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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 a Schumpeterian growth model that features endogenous takeoff, we find that a more self-interested government engages in more rent-seeking taxation, which delays the economy's transition from pre-industrial stagnation to modern economic growth. Quantitatively, a completely self-interested government could have delayed industrialization, relative to a benevolent government, by about two centuries in the UK.

JEL classification: H20, O30, O40
Keywords: rent-seeking government, endogenous takeoff, industrialization

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> Inclusive economic institutions that enforce property rights, create a level playing field, and encourage investments in new technologies and skills are more conducive to economic growth than extractive economic institutions that are structured to extract resources from the many by the few and that fail to protect property rights or provide incentives for economic activity. Acemoglu and Robinson (2012, p. 429-430)

1 Introduction

The Industrial Revolution is arguably one of the most important events in the history of economic development. As a result of industrialization, the average annual growth rate of real GDP per capita in Britain accelerated from 0.4% in the 18th century to 1.0% in the 19th century and reached 1.7% in the 20th century.[1] An early study by DeLong and Shleifer (1993) documents evidence that the rent-seeking behavior of ruling elites can impede economic development and delay industrialization. Allen (2011, p. 15) also argues 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 [...] and rent-seeking".

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 endogenous takeoff. We find that a self-interested government that is subject to weaker constitutional restrictions engages in more rent-seeking taxation,[2] which delays the transition of the economy from pre-industrial stagnation to modern economic growth. This result captures the idea in the influential work of Acemoglu and Robinson (2012) on extractive political institutions stifling economic development. Furthermore, our growth-theoretic framework enables us to perform a quantitative analysis, which shows that a completely self-interested government could have delayed industrialization, relative to a benevolent government, by about two centuries in the UK.

The intuition of our results can be explained as follows. Rent-seeking taxation 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 takeoff of an economy even when its effect on long-run growth is neutral, highlighting the importance of considering the effects on the long-run transition of the economy from stagnation to growth.

This study relates to the literature on growth and innovation. Seminal studies by Romer

[1] With an annual growth rate of 1.7%, income per capita would more than quintuple in a century, whereas it would only increase by half with a growth rate of 0.4%.

[2] According to Drazen (2000, p. 459), "property rights can be considered in the narrow sense as applying to taxation of property: even in the absence of the threat of outright expropriation, societies can nonetheless legally expropriate the fruits of accumulation via taxation."

(1990), Segerstrom *et al.* (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992) develop the R&D-based growth model in which either the development of new goods or the quality improvement of goods drives innovation in the economy. Subsequent studies by Peretto (1994) and Smulders (1994) combine the development of new goods and the quality improvement of goods to develop the Schumpeterian growth model with endogenous market structure.[3] An advantage of the Schumpeterian growth model with endogenous market structure is that its implications are supported by empirical evidence.[4] A number of studies, such as Peretto (2003, 2007, 2011) and Ferraro *et al.* (2020), use the Schumpeterian growth model with endogenous market structure to explore the effects of tax policies on innovation-driven growth. This study builds on this literature by using a Schumpeterian growth model with endogenous market structure to explore how rent-seeking taxation affects the endogenous takeoff of an economy and its transition from stagnation to growth.[5]

This study also builds on the literature on endogenous takeoff, in which the seminal study by Galor and Weil (2000) develops unified growth theory; see also Galor and Moav (2002), Galor and Mountford (2008) and Galor *et al.* (2009).[6] Unified growth theory explores how an economy transits from a pre-industrial Malthusian trap to modern economic growth; see Galor (2005, 2011) for a comprehensive review of this literature. This study also considers an economy's endogenous transition from stagnation to growth but in a Schumpeterian model in which the endogenous activations of two dimensions of technological progress (i.e., the development of new goods and the quality improvement of goods) determine the takeoff.[7] Therefore, this study contributes to a recent branch of this literature on endogenous takeoff in the Schumpeterian growth model developed in Peretto (2015) by deriving the entire transition dynamics of the economy and quantifying the effect of rent-seeking taxation on its takeoff; see also Iacopetta and Peretto (2021) 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 is initially in a pre-industrial era without innovation and gradually transits to an industrial era with product development and quality improvement.

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

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

[5] Chaudhry and Garner (2007) develop a Schumpeterian model in which self-interested elites may block innovation, whereas Spinesi (2009) develops a Schumpeterian model in which rent-seeking bureaucrats may divert resources from innovative activities. Both studies focus on long-run growth.

[6] See also Hansen and Prescott (2002), Jones (2001) and Kalemli-Ozcan (2002) for other early studies on endogenous takeoff.

[7] Wang and Xie (2004) develop an interesting static model to explore the mechanism for the activation of a modern industry; see Chang, Wang and Xie (2016) who incorporate this framework into a dynamic growth model to explore endogenous takeoff. See also Desmet and Parente (2012) who develop a growth model in which the expansion of the market causes the takeoff of industry.

2.1 Household

The economy features a representative household. Its utility function is given by

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

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

Final good is produced by competitive firms. The production function is given by

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

where $\{\theta, \alpha, \sigma\} \in (0,1)$. L_t is production labor and 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 $Z_t \equiv \int_0^{N_t} Z_t(j)\, dj / N_t$. This formulation captures technology spillovers. The parameter σ determines the magnitude of 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 (levied by ruling elites) on the output Y_t of the economy.[8] From profit maximization, we derive 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.

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

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.[9] 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. For the improvement of the quality of its products, the firm devotes $I_t(i)$ units of final good to in-house R&D, specified as

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

The firm's profit flow before R&D is[10]

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

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 manufacture $X_t(i)$ with the same quality $Z_t(i)$ as the monopolistic firm, but they need to incur a higher unit cost of production given by $\mu > 1$. To price these competitive firms out of the market, the monopolistic firm sets its price as

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

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

In a symmetric equilibrium, we have $Z_t(i) = Z_t$ for $i \in [0, N_t]$, which together with (6) implies an equal firm size $X_t(i) = X_t$ across industries.[11] 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 that acts as a wedge and reduces firm size. 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 presents the rate of return on quality-improving R&D, which is decreasing in the tax rate and increasing in firm size x_t.

[9] This common assumption simplifies the transition dynamics. If intermediate goods were produced using capital instead, then rent-seeking taxation would also create a distortion that reduces capital accumulation and shrinks the size of firms. However, the transition dynamics would become more complicated.

[10] For simplicity, we do not consider other tax instruments in our baseline model. See Peretto (2007) for an analysis of different tax instruments in the Schumpeterian growth model with endogenous market structure and also Iacopetta and Peretto (2020) in which corporate governance distortion acts like a tax on monopolistic profit.

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

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. Let V_t denote the value of a new intermediate good at time t.[12] 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 decreasing in the tax rate and increasing in firm size x_t.

2.5 Aggregation

We substitute (6) and (10) into (4) to derive the aggregate level of output 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[13]

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

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

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

[13] One can also subtract intermediate inputs from output to compute the growth rate of GDP per capita. Derivations are available upon request.

2.6 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 $\{r_t, w_t\}$ 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:

  $$Y_t = c_t L_t + \mu N_t X_t + T_t,$$

  which applies to the pre-industrial era, and

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

  which applies to the industrial era.

2.7 Dynamics of firm size

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

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

In Section 3, we will show that given an initial value x_0, firm size x_t gradually increases towards a steady-state value x^*. The economy is initially in a pre-industrial era in which the variety growth rate n_t and the quality growth rate z_t are both zero because firm size x_t is too small to provide sufficient incentives for innovation.[14] As firm size x_t becomes sufficiently large, the economy enters the first phase of the industrial era in which firms begin to invent new intermediate goods and n_t becomes positive. Then, as firm size x_t becomes even larger,[15] the economy enters the second phase of the industrial era in which firms begin to also improve the quality of intermediate goods and z_t becomes positive as well. Eventually, the economy reaches the balanced growth path along which per capita output grows at a steady-state growth rate.

[14]Specifically, $x_t < x_N$ in (27).
[15]Specifically, $x_t > x_Z$ in (35).

2.8 Dynamics of the consumption-output ratio

We follow Chu, Peretto and Wang (2020) to assume that monopolistic firms do not yet operate in the pre-industrial era and only emerge when innovation occurs. In this case, competitive firms produce intermediate goods. As a result, the intermediate-good sector generates zero profit in the pre-industrial era in which per capita consumption is simply

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

which implies a stationary consumption-output ratio $c_t/y_t = (1-\tau)(1-\theta)$.[16]

As soon as 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

Given that the tax rate τ acts as a wedge and reduces the rates of return to innovation, we now explore its determinants. Self-interested elites control the government and consume the tax revenue $T_t = \tau Y_t$.[17] For simplicity, they are myopic and have a static objective function:[18]

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

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

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

which shows that the tax rate τ chosen by the elites has a nice property of being stationary across all eras. Although τ is constant, it is endogenous and determined by two structural

[16] This helps to ensure that the tax rate to be chosen by the government is constant; see (24).

[17] See Section 4.2 for an extension with the presence of a public good.

[18] See Chu (2010) for a fully dynamic analysis of rent-seeking elites in an AK growth model. In Section 4.3, we discuss the implications of dynamic optimization.

parameters: the degree φ of the elites' self-interest and the intensity θ of intermediate goods in production. Equation (24) shows that τ is 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 $1-\theta$, which is decreasing in θ because a larger θ amplifies the distortionary effect of the tax wedge on intermediate goods X_t as shown in (6).

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 does not experience economic growth because x_t is too small to provide incentives for innovation; see (27) and (28). 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.

3.2 The first phase of the industrial era

Variety-expanding innovation is activated when x_t rises above a threshold:

$$x_N \equiv \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{\phi}{\mu - 1 - \delta(\rho - \lambda)} > x_0. \tag{27}$$

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 incentives for the entry of firms. The variety growth rate can be derived from (16) as[19]

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

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

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

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

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 rises above a second threshold $x_Z > x_N$,[20] 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 because it reduces the return on quality-improving R&D. As firm size x_t continues to expand, the growth rate g_t in (31) gradually rises as before.

In the second phase of the industrial era, economic growth is determined 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

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

where the variety growth rate n_t can be derived from (16) as[21]

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

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

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

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

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

3.4 Balanced growth path

In the long run, firm size x_t converges to a steady-state value:[22]

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

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 because its direct negative effect and the indirect positive effect via x^* cancel each other. This result reflects the scale-invariant property from endogenous market structure in the Schumpeterian growth model. In other words, the tax wedge affecting the economy via firm size does not stifle economic growth in the long run; however, its effects on the economy can still be severe as we will show next.

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 the steady-state growth rate g^*; see Figure 1.

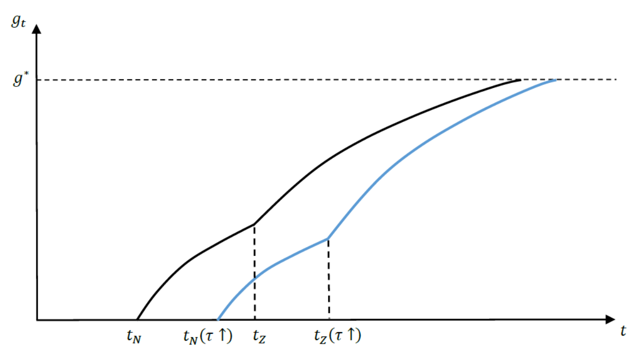

Figure 1: Endogenous takeoff

Figure 1 shows that a higher tax rate τ delays the takeoff because x_N in (27) is increasing in τ. For a given firm size 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

[22] Given $\dot{x}_t/x_t = \lambda - (1-\sigma)n_t = 0$, the steady-state variety growth rate is simply $n^* = \lambda/(1-\sigma)$.

(37) is neutral due to the scale-invariant property of the model. Therefore, although rent-seeking taxation does not affect long-run growth, it delays the takeoff of the economy and slows down its growth on the transition path, which highlights the importance of considering the effects of taxation on the entire path of economic growth.

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. ■

Finally, we quantify the effect of rent-seeking taxation on the delay in the takeoff of the economy. The tractability of the Peretto model enables us to derive a closed-form solution for this effect. 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:

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

The equilibrium expression for Δt_N in (38) has the advantage of depending on only two parameters.[23] We calibrate the values of θ and λ in (38) by considering a labor share $1-\theta$ of 0.70 and a historical population growth rate λ of 0.8% in the 18th to early 19th century in the UK.[24] Given these parameter values, Δt_N is 215 years. Figure 2 presents Δt_N for $\lambda \in [0.5\%, 1.5\%]$ and $\theta \in [0.1, 0.5]$. For example, if $\lambda = 0.8\%$ and $\theta \in [0.1, 0.5]$, then Δt_N ranges from 173 years to 320 years. If $\theta = 0.3$ and $\lambda \in [0.5\%, 1.5\%]$, then Δt_N varies more significantly from 115 years to 344 years. Therefore, a larger portion of the variation in Δt_N comes from changes in λ because the population growth rate determines how fast firm size x_t reaches the first threshold x_N.

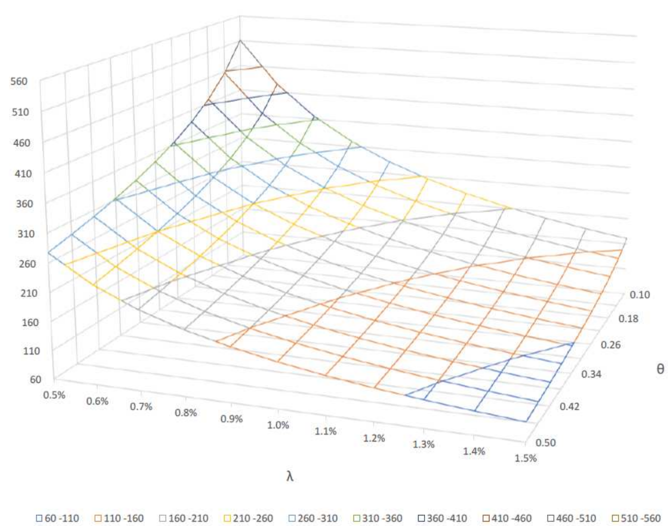

Figure 2: Years of delay in industrialization

[23] This result is robust to the inclusion of a public good; see Section 4.2.

[24] Data source: Maddison Project Database.

4 Extensions

In this section, we consider three extensions to our baseline models. Section 4.1 introduces corporate profit tax. Section 4.2 allows for a public good. Section 4.3 explores the dynamic optimization of elites. For simplicity, we consider these extensions separately in each of the following subsections.

4.1 Corporate profit tax

In this subsection, we consider an alternative tax instrument in the form of a corporate profit tax by modifying (9) as follows:

$$V_t(i) = \int_t^{\infty} \exp\left(-\int_t^s r_u du\right) \left[(1-\tau_\Pi)\Pi_s(i) - (1-\kappa\tau_\Pi)I_s(i)\right] ds, \tag{39}$$

where $\tau_\Pi \in [0,1)$ is the tax rate on corporate profit and $\kappa \in \{0,1\}$ determines whether R&D investment is tax deductible (i.e., $\kappa = 1$) or not (i.e., $\kappa = 0$). The rest of this section shows that if we consider this corporate profit tax τ_Π, then a higher tax rate would not only delay the takeoff but also affect economic growth in the long run. We sketch out the key equations and discuss the intuition in this section.[25]

In the first phase of the industrial era, the variety growth rate is given by

$$n_t = \frac{1-\tau_\Pi}{\delta}\left[(\mu-1) - \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{\phi}{x_t}\right] + \lambda - \rho, \tag{40}$$

which is decreasing in τ_Π. Also, n_t is positive if and only if

$$x_t > x_N \equiv \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{\phi}{\mu - 1 - \delta(\rho-\lambda)/(1-\tau_\Pi)}, \tag{41}$$

where x_N is increasing in τ_Π. Intuitively, the corporate tax distortion reduces the incentives for the entry of firms and delays the takeoff of the economy.

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

$$r_t^q = \frac{\alpha(1-\tau_\Pi)}{1-\kappa\tau_\Pi}\left[(\mu-1)\left(\frac{1-\tau}{\mu}\right)^{1/(1-\theta)} x_t - \phi\right]. \tag{42}$$

Therefore, in the second phase of the industrial era, the growth rate of output per capita is

$$g_t = r_t^q - \rho = \frac{\alpha(1-\tau_\Pi)}{1-\kappa\tau_\Pi}\left[(\mu-1)\left(\frac{1-\tau}{\mu}\right)^{1/(1-\theta)} x_t - \phi\right] - \rho, \tag{43}$$

[25] See online Appendix B for the detailed derivations.

which is decreasing in τ_Π (unless $\kappa = 1$) for a given x_t. Intuitively, for a given firm size, the corporate tax distortion stifles economic growth and reduces the incentives for quality-improving in-house R&D (unless R&D investment is tax deductible). However, in the long run, the reduced entry of firms increases the steady-state firm size x^* given by

$$x^* = \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{(1-\tau_\Pi)(1-\alpha)\phi - (1-\kappa\tau_\Pi)[\rho + \sigma\lambda/(1-\sigma)]}{(1-\tau_\Pi)(1-\alpha)(\mu-1) - \delta[\rho + \sigma\lambda/(1-\sigma)]}, \tag{44}$$

which is increasing in τ_Π given (19).

Substituting (44) into (43) and rearranging some terms yield the steady-state growth rate of output per capita as

$$g^* = \frac{\alpha(1-\tau_\Pi)}{1-\kappa\tau_\Pi}\left\{\frac{\phi\delta[\rho + \sigma\lambda/(1-\sigma)] - (1-\kappa\tau_\Pi)(\mu-1)[\rho + \sigma\lambda/(1-\sigma)]}{(1-\tau_\Pi)(1-\alpha)(\mu-1) - \delta[\rho + \sigma\lambda/(1-\sigma)]}\right\} - \rho, \tag{45}$$

which features both a negative direct effect of τ_Π (unless $\kappa = 1$) and a positive indirect effect of τ_Π via a larger firm size x^*. If R&D investment is tax deductible (i.e., $\kappa = 1$), then the negative direct effect of τ_Π on the steady-state growth rate disappears, and we are left with the positive indirect effect of τ_Π via a larger x^*. If R&D investment is not tax deductible (i.e., $\kappa = 0$), then both positive and negative effects exist. However, (45) shows that the positive effect dominates the negative effect such that the overall effect of τ_Π on the steady-state growth rate is still positive. We summarize the results as follows.

Proposition 2 *Raising the corporate profit tax rate delays the takeoff and reduces the transitional growth rate as in our benchmark model. However, it also has an additional effect by increasing the steady-state growth rate.*

Proof. Use (41) and (45) to show that x_N and g^* are increasing in τ_Π. ■

4.2 Public good

In this subsection, we explore the robustness of our analytical and numerical results in the presence of a public good $G_t = \gamma Y_t$, where $\gamma \in [0, 1)$ is a parameter. In this case, the tax revenue consumed by the self-interested elites is

$$T_t = (\tau - \gamma)Y_t. \tag{46}$$

Substituting (46) along with (17) and (20) or (21) into (22) yields

$$W_t = \varphi \ln(\tau - \gamma) + (1-\varphi)\ln(1-\tau) + \frac{\theta}{1-\theta}\ln(1-\tau). \tag{47}$$

Then, differentiating (47) with respect to τ yields

$$\tau = \gamma + (1-\gamma)\varphi(1-\theta), \tag{48}$$

which is increasing in φ as before. A completely self-interested government chooses $\tau^s = \gamma + (1-\gamma)(1-\theta)$, whereas a benevolent government chooses $\tau^b = \gamma$. Substituting τ^s and τ^b into (38) yields

$$\Delta t_N = \frac{1}{\lambda(1-\theta)} \ln\left(\frac{1}{\theta}\right), \tag{49}$$

which shows the same expression as (38) for the delay in the industrialization of the economy.

It is useful to note that the presence of a public good G_t does affect the timing of the takeoff. Equation (48) shows that the tax rate τ is increasing in γ.

$$\frac{\partial \tau}{\partial \gamma} = 1 - \varphi(1-\theta), \tag{50}$$

which is positive because $\tau = \gamma + (1-\gamma)\varphi(1-\theta) < 1$. As a result, a larger public-good share γ leads to a higher tax rate, which in turn delays the takeoff of the economy. However, what the public-good share γ does not affect is the difference in the timing of the takeoff under a completely self-interested government versus a benevolent government. The reason is that the ratio $(1-\tau^b)/(1-\tau^s)$ is independent of γ even though both τ^b and τ^s are increasing in γ.

It is useful to note that the independence of Δt_N with respect to γ is due to the specific structure of our model and the specific functional forms involved. One crucial assumption is that the level of public good is a constant fraction of output (i.e., $G_t = \gamma Y_t$). Equation (27) shows that the threshold x_N is a function of $1-\tau$, which is given by $1-\tau = (1-\gamma)[1-\varphi(1-\theta)]$ from (48). Taking the log of this equation yields

$$\ln(1-\tau) = \ln(1-\gamma) + \ln[1-\varphi(1-\theta)],$$

which is decreasing in both γ and φ. This implies that either a larger public-good share or a more self-interested group of elites would delay the takeoff by increasing in the tax rate τ. However, these two effects do not interact with each other because we have assumed that the government spending ratio γ is independent of the degree of elites' self interest φ. In a more general model, the government spending ratio γ can become a function of φ. For example, suppose the elites also value the public good. In this case, a more self-interested group of elites would choose a larger government spending ratio and further delay the takeoff of the economy via the additional taxation required for the provision of the public good.

4.3 Dynamic optimization of elites

In this subsection, we consider the case in which the elites choose τ_t to maximize

$$W = \varphi \int_0^\infty e^{-(\rho-\lambda)t} \ln T_t dt + (1-\varphi)U = \int_0^\infty e^{-(\rho-\lambda)t} \left[\varphi \ln T_t + (1-\varphi)\ln c_t\right] dt, \tag{51}$$

where U is given by (1). Given the complexity of this dynamic rent-seeking problem, we formally consider only a special case: the economy remains indefinitely in the pre-industrial era. Then, we offer some conjecture on the general case followed by a numerical analysis.

For the special case, by $T_t = \tau Y_t$ and (20), the objective function in (51) for the pre-industrial era can be rewritten as

$$W = \frac{1}{\rho - \lambda}\left[\varphi \ln \tau + (1-\varphi)\ln(1-\tau) + \frac{\theta}{1-\theta}\ln(1-\tau)\right], \quad (52)$$

where we have dropped the exogenous variables such as $N_0^\sigma Z_0$ because they are independent of τ. Differentiating W with respect to τ shows that the tax rate chosen by the government would be the same as (24) despite changing (23) to (51) if the economy remains indefinitely in the pre-industrial era. We summarize this result as follows.

Proposition 3 *If the economy remains indefinitely in the pre-industrial era, then the tax rate chosen by the government under dynamic rent-seeking would be the same as that under static rent-seeking in (24).*

Proof. Use (52) to derive the optimal τ for the elites. ■

For the general case, given that a lower tax rate leads to an earlier takeoff, the elites should choose a lower tax rate than that in (24) in order to benefit from economic growth after the takeoff. In this case, we need to add the term $\ln(N_t^\sigma Z_t)$ to (52) such that

$$W = \frac{1}{\rho - \lambda}\left[\varphi \ln \tau + (1-\varphi)\ln(1-\tau) + \frac{\theta}{1-\theta}\ln(1-\tau)\right] + \int_0^\infty e^{-(\rho-\lambda)t}\ln(N_t^\sigma Z_t)dt. \quad (53)$$

The last term in (53) can be expressed as

$$\Omega \equiv \int_0^\infty e^{-(\rho-\lambda)t}\ln(N_t^\sigma Z_t)dt = \int_0^\infty e^{-(\rho-\lambda)t}\left[\ln(N_0^\sigma Z_0) + \int_0^t g_s ds\right]dt, \quad (54)$$

where $N_0^\sigma Z_0$ is exogenous and g_t is given by (25) in the pre-industrial era, by (30) in the first phase of the industrial era and by (31) in the second phase of the industrial era. It is useful to recall that x_N is increasing in τ and g_t in (30) and (31) is decreasing in τ for a given x_t. Formally,

$$\frac{\partial \Omega}{\partial \tau} = \int_0^\infty e^{-(\rho-\lambda)t}\left[\int_0^t \frac{\partial g_s}{\partial \tau}ds\right]dt < 0. \quad (55)$$

In other words, an increase in τ delays the takeoff of the economy and dampens the growth paths of N_t and Z_t. Therefore, the elites would take these negative effects of τ into account and choose a lower tax rate than that in (24) because a lower tax rate leads to an earlier takeoff and raises the transitional growth rate of the economy in the industrial era. If we allow the tax rate to be a function of x_t, then $\tau(x_t)$ would converge to $\varphi(1-\theta)$ in (24) as x_t converges to x^* because the negative effect of τ on the steady-state growth rate disappears in the long run (i.e., $\partial g^*/\partial \tau = 0$). Therefore, we conjecture that $\tau(x_t)$ can be linearly approximated by the following function:

$$\tau(x_t) = \varphi(1-\theta) + b(x_t - x^*), \quad (56)$$

where $b > 0$. To confirm this conjecture, what we will do next is to numerically compute the optimal value of b for the elites and show that it is positive.

We calibrate the rest of the model to UK data in order to perform a numerical analysis. In addition to θ and λ, the model also features the following parameters: $\{\rho, \mu, \alpha, \sigma, \delta, \phi, \varphi\}$. We set the discount rate ρ to 0.04 and the markup ratio μ to 1.40. We follow Iacopetta *et al.* (2019) to set the degree of technology spillovers $1 - \alpha$ to 0.833 and the social return of variety σ to 0.25. Then, we calibrate the two parameters $\{\delta, \phi\}$ by matching the following moments from the modern UK economy: a steady-state R&D share of 1.63% and a steady-state growth rate of 2%. As for φ, we compute the value of b that maximizes W in (51) (i.e., the optimal value of b for the elites) under a range of values for $\varphi \in [0, 0.3]$.[26] Table 1 summarizes the parameter values. Figure 3 plots the optimal values of b against φ. At $\varphi = 0$, the optimal value of b is zero because the optimal tax rate is zero. As φ increases, the optimal value of b becomes positive and increasing in φ.

Table 1: Calibrated parameter values

θ	λ	ρ	μ	α	σ	δ	ϕ	φ
0.300	0.008	0.040	1.400	0.167	0.250	5.931	0.182	0
0.300	0.008	0.040	1.400	0.167	0.250	6.378	0.144	0.100
0.300	0.008	0.040	1.400	0.167	0.250	6.897	0.106	0.200
0.300	0.008	0.040	1.400	0.167	0.250	7.508	0.068	0.300

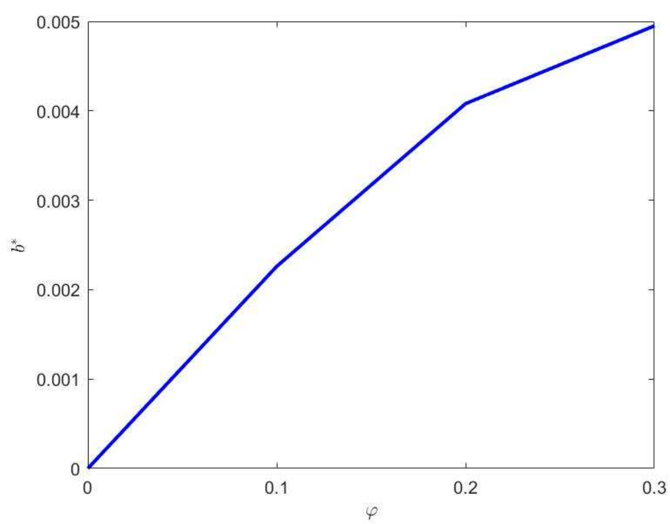

Figure 3: The optimal values of b for elites

[26] For larger values of φ, the inequality in (19) does not hold.

5 Conclusion

In this paper, we have analyzed rent-seeking elites in a Schumpeterian growth model with endogenous takeoff. Specifically, the elites impose a tax on the economy to extract resources for their self-interest, capturing the idea of extractive political institutions in Acemoglu and Robinson (2012). A higher degree of the elites' self-interest causes more rent-seeking taxation, which impedes economic development and delays industrialization. Quantitatively, the delay is in the order of centuries. For simplicity, we have considered myopic elites. Forward-looking elites would still engage in rent-seeking taxation, but to a lesser extent in order to benefit from economic growth. Therefore, our quantitative results should be viewed as an upper bound on the magnitude of the delay in industrialization.

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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 in (15) 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 for a given x_t. Use (37) to show that g^* is independent of τ. ■

Appendix B: Corporate profit tax

In this appendix, we provide the detailed derivations for the case of a corporate profit tax τ_Π. First of all, we revise the proof of Appendix A as follows. We have a new current-value Hamiltonian as

$$H_t(i) = (1-\tau_\Pi)\Pi_t(i) - (1-\kappa\tau_\Pi)I_t(i) + \zeta_t(i)\dot{Z}_t(i) + \xi_t(i)[\mu - P_t(i)]. \tag{B1}$$

We substitute (6)-(8) into (B1) and derive

$$\frac{\partial H_t(i)}{\partial P_t(i)} = 0 \Rightarrow (1-\tau_\Pi)\frac{\partial \Pi_t(i)}{\partial P_t(i)} = \xi_t(i), \tag{B2}$$

$$\frac{\partial H_t(i)}{\partial I_t(i)} = 0 \Rightarrow \zeta_t(i) = 1-\kappa\tau_\Pi, \tag{B3}$$

$$\frac{\partial H_t(i)}{\partial Z_t(i)} = \alpha(1-\tau_\Pi)\left\{[P_t(i)-1]\left[\frac{(1-\tau)\theta}{P_t(i)}\right]^{1/(1-\theta)}\frac{L_t}{N_t^{1-\sigma}} - \phi\right\}\frac{Z_t^{1-\alpha}}{Z_t^{1-\alpha}(i)} = r_t\zeta_t(i) - \dot{\zeta}_t(i). \tag{B4}$$

As in the proof of Appendix A, 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 (B3), (12) and $P_t(i) = \mu$ into (B4) and imposing symmetry yield

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

Accordingly, (14) is revised as

$$r_t = \frac{(1-\tau_\Pi)\Pi_t - (1-\kappa\tau_\Pi)I_t}{V_t} + \frac{\dot{V}_t}{V_t}; \tag{14'}$$

and (16) is revised as

$$r_t^e = \frac{1}{\delta}\left[(1-\tau_\Pi)(\mu-1) - \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)}\frac{(1-\tau_\Pi)\phi + (1-\kappa\tau_\Pi)z_t}{x_t}\right] + z_t + \frac{\dot{x}_t}{x_t}. \tag{16'}$$

The First Phase. Applying $z_t = 0$, $r_t^e = r_t = \rho + g_t = \rho + \sigma n_t$, and $\dot{x}_t/x_t = \lambda - (1-\sigma)n_t$ to (16'), we have the variety growth rate in the first phase of industrialization as

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

which is positive under

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

The Second Phase. In the second phase, where quality improvement also occurs, the growth rate is determined by the return rate of quality-improving innovation; $r_t^q = r_t = \rho + g_t$. From (13'), we have

$$g_t = \frac{\alpha(1-\tau_\Pi)}{1-\kappa\tau_\Pi}\left[(\mu-1)\left(\frac{1-\tau}{\mu}\right)^{1/(1-\theta)} x_t - \phi\right] - \rho. \tag{31'}$$

From (31'), with $z_t = g_t - \sigma n_t$, we have

$$z_t = \frac{\alpha(1-\tau_\Pi)}{1-\kappa\tau_\Pi}\left[(\mu-1)\left(\frac{1-\tau}{\mu}\right)^{1/(1-\theta)} x_t - \phi\right] - \rho - \sigma n_t. \tag{32'}$$

Applying $r_t^e = r_t = \rho + g_t = \rho + \sigma n_t + z_t$ and $\dot{x}_t/x_t = \lambda - (1-\sigma)n_t$ to (16'),

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

In the second phase, x_t converges to its steady-state value.

The Steady State. In the steady state, $\dot{x}_t/x_t = \lambda - (1-\sigma)n_t = 0$ holds, implying $n_t = \lambda/(1-\sigma)$. Thus, by substituting $n_t = \lambda/(1-\sigma)$ into (32') and (33'), both become

$$z_t = \frac{\alpha(1-\tau_\Pi)}{1-\kappa\tau_\Pi}\left[(\mu-1)\left(\frac{1-\tau}{\mu}\right)^{1/(1-\theta)} x_t - \phi\right] - \left(\rho + \frac{\sigma\lambda}{1-\sigma}\right) \tag{32''}$$

and

$$z_t = \frac{1}{1-\kappa\tau_\Pi}\left\{\left(\frac{1-\tau}{\mu}\right)^{1/(1-\theta)}\left[(1-\tau_\Pi)(\mu-1) - \delta\left(\frac{\sigma\lambda}{1-\sigma} + \rho\right)\right] x_t - (1-\tau_\Pi)\phi\right\}. \tag{33''}$$

Solving these two for x_t yields the steady state value of x^* as

$$x^* = \left(\frac{\mu}{1-\tau}\right)^{1/(1-\theta)} \frac{(1-\tau_\Pi)(1-\alpha)\phi - (1-\kappa\tau_\Pi)[\rho + \sigma\lambda/(1-\sigma)]}{(1-\tau_\Pi)(1-\alpha)(\mu-1) - \delta[\rho + \sigma\lambda/(1-\sigma)]}. \tag{36'}$$

Substituting (36') into (31') yields the steady-state growth rate as

$$g^* = \frac{\alpha(1-\tau_\Pi)}{1-\kappa\tau_\Pi}\left\{(\mu-1)\frac{(1-\tau_\Pi)(1-\alpha)\phi - (1-\kappa\tau_\Pi)[\rho + \sigma\lambda/(1-\sigma)]}{(1-\tau_\Pi)(1-\alpha)(\mu-1) - \delta[\rho + \sigma\lambda/(1-\sigma)]} - \phi\right\} - \rho. \tag{37'}$$