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Abstract

This study explores how the rent-seeking behavior of the government may impede economic development and delay industrialization. Introducing a rent-seeking government to the Schumpeterian growth model with endogenous takeoff, we find that a more self-interested government engages more in rent-seeking taxation, which delays the transition of the economy from pre-industrial stagnation to modern economic growth. Quantitatively, a completely self-interested government delays industrialization, relative to a benevolent government, by eight decades.

JEL classification: O30, O40
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> Economies in which security of property is lacking—because of either the possibility of arrest, ruin, or execution at the command of the ruling prince or the possibility of ruinous taxation—should experience relative stagnation. By contrast, economies in which property is secure—either because of strong constitutional restrictions on the prince or because the ruling elite is made up of merchants rather than princes—should prosper and grow. DeLong and Shleifer (1993, p. 671)

> Many economists argue that economic success is the result of secure property rights, low taxes, and minimal government. Arbitrary government is bad for growth because it leads to high taxes, regulations, corruption and rent-seeking—all of which reduce the incentives to produce. Allen (2011, p. 15)

1 Introduction

DeLong and Shleifer (1993) document evidence that the rent-seeking behavior of ruling elites can impede economic development and delay industrialization. To provide a growth-theoretic analysis on this issue, we introduce a rent-seeking government to a recent variant of the Schumpeterian growth model that features an endogenous takeoff. We find that a self-interested government that is subject to weaker constitutional restrictions engages more in rent-seeking taxation, which delays the transition of the economy from pre-industrial stagnation to modern economic growth. Quantitatively, a completely self-interested government delays industrialization, relative to a benevolent government, by over eight decades.

Intuitively, the tax imposed by the government creates a distortion that shrinks the level of output in the economy and the market size, which in turn reduces incentives for the entry of firms. Therefore, rent-seeking taxation delays the endogenous takeoff of the economy and stifles economic growth in the short run. However, the reduced entry of new firms eventually increases the size of incumbent firms, which gives rise to a positive effect on quality improvement and economic growth. In the long run, the positive and negative effects cancel each other rendering a neutral effect of the tax rate on the steady-state growth rate. These results show that rent-seeking taxation could have a severe impact on the growth path of an economy even when its effect on steady-state growth is neutral, highlighting the importance of considering the transitional effects on economic growth.

This study relates to the literature on economic growth and innovation. Seminal studies by Romer (1990), Segerstrom *et al.* (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992) develop the first-generation R&D-based growth model in which either the invention of new products or the quality improvement of existing products drives innovation in the economy. Subsequent studies by Peretto (1994) and Smulders and van de Klundert (1995) combine the invention of new products and the quality improvement of products to develop the second-generation R&D-based growth model,[1] whose implications are supported by empirical evidence.[2] This study uses a second-generation R&D-based growth model to explore how a rent-seeking government affects the endogenous takeoff of an economy.

[1] See also Dinopoulos and Thompson (1998), Howitt (1999), Peretto (1998, 1999) and Young (1998).

[2] See Ang and Madsen (2011), Ha and Howitt (2007), Laincz and Peretto (2006) and Madsen (2008, 2010).

This study also relates to the literature on endogenous takeoff, in which the seminal study by Galor and Weil (2000) develops unified growth theory.[3] Unified growth theory explores the endogenous transition of an economy from pre-industrial stagnation to modern economic growth; see Galor (2011) for a review.[4] This study also considers the transition of an economy from stagnation to growth but in a Schumpeterian model in which the endogenous activations of the invention of new products and the quality improvement of products determine the takeoff. Therefore, this study contributes to a growing branch of this literature on endogenous takeoff in the Schumpeterian growth model developed in Peretto (2015) by considering a rent-seeking government; see also Iacopetta and Peretto (2020) on corporate governance, Chu, Fan and Wang (2020) on status-seeking culture, Chu, Kou and Wang (2020) on intellectual property rights, and Chu, Peretto and Wang (2020) on agricultural technology.

2 The model

We introduce a rent-seeking government to the Schumpeterian model of endogenous takeoff in Peretto (2015). The economy begins in a pre-industrial era without innovation and gradually transits to an industrial era with new product development and then quality improvement.

2.1 Household

The utility function of the representative household is

$$U = \int_0^\infty e^{-(\rho-\lambda)t} \ln c_t dt, \tag{1}$$

where c_t denotes per capita consumption of a final good (numeraire). The parameter ρ denotes the discount rate, whereas λ is the growth rate of population L_t. We impose the following parameter restriction: $\rho > \lambda > 0$. The asset-accumulation equation is

$$\dot{a}_t = (r_t - \lambda)a_t + w_t - c_t, \tag{2}$$

where r_t is the interest rate. a_t is the value of assets owned by each household member, who supplies one unit of labor to earn a wage income w_t. Dynamic optimization yields

$$\frac{\dot{c}_t}{c_t} = r_t - \rho. \tag{3}$$

2.2 Final good

The production function of the final good is

$$Y_t = \int_0^{N_t} X_t^\theta(i) \left[Z_t^\alpha(i) Z_t^{1-\alpha} L_t / N_t^{1-\sigma}\right]^{1-\theta} di, \tag{4}$$

[3]See also Hansen and Prescott (2002) and Jones (2001) for other early studies on endogenous takeoff.
[4]See also Galor and Moav (2002), Galor and Mountford (2008) and Galor *et al.* (2009).

where $\{\theta, \alpha, \sigma\} \in (0,1)$. L_t denotes production labor and is determined by the population size. N_t is the number of differentiated intermediate goods. $X_t(i)$ is the quantity of non-durable intermediate good $i \in [0, N_t]$. The productivity of $X_t(i)$ depends on its own quality $Z_t(i)$ and the average quality $Z_t \equiv \int_0^{N_t} Z_t(j)\, dj/N_t$, capturing technology spillovers. The parameter σ determines a congestion effect $1-\sigma$ of variety, which removes the scale effect.

The profit function is given by

$$\pi_t = (1-\tau)Y_t - w_t L_t - \int_0^{N_t} P_t(i)\, X_t(i)\, di,$$

where $P_t(i)$ is the price of $X_t(i)$ and $\tau \in [0,1)$ is the tax rate on the output Y_t of the economy.[5] Profit maximization yields the conditional demand functions:

$$w_t = (1-\tau)(1-\theta)\frac{Y_t}{L_t}, \tag{5}$$

$$X_t(i) = \left[\frac{(1-\tau)\theta}{P_t(i)}\right]^{1/(1-\theta)} \frac{Z_t^{\alpha}(i)\, Z_t^{1-\alpha} L_t}{N_t^{1-\sigma}}, \tag{6}$$

where $X_t(i)$ is decreasing in the tax rate τ. Competitive final-good firms pay $w_t L_t = (1-\tau)(1-\theta)Y_t$ for labor and $\int_0^{N_t} P_t(i)\, X_t(i)\, di = (1-\tau)\theta Y_t$ for intermediate goods.

2.3 Intermediate goods and in-house R&D

A monopolistic firm uses $X_t(i)$ units of final good to produce $X_t(i)$ units of intermediate good i. The monopolistic firm also needs to incur $\phi Z_t^{\alpha}(i)\, Z_t^{1-\alpha}$ units of final good as a fixed operating cost. To improve the quality of its products, the firm devotes $I_t(i)$ units of final good to in-house R&D. The process of in-house R&D is specified as

$$\dot{Z}_t(i) = I_t(i). \tag{7}$$

The firm's profit flow before R&D is[6]

$$\Pi_t(i) = [P_t(i) - 1]\, X_t(i) - \phi Z_t^{\alpha}(i)\, Z_t^{1-\alpha}. \tag{8}$$

The value of the monopolistic firm in industry i is

$$V_t(i) = \int_t^{\infty} \exp\left(-\int_t^{s} r_u du\right) [\Pi_s(i) - I_s(i)]\, ds. \tag{9}$$

The firm maximizes (9) subject to (7) and (8). Solving this dynamic optimization problem yields the profit-maximizing price as $P_t(i) = 1/\theta$. Here, we follow Chu, Kou and Wang (2020) to assume that competitive firms can also produce $X_t(i)$ with the same quality $Z_t(i)$ as the

[5] Our results are robust to taxing factor inputs instead; $\pi_t = Y_t - (1+\tau)\left[w_t L_t + \int_0^{N_t} P_t(i)\, X_t(i)\, di\right]$.

[6] For simplicity, we do not consider other tax instruments in this sector. See Peretto (2007) for an analysis of different tax instruments in the second-generation Schumpeterian growth model.

monopolistic firm, but they face a higher unit cost of production given by $\mu > 1$. To price these competitors out of the market, the monopolistic firm sets its price as

$$P_t(i) = \min\{\mu, 1/\theta\} = \mu, \tag{10}$$

where we assume $\mu < 1/\theta$.

We consider a symmetric equilibrium in which $Z_t(i) = Z_t$ for $i \in [0, N_t]$, which together with (6) implies an equal firm size $X_t(i) = X_t$ across industries.[7] From (6) and (10), the quality-adjusted firm size is

$$\frac{X_t}{Z_t} = \left[\frac{(1-\tau)\theta}{\mu}\right]^{1/(1-\theta)} \frac{L_t}{N_t^{1-\sigma}}, \tag{11}$$

which is decreasing in the tax rate τ. We define the following transformed variable:

$$x_t \equiv \theta^{1/(1-\theta)} \frac{L_t}{N_t^{1-\sigma}} = \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{X_t}{Z_t}, \tag{12}$$

which is a state variable that depends on $L_t/N_t^{1-\sigma}$. Lemma 1 derives the rate of return on quality-improving R&D, which is increasing in firm size x_t and decreasing in the tax rate.

Lemma 1 *The rate of return on quality-improving in-house R&D is given by*

$$r_t^q = \alpha \frac{\Pi_t}{Z_t} = \alpha \left[(\mu - 1)\left(\frac{1-\tau}{\mu}\right)^{1/(1-\theta)} x_t - \phi\right]. \tag{13}$$

Proof. See Appendix A. ■

2.4 Entrants

Developing a new variety of intermediate goods and setting up its operation require δX_t units of final good, where $\delta > 0$ is an entry-cost parameter. The value of a new product at time t is V_t.[8] The familiar asset-pricing equation is

$$r_t = \frac{\Pi_t - I_t}{V_t} + \frac{\dot{V}_t}{V_t}. \tag{14}$$

When entry is positive, the entry condition is given by

$$V_t = \delta X_t. \tag{15}$$

Using (8), (10), (12), (14) and (15), we can derive the rate of return on entry as

$$r_t^e = \frac{\Pi_t - I_t}{\delta Z_t} \frac{Z_t}{X_t} + \frac{\dot{X}_t}{X_t} = \frac{1}{\delta}\left[\mu - 1 - \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{\phi + z_t}{x_t}\right] + z_t + \frac{\dot{x}_t}{x_t}, \tag{16}$$

which also uses $\dot{V}_t/V_t = \dot{X}_t/X_t = z_t + \dot{x}_t/x_t$, where $z_t \equiv \dot{Z}_t/Z_t$ is the quality growth rate. Equation (16) shows that r_t^e is also increasing in firm size x_t and decreasing in the tax rate.

[7] Symmetry also implies $\Pi_t(i) = \Pi_t$, $I_t(i) = I_t$ and $V_t(i) = V_t$.

[8] To ensure symmetry, we assume that all new firms at time t have access to the aggregate technology Z_t.

2.5 Aggregation

We substitute (6) and (10) into (4) to derive the aggregate production function as

$$Y_t = \left[\frac{(1-\tau)\theta}{\mu}\right]^{\theta/(1-\theta)} N_t^\sigma Z_t L_t, \tag{17}$$

which is decreasing in the tax rate τ. The growth rate of per capita output $y_t \equiv Y_t/L_t$ is

$$g_t \equiv \frac{\dot{y}_t}{y_t} = \sigma n_t + z_t, \tag{18}$$

which is determined by the variety growth rate $n_t \equiv \dot{N}_t/N_t$ and the quality growth rate z_t.

2.6 Equilibrium

See Appendix B for the definition of the equilibrium.

2.7 Dynamics of firm size

The dynamics of the state variable x_t is stable given the following parameter restriction:

$$\delta\phi > \frac{1}{\alpha}\left[\mu - 1 - \delta\left(\rho + \frac{\sigma\lambda}{1-\sigma}\right)\right] > \mu - 1. \tag{19}$$

We will show that given an initial value x_0, firm size x_t gradually increases towards a steady-state value x^*. The economy begins in a pre-industrial era in which the variety growth rate n_t and the quality growth rate z_t are both zero. As x_t becomes sufficiently large, the economy enters the first phase of the industrial era in which firms start to invent new products and n_t becomes positive. Then, as x_t becomes even larger, the economy enters the second phase of the industrial era in which firms start to improve the quality of products and z_t also becomes positive. Eventually, the economy reaches the balanced growth path along which per capita output grows at a steady-state growth rate.

2.8 Dynamics of the consumption-output ratio

For simplicity, we assume that monopolistic firms do not operate in the pre-industrial era and only emerge when innovation occurs. In this case, intermediate goods are produced by competitive firms. As a result, the intermediate-good sector generates zero profit, and per capita consumption in the pre-industrial era is simply

$$c_t = w_t = (1-\tau)(1-\theta)y_t, \tag{20}$$

which implies a stationary consumption-output ratio $c_t/y_t = (1-\tau)(1-\theta)$.

When the economy enters the first phase of the industrial era, innovation is activated, and the entry condition $V_t = \delta X_t$ in (15) holds.

Lemma 2 *When the entry condition holds, the consumption-output ratio c_t/y_t jumps to*

$$\frac{c_t}{y_t} = (1-\tau)\left[1-\theta+\frac{(\rho-\lambda)\delta\theta}{\mu}\right]. \tag{21}$$

Proof. See Appendix A. ■

3 Rent-seeking government and endogenous takeoff

A self-interested government consumes the tax revenue $T_t = \tau Y_t$. For simplicity, the government is myopic and has a static objective function:[9]

$$W_t = \varphi \ln T_t + (1-\varphi)\ln c_t, \tag{22}$$

where the parameter $\varphi \in [0,1]$ is the weight that the government places on its self-interest at the expense of the household. A larger φ implies a more self-interested government. Therefore, φ is decreasing in the degree to which a government needs to be responsible to its citizens and is subject to "constitutional restrictions".

Substituting (17) and (20) or (21) into (22) yields

$$W_t = \varphi \ln \tau + (1-\varphi)\ln(1-\tau) + \frac{\theta}{1-\theta}\ln(1-\tau), \tag{23}$$

where we have dropped the exogenous terms and the pre-determined variables. Differentiating (23) with respect to τ yields

$$\tau = \varphi(1-\theta). \tag{24}$$

The tax rate τ chosen by the government is stationary across all eras and increasing in the degree φ of its self-interest. If the government is completely benevolent (i.e., $\varphi = 0$), then the tax rate τ would be zero. If the government is completely self-interested (i.e., $\varphi = 1$), then the tax rate τ would be $1-\theta$.

3.1 The pre-industrial era

In the pre-industrial era, the firm size x_t is not large enough to activate innovation. Therefore, the growth rate of output per capita is

$$g_t = \sigma n_t + z_t = 0 \tag{25}$$

because $n_t = z_t = 0$. In the pre-industrial era, the economy is in an equilibrium without growth because x_t is too small to provide incentives for innovation. However, given x_0, $x_t = \theta^{1/(1-\theta)} L_t / N_0^{1-\sigma}$ increases according to

$$\frac{\dot{x}_t}{x_t} = \lambda, \tag{26}$$

and hence, x_t eventually becomes sufficiently large to activate innovation.

[9] See Chu (2010) for a fully dynamic analysis of rent-seeking governments in an AK growth model.

3.2 The first phase of the industrial era

Variety-expanding innovation is activated when x_t reaches a threshold:

$$x_N \equiv \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{\phi}{\mu - 1 - \delta(\rho - \lambda)}. \tag{27}$$

A higher tax rate τ increases x_N and delays industrialization at time $t_N = \ln(x_N/x_0)/\lambda$. Intuitively, the rent-seeking distortion reduces the incentives for entry. We can use (16) to derive the variety growth rate as[10]

$$n_t = \frac{1}{\delta}\left[\mu - 1 - \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{\phi}{x_t}\right] - \rho + \lambda > 0, \tag{28}$$

which is positive if and only if $x_t > x_N$. Substituting (28) into $\dot{x}_t/x_t = \lambda - (1-\sigma)n_t$ yields

$$\dot{x}_t = \frac{1-\sigma}{\delta}\left\{\left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \phi - \left[\mu - 1 - \delta\left(\rho + \frac{\sigma\lambda}{1-\sigma}\right)\right] x_t\right\} > 0, \tag{29}$$

which implies x_t continues to grow despite $n_t > 0$. The growth rate of output per capita is

$$g_t = \sigma n_t = \frac{\sigma}{\delta}\left[\mu - 1 - \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{\phi}{x_t}\right] - \sigma(\rho - \lambda) > 0, \tag{30}$$

which is decreasing in the tax rate τ for a given x_t. Intuitively, rent-seeking distortion reduces the entry of firms. In the first phase of the industrial era, the growth rate g_t in (30) is determined by variety-expanding innovation and gradually rises as x_t increases.

3.3 The second phase of the industrial era

When x_t reaches the second threshold $x_Z > x_N$,[11] quality-improving innovation is also activated. In this case, the growth rate of output per capita is determined by the rate of return on quality-improving R&D in (13) because $r_t^q = r_t = \rho + g_t$. Therefore,

$$g_t = \alpha\left[(\mu - 1)\left(\frac{1-\tau}{\mu}\right)^{1/(1-\theta)} x_t - \phi\right] - \rho > 0, \tag{31}$$

which is decreasing in the tax rate τ. Intuitively, rent-seeking distortion reduces quality-improving R&D. The growth rate g_t in (31) continues to rise gradually as firm size x_t expands.

In the second phase of the industrial era, economic growth is driven by both quality-improving innovation and variety-expanding innovation; i.e., $g_t = z_t + \sigma n_t$. Therefore, (31) implies that the quality growth rate z_t is given by

$$z_t = g_t - \sigma n_t = \alpha\left[(\mu - 1)\left(\frac{1-\tau}{\mu}\right)^{1/(1-\theta)} x_t - \phi\right] - \rho - \sigma n_t > 0, \tag{32}$$

[10] Here, we use $z_t = 0$, $r_t^e = r_t = \rho + g_t = \rho + \sigma n_t$ and $\dot{x}_t/x_t = \lambda - (1-\sigma)n_t$.

[11] This inequality holds if α is below a threshold. Derivations are available upon request.

where the variety growth rate n_t can be derived from (16) as[12]

$$n_t = \frac{1}{\delta}\left[\mu - 1 - \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{\phi + z_t}{x_t}\right] - \rho + \lambda > 0. \tag{33}$$

Equations (32)-(33) determine the variety growth rate n_t as a function of x_t, which evolves according to $\dot{x}_t/x_t = \lambda - (1-\sigma)n_t$. Thus, the linearized dynamics of x_t can be derived as

$$\dot{x}_t = \frac{1-\sigma}{\delta}\left\{\left[(1-\alpha)\,\phi - \left(\rho + \frac{\sigma\lambda}{1-\sigma}\right)\right]\left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} - \left[(1-\alpha)\,(\mu-1) - \delta\left(\rho + \frac{\sigma\lambda}{1-\sigma}\right)\right] x_t\right\}, \tag{34}$$

which is stable given (19). Equations (32)-(33) also determine the quality growth rate z_t as a function of x_t. The threshold x_Z that ensures $z_t > 0$ is

$$x_Z \equiv \underset{x}{\arg\text{solve}}\left\{\left[(\mu-1)\left(\frac{1-\tau}{\mu}\right)^{1/(1-\theta)} x - \phi\right]\left[\alpha - \frac{\sigma}{\delta x}\left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)}\right] = (1-\sigma)(\rho-\lambda) + \lambda\right\}. \tag{35}$$

3.4 Balanced growth path

In the long run, firm size x_t converges to a steady-state value:

$$x^* = \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{(1-\alpha)\phi - [\rho + \sigma\lambda/(1-\sigma)]}{(1-\alpha)(\mu-1) - \delta\,[\rho + \sigma\lambda/(1-\sigma)]} > 0, \tag{36}$$

which is increasing in the tax rate τ due to the reduced entry of firms. Substituting (36) into (31) yields the steady-state growth rate as

$$g^* = \alpha\left[(\mu-1)\frac{(1-\alpha)\phi - [\rho + \sigma\lambda/(1-\sigma)]}{(1-\alpha)(\mu-1) - \delta\,[\rho + \sigma\lambda/(1-\sigma)]} - \phi\right] - \rho > 0, \tag{37}$$

which is independent of the tax rate τ due to the scale-invariant property of the Schumpeterian growth model with endogenous market structure.

3.5 From stagnation to growth

In the pre-industrial era, output per capita remains constant. In the first phase of the industrial era (i.e., $t \geq t_N$), variety-expanding innovation is activated, and output per capita starts to grow. In the second phase (i.e., $t \geq t_Z$), quality-improving innovation is also activated. Gradually, the growth rate of output per capita rises towards g^*; see Figure 1.

[12] Here, we use $r_t^e = r_t = \rho + g_t = \rho + \sigma n_t + z_t$ and $\dot{x}_t/x_t = \lambda - (1-\sigma)n_t$.

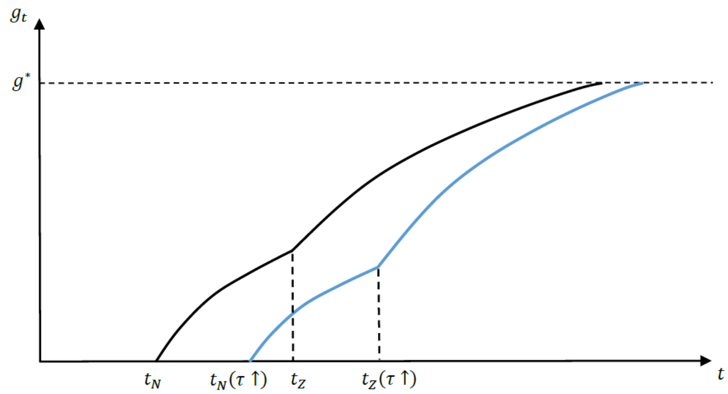

Figure 1: Endogenous takeoff

Figure 1 shows that a higher tax rate τ delays the takeoff because x_N in (27) is increasing in τ. For a given x_t, a higher tax rate τ also decreases the transitional growth rate g_t; see (30) and (31). Intuitively, rent-seeking distortion reduces the incentives for entry and quality-improving R&D. However, the steady-state firm size x^* in (36) is increasing in τ due to the reduced entry of firms. Overall, the effect of τ on the steady-state growth rate g^* in (37) is neutral due to the scale-invariant property of the model.

Proposition 1 *A stronger preference φ of the government for rent seeking leads to a higher tax rate, a later takeoff of the economy and a lower transitional growth rate (for a given firm size) in the industrial era but does not affect the steady-state growth rate.*

Proof. See Appendix A. ■

Quantitatively, a completely self-interested government (i.e., $\tau^s = 1 - \theta$) delays industrialization, relative to a benevolent government (i.e., $\tau^b = 0$), by Δt_N years:

$$\Delta t_N = \frac{1}{\lambda} \ln \left[\frac{x_N(\tau^s)}{x_N(\tau^b)} \right] = \frac{1}{\lambda(1-\theta)} \ln \left(\frac{1}{\theta} \right). \tag{38}$$

We calibrate the values of θ and λ in (38) by considering a conventional labor share $1 - \theta$ of 0.60 and a long-run population growth rate λ of 1.8% in the US.[13] Given these parameter values, Δt_N is 84.8 years. If $\lambda \in \{1\%, 2\%\}$, then Δt_N ranges from 76.4 years to 152.7 years.

4 Conclusion

In this paper, we have analyzed a rent-seeking government in a Schumpeterian growth model with endogenous takeoff. The government levies a tax on the economy for its self-interest. A higher degree of its self-interest causes the government to engage more in rent-seeking taxation, which impedes economic development and delays industrialization. Quantitatively, the delay is in the order of several decades to even a century. This growth-theoretic analysis provides a contribution by formalizing some of the ideas in DeLong and Shleifer (1993).

[13] Data source: Maddison Project Database.

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Appendix A: Proofs

Proof of Lemma 1. We use the Hamiltonian to solve the firm's dynamic optimization. The current-value Hamiltonian of firm i is given by

$$H_t(i) = \Pi_t(i) - I_t(i) + \zeta_t(i)\dot{Z}_t(i) + \xi_t(i)[\mu - P_t(i)], \tag{A1}$$

where $\zeta_t(i)$ is the costate variable on $\dot{Z}_t(i)$ and $\xi_t(i)$ is the multiplier on $P_t(i) \leq \mu$. We substitute (6)-(8) into (A1) and derive

$$\frac{\partial H_t(i)}{\partial P_t(i)} = 0 \Rightarrow \frac{\partial \Pi_t(i)}{\partial P_t(i)} = \xi_t(i), \tag{A2}$$

$$\frac{\partial H_t(i)}{\partial I_t(i)} = 0 \Rightarrow \zeta_t(i) = 1, \tag{A3}$$

$$\frac{\partial H_t(i)}{\partial Z_t(i)} = \alpha \left\{ [P_t(i) - 1] \left[\frac{(1-\tau)\theta}{P_t(i)}\right]^{1/(1-\theta)} \frac{L_t}{N^{1-\sigma}} - \phi \right\} \frac{Z_t^{1-\alpha}}{Z_t^{1-\alpha}(i)} = r_t\zeta_t(i) - \dot{\zeta}_t(i), \tag{A4}$$

where $Z_t(i)$ is a state variable. If $P_t(i) < \mu$, then $\xi_t(i) = 0$. In this case, $\partial \Pi_t(i)/\partial P_t(i) = 0$ yields $P_t(i) = 1/\theta$. If the constraint on $P_t(i)$ is binding, then $\xi_t(i) > 0$. In this case, we have $P_t(i) = \mu$. This proves (10). Then, the assumption $\mu < 1/\theta$ implies $P_t(i) = \mu$. Substituting (A3), (12) and $P_t(i) = \mu$ into (A4) and imposing symmetry yield (13). ∎

Proof of Lemma 2. We use the entry condition $V_t = \delta X_t$ to derive

$$a_t = \frac{V_t N_t}{L_t} = \frac{\delta X_t N_t}{L_t} = \frac{\delta(1-\tau)\theta}{\mu} y_t, \tag{A5}$$

which also uses $(1-\tau)\theta Y_t = \mu X_t N_t$. Differentiating (A5) with respect to t yields

$$\frac{\delta(1-\tau)\theta}{\mu}\dot{y}_t = \dot{a}_t = (r_t - \lambda)a_t + (1-\tau)(1-\theta)y_t - c_t, \tag{A6}$$

which uses (2) and (5). Then, we use (3) and (A5) to rearrange (A6) as

$$\frac{\dot{c}_t}{c_t} - \frac{\dot{y}_t}{y_t} = \frac{\mu}{\delta(1-\tau)\theta}\frac{c_t}{y_t} - \left[\frac{\mu(1-\theta)}{\delta\theta} + \rho - \lambda\right], \tag{A7}$$

which implies that the consumption-output ratio jumps to the steady-state value in (21) whenever the entry condition holds. ∎

Proof of Proposition 1. Use (24) to show that τ is increasing in φ. Use (27) to show that x_N is increasing in τ. Use (30) and (31) to show that g_t is decreasing in τ. Use (37) to show that g^* is independent of τ. ∎

Appendix B: Equilibrium

The equilibrium is a time path of allocations $\{a_t, c_t, Y_t, X_t, I_t\}$ and prices $\{r_t, w_t, P_t, V_t\}$ such that

- the household maximizes utility taking r_t as given;
- competitive final-good firms produce Y_t and maximize profits taking $\{w_t, P_t\}$ as given;
- intermediate-good firms choose $\{P_t, I_t\}$ to maximize V_t taking r_t as given;
- entrants make entry decisions taking V_t as given;
- the value of monopolistic firms adds up to the value of the household's assets such that $N_t V_t = a_t L_t$;
- the government balances its fiscal budget $T_t = \tau Y_t$; and
- the market-clearing condition of the final good holds:

$$Y_t = c_t L_t + \mu N_t X_t + T_t, \tag{B1}$$

$$Y_t = c_t L_t + N_t \left(X_t + \phi Z_t + I_t \right) + \dot{N}_t \delta X_t + T_t, \tag{B2}$$

where (B1) applies to the pre-industrial era and (B2) applies to the industrial era.