation Rate

In some studies, the inflation rate is measured as the percentage change in the CPI (see Aghion et al., 2009). As discussed, in the CBI-inflation nexus literature, authors have usually used the logarithm of (1+inflation rate) as the dependent variable (see Dincer & Eichengreen, 2014). We follow suit. As discussed, we will check the robustness of our results by using the change in CPI as the measure of inflation. The PWT 9.0 does not provide data on CPI. For this reason, we acquire this data from the IFS of the IMF to obtain the data on CPI for over 100 countries (including the 68 countries in our sample) during 1950–2015. Table 1 reports the summary statistics of the inflation rate in our sample.

[Table 1 Here]

3.4 Measuring Central Bank Independence

The seminal study of Bade and Parkin (1988) was among the first to empirically investigate the variations in the degree of CBI across countries. Following this, there emerged a large body of literature measuring CBI (see Alesina, 1988; Cukierman, Webb, & Neyapti, 1992; and Alesina & Summers, 1993, for early studies; and Dincer & Eichengreen, 2014; Garriga, 2016, for recent contributions). We use the most recent data on CBI from Dincer and Eichengreen (2014) (DE hereafter). DE report updated measures of independence for more than 100 central banks during 1998–2010. DE follow Cukierman, Webb, and Neyapti (1992) (CWN hereafter) but add other aspects of CBI emphasized in the subsequent literature to measure CBI. Specifically, DE use the sixteen criteria employed by CWN and eight additional criteria (twenty-four in total, see DE, pp. 218–219 for details).

DE first aggregate their twenty-four criteria into nine as follows: "(1) The five variables regarding appointment of the CEO are aggregated into one using equal weights; (2) the four variables under policy formulation are aggregated into one using equal weights; (3) the objectives criterion stands on its own as number 3; (4–7) the first four criteria on limits on lending are each treated as a separate variable; (8) the last four criteria on limits on lending are aggregated into a single variable using equal weights; and (9) the criteria regarding board members is treated as a single variable" (DE, p. 219). Each criterion is coded on a scale of 0 (lowest degree of CBI) to 1 (highest degree of CBI). The final aggregate measure on CBI also ranges from 0 to 1 (lowest and highest degrees of CBI, respectively). DE compute two indices on CBI by aggregating the nine variables: CBIW is the weighted average of the nine aggregated variables, and CBIU is the corresponding unweighted average. Because DE report the data on CBIW, we use CBIW to measure CBI, denoted CBI. The summary statistics on CBI is presented in Table 1.

If CBI does not change much over time, time dimension is not necessary. Therefore, we have checked whether the CBI measure varies a great deal over time within a country. In our sample (see the Appendix), 25 out of 68 countries experienced a change in the degree of CBI during 1998–2010 (most of the countries are developing countries, but some are advanced, developed ones—namely, Australia, the United Kingdom, Iceland, Norway, and New Zealand).

As CBI does change over time, we report the results from panel data regressions. The advantage of panel data regression is that it allows us to control for fixed country effects. We have checked the results from cross-country regressions, and we have found that the results from cross-country regressions differ greatly from those from panel data regressions. Therefore, cross-country regressions without controlling for country fixed effects would suffer from the bias from omitting such effects.

3.5 Measuring Control Variables

For financial depth, we have used the WDI of the World Bank to obtain the necessary data. Specifically, we measure financial depth (i.e., FD/GDP) as the indicator "Domestic credit to private sector (% of GDP)". Our control variable current account balance is constructed as follows. We add together the csh_x (the ratio of export value to GDP) and csh_m (the ratio of import value to GDP, the numbers are negative) series in PWT 9.0 to get the share of current account to GDP (i.e., CA/GDP). Our government spending variable is GOV/GDP, which is the ratio of government spending to GDP. We use the csh_g series in PWT 9.0.

According to Feenstra, Inklaar, and Timmer (2015, p. 3157): "If the sole object is to compare the growth performance of economies, we would recommend using the $RGDP^{NA}$ series (and this is closest to earlier versions of PWT)." Thus, we use the $RGDP^{NA}$ series to measure real GDP. Dividing the $RGDP^{NA}$ series by the emp series in PWT 9.0 would yield real GDP per employment. Initial real GDP per employment (i.e., $(RGDP/emp)_{t-1}$) takes the value of the previous year. The physical and human capital investment rates (i.e., *I/GDP* and *Human*) are measured by the *csh_i* and *hc* series, respectively, in PWT 9.0. The labor force growth measure, *labor*, is measured as the sum of the labor force growth rate and 0.05.[4] The labor force growth rate is measured as the annual growth of the *emp* series in PWT 9.0.

Table 1 presents the summary statistics of the final data.

4 Estimation Results

4.1 System GMM Estimation

Although our theory does not predict a feedback effect from inflation to CBI, inflation may have an effect on CBI by affecting growth in real world situations. As discussed, the dynamic panel data specification will allow us to use system GMM to deal with the potential endogeneity of CBI and all the other independent variables. The system GMM estimation has become popular in aggregate level studies (see Aghion et al., 2009). Aghion et al. (2009) use dynamic panel data and system GMM estimation to test the interaction effect between exchange rate regimes and financial development in promoting growth.

Our model has the characteristics (especially "large N and small T") listed in Roodman (2006). Therefore, we use the most efficient system GMM estimator to establish a causal relationship between inflation and CBI. Since we use macro-level data, it is possible that other explanatory variables may also be endogenous due to reverse causality. However, since we use yearly data, we have enough observations to deal with the potential endogeneity problem of all the important explanatory variables. In using the system GMM estimation, we treat lagged variables as predetermined and the other variables as endogenous. Moreover, following Roodman (2006), the fixed country dummies are excluded, while the year dummies are used as exogenous instruments in xtabond2 in Stata (the proprietor program written by Roodman, 2006, and used in our analysis).

Moreover, because the two-step GMM is asymptotically more efficient than the corresponding one-step GMM, we use the two-step system GMM estimation. However, the two-step GMM presents estimates of the standard errors that tend to be severely downward biased. To solve this problem, Windmeijer (2005) proposes a small-sample correction for the two-step standard errors that will lead two-step robust estimations to be more efficient than corresponding one-step estimations, especially for system GMM. Thus, we take the Windmeijer correction into account in using two-step system GMM estimations. Furthermore, to make sure our results are not driven by outliers, we delete the outliers with annual inflation rates above 100% (our results remain robust without dropping the outliers, and the inflation rates in developed countries were all below 100% in our sample). The two-step system GMM estimation results are presented in Table 2.

[4] That is, we follow Mankiw et al. (1992) to use 0.05 for $(g + \delta)$. That is, we assume a 2% world annual growth (i.e., g) and a 3% depreciation rate (i.e., δ).

According to Table 2, both the Hansen and the difference-in-Hansen tests confirm that the instrument set can be considered valid. The F-test shows that the overall regression is significant. The Arellano-Bond AR(2) test accepts the hypothesis of no autocorrelation of the second order. Following Roodman (2006), we have collapsed the instruments to deal with the instruments proliferation problem. Now the number of instruments is smaller than the number of groups (i.e., 68). These support system GMM estimation.

Regression 2.1 of Table 2 present the system GMM estimation for the full sample of both advanced and developing countries. The results indicate that the estimated coefficient on CBI is positive and significant at the 5% level. Regression 2.3 of Table 2 reports the results with annual inflation below 50%. The estimated coefficient on CBI remains positive and significant at the 5% level.

[Table 2 Here]

4.1.1 Samples with Developing Countries

According to our theory (e.g., Propositions 1 and 2 and discussions therein), it may not be a good idea to put the advanced and developing countries together in a regression. This is because the advanced and developing countries may differ a lot. First, they may differ in the step-size of innovation. Second, the elasticity of labor supply may be different. Third, the share of the seigniorage revenue in subsidizing business-promoting activities may be much larger in developed countries with a higher degree of CBI.

Therefore, it is meaningful to check whether differences exist between our results for advanced countries and those for developing ones. As discussed, our sample consists of 68 countries, among which 12 are advanced and 56 are developing. We have split the sample into two: one with 12 advanced countries and the other with 56 that are developing. The system GMM estimation usually applies to samples with "large N and small T". Therefore, we only report the results with the sample of 56 developing countries. The results in regression 2.2 of Table 2 indicate that the estimated coefficient on CBI is positive and significant at the 10% level in the sample of developing countries. Regression 2.4 indicates that the results remain robust when using the sample with annual inflation below 50%.

4.1.2 Using the Inflation Rate as the Dependent Variable

We have also checked the results with the change in CPI as the dependent variable. The system GMM estimation results are presented in Table 3. This table shows that both the Hansen and the difference-in-Hansen tests confirm that the instrument set can be considered valid. The F-test indicates that the overall regression is significant. The Arellano-Bond AR(2) test accepts the hypothesis of no autocorrelation of the second order. Following Roodman (2006), we have collapsed the instruments to deal with the instrument proliferation problem. Now the number of instruments is smaller than the number of groups (i.e., 68). These support system GMM estimation.

Regression 3.1 of Table 3 presents the system GMM estimation for the full sample of both advanced and developing countries. The results indicate that the estimated coefficient on CBI remains positive and significant at the 10% level. Regression 3.3 of Table 3 reports the results with annual inflation below 50%. The estimated coefficient on CBI remains positive but becomes insignificant at the 10% level. The results in regression 3.2 of Table 3 indicate that the estimated coefficient on CBI is positive and insignificant at the 10% level in the sample of developing countries. The results remain robust when use the sample with annual inflation below 50% (see regression 3.4).

[Table 3 Here]

4.2 IV Estimation

As discussed, there may be a large difference between the *de jure* and the *de facto* measures of CBI, especially in developing countries. As the *de jure* measure of CBI may be related to the rule of law in a country, here we use static panel data and legal origins as instruments in IV regressions to check the robustness of our results.

We get the data on "The Quality of Government" by La Porta et al. (1999). To do so, we accessed http://scholar.harvard.edu/shleifer/publications/quality-government to acquire the data on legal origins. The legal origins are represented by five dummy variables—*legor_uk, legor_fr, legor_so, legor_ge,* and *legor_sc*,—meaning that the legal origins are British, French, Socialist, German, and Scandinavian, respectively. The data on legal origins cover years before 1997 (see La Porta et al., 1999). Because these data on legal origins have no time dimension, we cannot control for fixed country effects. We still control for fixed year effects.

Table 4 presents the first-stage results of the 2SLS (two-stage least squares) estimation. According to regression 4.1 of Table 4, legal origins have significant effects on CBI during 1998–2010. Regressions 4.2 and 4.3 indicate that the instruments also have significant effects on CBI in advanced and developing countries, respectively. The values of the F-test statistics on the excluded instruments are all much larger than 10, the rule of thumb for indicating strong instruments provided by Staiger and Stock (1997). Therefore, the instruments are strong, and we use 2SLS estimation.

[Table 4 Here]

The corresponding second-stage results of the 2SLS estimation are presented in Table 5. Regression 5.1 of Table 5 indicates that the estimated coefficient on CBI is insignificant, meaning CBI has no significant, causal effect on inflation in the full sample. The Sargan overidentification tests yield a p-value above 10%, meaning the instruments are valid.

When we split the full sample into advanced and developing countries, regression 5.2 of Table 5 indicates that the estimated coefficient on CBI is positive and significant at the 1% level in advanced countries, meaning CBI has a significant, positive, causal effect on inflation in advanced countries during 1998–2010. The Sargan overidentification tests yield a p-value below 10%, meaning the instruments are invalid. This may be due to the blunt instruments problem (see Bazzi & Clemens, 2013). In contrast, regression 5.3 of Table 5 indicates that the estimated coefficient on CBI is positive and insignificant in developing countries. The Sargan overidentification tests yield a p-value above 10%, meaning the instruments are valid in developing countries.

[Table 5 Here]

We have checked the robustness of our results by using the logarithm of (1+inflation rate) as the dependent variable. The second-stage results of the 2SLS estimation are presented in Table 6. Regression 6.1 of Table 6 indicates that the estimated coefficient on CBI is negative and insignificant at the 10% level. One can observe that the Sargan overidentification tests yield a p-value below 10%, meaning the instruments may affect inflation through other channels (i.e., the instruments are invalid). Regression 6.2 of Table 6 indicates that the estimated coefficient on CBI is positive and significant at the 1% level in advanced countries. In contrast, regression 6.3 of Table 6 indicates that the estimated coefficient on CBI is negative and insignificant in developing countries. The Sargan overidentification tests yield a p-value above 10%, meaning the instruments are valid in developing countries.

[Table 6 Here]

As discussed, our results can be rationalized by our theory. When the step-size of innovation is above a threshold in all countries, the elasticity of labor supply may be larger in developed countries. As a result, CBI would have a positive effect on the optimal nominal interest rate and, therefore, the inflation rate in advanced countries, while CBI would a negative effect on the optimal nominal interest rate and, therefore, the inflation rate in developing countries. Additionally, our results can also be rationalized by the allocation of seigniorage between government and the entrepreneurs as illustrated in Proposition 2: when the majority of the seigniorage revenue is used to finance non-productive government spending (a situation more commonly found in developing countries), the Friedman rule is optimal and CBI has no effect on the nominal interest rate; when the seigniorage revenue is mainly channeled to subsidize business-promoting activities (a condition that is more likely in developed countries,), CBI has a positive effect on the nominal interest rate.

5 Conclusion

There is a long-standing debate over the effect of CBI on inflation. In this paper, we first use a monetary Schumpeterian model to investigate how CBI affects inflation. We find that we cannot predict a monotone relationship between CBI and inflation. Under inelastic labor supply, when the step-size of innovation is small, CBI has a positive effect on inflation, and when it is large, it has a negative effect. Moreover, when the elasticity of labor supply is high and/or the seigniorage is mainly used to finance entrepreneurs, a condition that is more likely in developed countries, CBI has a positive effect on inflation; in contrast, when labor supply is inelastic and/or the seigniorage is mainly used to finance non-productive government spending, a situation more commonly found in developing countries, CBI has a negative effect or no effect on inflation.

We calibrate the model to estimate the growth and welfare effects. We find the following. When the nominal interest rate i increases from 8.3% (the sample mean) to the optimal value of 28.1%, the equilibrium rate of economic growth increases from the benchmark value of 1.8% to 1.99%, and the welfare gain is equivalent to a permanent increase in consumption of 1.02%. After that, any further increase in the nominal interest rate will decrease the social welfare. The growth and welfare effects are much larger with a larger value of CBI. Additionally, under elastic labor supply, the optimal nominal interest rate increases with the degree of CBI. We also calibrate the case of inelastic labor supply. Under inelastic labor supply, when the step-size of innovation is above a threshold, the optimal nominal interest rate is positive, which decreases with the degree of CBI.

We then test the effect of CBI on inflation. Using inflation data from the IFS of the IMF, CBI data from Dincer and Eichengreen (2014), World Bank data, and PWT 9.0 data, we build panel data for 68 countries during 1998–2010. We find the effect of CBI on inflation is positive and significant (at the 5% level) in system GMM estimation that deals with the endogeneity of CBI. Our results remain robust to the consideration of financial crises.

When we split the sample into advanced and developing countries, our empirical findings match better with our prediction. The effect of CBI on inflation is positive and significant in advanced countries, and it is insignificant in developing countries in both system GMM and 2SLS estimations. Our empirical findings provide support for our theory, which also helps to resolve the debate over the effect CBI has on inflation.

For future research, one may need to look into real-world institutional arrangements and details to investigate the impact of CBI. For instance, one can analyze how central banks operate and evolve in an economy, including how they allocate seigniorage, manage financial assets, and improve their own efficiency (see Ize, 2007, for an early contribution). Studies along this line would be important for us to further investigate the role of CBI in the making of monetary policy.

Appendix A: Data on Central Bank Independence

		Data on CBI in year												
	Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Angola	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
2	Albania	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
3	United Arab Emirates	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
4	**Argentina**	0.62	0.62	0.62	0.62	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
5	**Armenia**	0.66	0.66	0.66	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
6	**Australia**	0.22	0.22	0.22	0.22	0.19	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.18
7	**Bulgaria**	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.58	0.58	0.58	0.58	0.58	0.58
8	Belize	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
9	Barbados	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
10	Botswana	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
11	Canada	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
12	**Chile**	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.69	0.69	0.69	0.69
13	China	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
14	Colombia	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
15	**Czech Republic**	0.64	0.64	0.70	0.70	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
16	Fiji	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
17	**United Kingdom**	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.23	0.23
18	Croatia	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
19	**Hungary**	0.47	0.52	0.52	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
20	Indonesia	–	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
21	India	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
22	**Iraq**	0.26	0.26	0.26	0.26	0.26	0.26	0.69	0.69	0.69	0.69	0.69	0.69	0.69
23	**Iceland**	0.17	0.17	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.69	0.69
24	**Israel**	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.52
25	Jamaica	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
26	Jordan	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
27	Japan	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
28	Kenya	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
29	Kyrgyzstan	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
30	Cambodia	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
31	Republic of Korea	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
32	Lao People's DR	–	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
33	**Sri Lanka**	0.57	0.57	0.57	0.57	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
34	Lesotho	–	–	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
35	Republic of Moldova	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68

Appendix A

(continued)

	Country	Data on CBI in year												
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
36	**Maldives**	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.17	0.17	0.17	0.17
37	Mexico	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
38	Mongolia	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
39	Mozambique	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
40	**Mauritius**	0.32	0.32	0.32	0.32	0.32	0.32	0.39	0.39	0.39	0.43	0.48	0.48	0.48
41	Malawi	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
42	**Malaysia**	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.49	0.49
43	Namibia	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
44	**Nigeria**	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.51	0.51	0.51	0.51
45	**Norway**	0.11	0.11	0.11	0.11	0.11	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
46	**New Zealand**	0.22	0.22	0.22	0.22	0.22	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.18
47	Peru	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
48	Philippines	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
49	**Poland**	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.37
50	**Romania**	0.60	0.60	0.60	0.60	0.60	0.60	0.79	0.79	0.79	0.79	0.79	0.79	0.79
51	Russian Federation	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
52	Saudi Arabia	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
53	Singapore	–	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
54	Sierra Leone	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
55	El Salvador	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
56	Sweden	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
57	Syrian Arab Republic	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
58	**Thailand**	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.26	0.26
59	Trinidad and Tobago	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
60	Tunisia	–	–	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
61	**Turkey**	0.42	0.42	0.42	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
62	**U.R. of Tanzania**	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.56	0.56	0.56	0.56	0.56
63	Uganda	–	–	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
64	United States	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
65	**Venezuela**	0.16	0.16	0.16	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
66	**Yemen**	0.29	0.29	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
67	South Africa	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
68	Zambia	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36

Source: Dincer and Eichengreen (2014). Countries experienced a change in CBI are in bold letters.

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Table 1: Descriptive Statistics

	Observations	Mean	Standard deviation	Minimum	Maximum
π *(%)*	854	8.75	18.82	−35.84	325.00
$\ln(1{+}\pi)$	836	1.78	1.00	−2.75	5.79
CBI	875	0.44	0.20	0.09	0.83
CA/GDP	884	-0.03	0.16	-0.56	0.63
$\ln(FD/GDP)$	883	3.43	1.09	0.24	5.74
$\ln(GOV/GDP)$	884	2.82	0.42	0.51	3.75
$\ln(GDP/emp)_{t-1}$	884	10.09	1.03	7.01	12.31
$\ln(Human)$	884	0.89	0.28	0.12	1.31
$\ln(I/GDP)$	884	3.01	0.38	1.40	4.13
$\ln(labor)$	866	1.89	0.50	−3.50	3.53

Note: the data are from the PWT 9.0 (unless indicated otherwise), covering 68 countries during 1998-2010. π is the inflation rate using the CPI data of IFS of IMF (in percentage term). *CBI* is the CBI measure constructed in Dincer and Eichengreen (2014). *FD/GDP* is the indicator "Domestic credit to private sector (% of GDP)" of the World Bank. *CA/GDP and GOV/GDP* are the ratios of current account and government spending to GDP, respectively. *GDP/emp* is real GDP per employment (in 2011 us$). *Human* measures human capital. *I/GDP* is the investment rate. *labor* is the employment growth. The variables are are multiplied by 100 before taking logarithms.

Table 2. System GMM Estimation betwen CBI and Inflation

Dynamic Panel-Data Estimation, Two-step System GMM. Dep. vari.: log(1+π) during 1998-2010

	Regression number			
	2.1	2.2	2.3	2.4
	$\pi < 100$		$\pi < 50$	
Indep. Variable	all countries	developing countries	all countries	developing countries
CBI	2.53**	2.70*	2.73**	2.72*
	(1.67)	(1.50)	(1.14)	(1.48)
$\ln(1+\pi)_{t-1}$	0.41***	0.39***	0.43***	0.40***
	(0.08)	(0.10)	(0.08)	(0.11)
CA/GDP	−0.03	−0.47	−0.45	−0.73
	(0.96)	(1.28)	(0.94)	(1.10)
$\ln(FD/GDP)$	−0.11	−0.40	−0.12	−0.47
	(0.42)	(0.45)	(0.39)	(0.37)
$\ln\left(\frac{GDP}{emp}\right)_{t-1}$	−0.17	−0.13	0.20	−0.13
	(0.24)	(0.38)	(0.32)	(0.40)
$\ln(GOV/GDP)$	−0.69	−1.22*	−0.51	−1.30**
	(0.65)	(0.61)	(0.63)	(0.52)
$\ln(I/GDP)$	−0.62*	−0.70**	−0.13	−0.61*
	(0.31)	(0.27)	(0.34)	(0.24)
$\ln(Human)$	0.61	0.55	−0.14	0.73
	(1.22)	(1.49)	(0.78)	(1.39)
$\ln(labor)$	0.05	−0.03	0.10	−0.03
	(0.11)	(0.14)	(0.11)	(0.13)
Time FE	YES	YES	YES	YES
Financial Crises Dummy	YES	YES	YES	YES
Hansen OverID test (p-value)	0.16	0.38	0.16	0.61
Difference-in-Hansen (p-value)	0.17	0.30	0.23	0.29
Number of Instruments	39	39	39	39
Arellano-Bond test for AR(2)	0.18	0.42	0.16	0.41
F-test	67.12***	38.03***	62.54***	43.65***
Observations	736	595	730	589

Note: lagged dependent variables are treated as predetermined. All other variables except the time dummies are treated as endogenous. Time dummies are used as instruments. π is the inflation rate using the CPI data of IFS of IMF. *CBI* is the CBI measure in Dincer and Eichengreen (2014). *GDP/emp* is real GDP (in 2011 us $) per employment. *CA/GDP, GOV/GDP, and FD/GDP* are the ratios of current account, government spending, and domestic credit to the private sector to GDP, respectively. *I/GDP* is the investment rate. *Human* is human capital. *labor* is the employment growth. ***Significant at the 0.01 level, ** at the 0.05 level, * at the 0.10 level
(corrected standard errors in parentheses)

Table 3. System GMM Estimation betwen CBI and Inflation

Dynamic Panel-Data Estimation, Two-step System GMM. Dep. vari.: π during 1998-2010

	Regression number			
	3.1	3.2	3.3	3.4
	$\pi < 100$		$\pi < 50$	
Indep. Variable	all countries	developing countries	all countries	developing countries
CBI	27.55*	47.29	32.37	59.48
	(15.19)	(40.70)	(19.99)	(41.27)
π_{t-1}	0.67***	0.61***	0.78***	0.70***
	(0.12)	(0.15)	(0.18)	(0.19)
CA/GDP	10.00	16.01	22.21	23.94
	(13.74)	(19.36)	(22.73)	(20.56)
$\ln(FD/GDP)$	4.64	5.67	6.08	7.69
	(3.50)	(5.41)	(4.56)	(5.63)
$\ln\left(\frac{GDP}{emp}\right)_{t-1}$	−0.84	0.32	−4.06	−3.50
	(4.10)	(7.09)	(5.96)	(8.40)
$\ln(GOV/GDP)$	−4.68	−0.82	−2.67	0.19
	(4.85)	(7.09)	(8.01)	(8.39)
$\ln(I/GDP)$	8.58	8.70	8.77	6.98
	(6.37)	(7.35)	(6.26)	(6.93)
$\ln(Human)$	−3.75	−4.49	2.86	3.56
	(12.33)	(16.43)	(14.09)	(18.92)
$\ln(labor)$	5.07	3.81	8.95	11.06
	(5.62)	(11.13)	(9.27)	(14.18)
Time FE	YES	YES	YES	YES
Financial Crises Dummy	YES	YES	YES	YES
Hansen OverID test (p-value)	0.86	0.64	0.83	0.71
Number of Instruments	30	30	30	30
Arellano-Bond test for AR(2)	0.65	0.69	0.73	0.68
F-test	28.03***	24.89***	12.33***	16.15***
Observations	765	622	759	616

Note: lagged dependent variables are treated as predetermined. All other variables except the time dummies are treated as endogenous. Time dummies are used as instruments. π is the inflation rate using the CPI data of IFS of IMF. *CBI* is the CBI measure in Dincer and Eichengreen (2014). *GDP/emp* is real GDP (in 2011 us $) per employment. *CA/GDP, GOV/GDP, and FD/GDP* are the ratios of current account, government spending, and domestic credit to the private sector to GDP, respectively. *I/GDP* is the investment rate. *Human* is human capital. *labor* is the employment growth. ***Significant at the 0.01 level, ** at the 0.05 level, * at the 0.10 level (corrected standard errors in parentheses)

Table 4. 2SLS Regressions (annual inflation $\pi < 100$)

First-stage results (first-stage dep. vari. *CBI* 1998-2010)

	Regression number		
	4.1	4.2	4.3
	Sample		
Indep. Variable	all countries	rich countries	poor countries
legor_uk	-0.31^{***}	-0.39^{***}	-0.26^{***}
	(0.03)	(0.03)	(0.02)
legor_fr	-0.14^{***}		-0.11^{***}
	(0.03)		(0.02)
legor_so	-0.05		
	(0.03)		
legor_ge	-0.23^{***}	-0.57^{***}	
	(0.04)	(0.06)	
Time fixed effects	YES	YES	YES
F-test on excluded instruments	F(4,783)=100	F(2,130)=104	F(2,633)=135
(prob.>F)	(0.00)	(0.00)	(0.00)
R^2(centered)	0.50	0.73	0.48
Observations	807	152	655

Note: *legor_uk, legor_fr, legor_so, legor_ge, and legor_sc* mean legal origins are British, French, Socialist, German, and Scandinavian, respectively.

Other variables in regression include $\ln\left(\frac{GDP}{emp}\right)_{t-1}$, $\ln(FD/GDP)$, CA/GDP, $\ln(GOV/GDP)$, $\ln(I/GDP)$, $\ln(Human)$, and $\ln(labor)$.

***Significant at the 0.01 level, ** at the 0.05 level, * at the 0.10 level

(standard errors in parentheses)

Table 5. 2SLS Regressions (Second-Stage Results)

Second-stage dependent variable: annual inflation π 1998-2010 ($\pi < 100$)

	Regression number		
	5.1	5.2	5.3
	Sample		
Indep. Variable	all countries	rich countries	poor countries
CBI	1.21	4.27^{***}	2.03
	(2.97)	(0.99)	(3.99)
CA/GDP	2.78	-8.49^{***}	4.19
	(2.40)	(1.84)	(2.80)
$\ln(FD/GDP)$	-3.31^{***}	-0.19	-3.23
	(0.49)	(0.54)	(2.51)
$\ln\left(\frac{GDP}{emp}\right)_{t-1}$	0.53	1.05	0.71
	(0.55)	(0.64)	(0.61)
$\ln(GOV/GDP)$	-0.42	-2.47^{**}	-0.67
	(0.95)	(0.97)	(1.12)
$\ln(I/GDP)$	1.40	-1.56^{*}	1.79
	(1.00)	(0.92)	(1.17)
$\ln(Human)$	-3.44^{*}	-2.31	-3.23
	(1.98)	(2.22)	(2.51)
$\ln(labor)$	-1.63^{**}	2.13^{***}	-1.70^{**}
	(0.70)	(0.56)	(0.80)
Time FE	YES	YES	YES
Financial Crises Dummy	YES	YES	YES
Sargan test	3.57	7.05	0.75
(p-value)	(0.31)	(0.01)	(0.69)
R^2	0.18	0.36	0.14
Observations	824	153	671

Note: π is the inflation rate using the CPI data of IFS of IMF. *CBI* is the CBI measure constructed in Dincer and Eichengreen (2014). *GDP/emp* is real GDP (in 2011 us $) per employment. *CA/GDP, GOV/GDP, I/GDP* are the ratios of current account, government spending, and investment to GDP, respectively. *Human* is human capital.

labor is the employment growth.

***Significant at the 0.01 level, ** at the 0.05 level, * at the 0.10 level

(standard errors in parentheses)

Table 6. 2SLS Regressions (Second-Stage Results)

Second-stage dependent variable: $\log(1+\pi)$ during 1998-2010 ($\pi < 100$)

	Regression number		
	6.1	6.2	6.3
	Sample		
Indep. Variable	all countries	rich countries	poor countries
CBI	-0.15	1.73^{***}	-0.31
	(0.28)	(0.39)	(0.35)
CA/GDP	-0.01	-3.79^{***}	0.38
	(0.23)	(0.74)	(0.25)
$\ln(FD/GDP)$	-0.33^{***}	-0.95	-0.29^{***}
	(0.05)	(0.88)	(0.05)
$\ln\left(\frac{GDP}{emp}\right)_{t-1}$	-0.01	0.50^{*}	0.002
	(0.05)	(0.26)	(0.05)
$\ln(GOV/GDP)$	0.03	-1.50^{***}	0.02
	(0.09)	(0.39)	(0.10)
$\ln(I/GDP)$	-0.05	-0.98^{***}	-0.06
	(0.10)	(0.37)	(0.10)
$\ln(Human)$	-0.36^{*}	-0.95	-0.21
	(0.19)	(0.88)	(0.22)
$\ln(labor)$	-0.11^{*}	1.03^{***}	-0.17^{**}
	(0.07)	(0.22)	(0.07)
Time FE	YES	YES	YES
Financial Crises Dummy	YES	YES	YES
Sargan test	26.98	10.71	4.47
(p-value)	(0.00)	(0.001)	(0.11)
R^2	0.24	0.28	0.16
Observations	807	152	655

Note: π is the inflation rate using the CPI data of IFS of IMF. *CBI* is the CBI measure constructed in Dincer and Eichengreen (2014). *GDP/emp* is real GDP (in 2011 us $) per employment. *CA/GDP, GOV/GDP, I/GDP* are the ratios of current account, government spending, and investment to GDP, respectively. *Human* is human capital.
labor is the employment growth.
***Significant at the 0.01 level, ** at the 0.05 level, * at the 0.10 level
(standard errors in parentheses)

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