Circular economy in cities: An economic theory to decouple economic development from waste

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Circular economy in cities: An economic theory to decouple economic development from waste*

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Abstract

This paper constructs the economic model to consider the circular economy in cities from the waste management perspective. Specifically, we analyze the link between migration, natural capital, human capital, and waste management by extending the new economic geography model. We show the results; the population distribution pattern in the long run varies depending on the congestion effect of natural capital and waste management's technological level. In particular, a full agglomeration equilibrium is stable in the long run for higher technological levels of waste management (lower congestion effects), an interior asymmetric equilibrium is stable for intermediate technological levels (intermediate congestion effects), and the symmetric dispersion equilibrium is stable for the lower technological levels (higher congestion effects).

Keywords: Circular economy; Waste management; Economic geography; Agglomeration; Natural capital

JEL codes: F18; Q53; R11; R12

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1 Introduction

This paper tries to construct the economic theory of circular economy in cities. Many researchers across a variety of disciplines consider circular economy an essential issue (Ghisellini et al., 2016; Geissdoerfer et al., 2017; Korhonen et al., 2018; Mayer et al., 2019; Sijtsema et al., 2020). For example, Cainelli et al. (2020) highlight the importance of environmental policies and demand-side factors in fostering the adoption of innovations that promote a circular economy using a large dataset of EU firms. Additionally, Massarutto et al. (2011) discuss the Italian incinerator from the perspective of a circular economy model. Further, Akao and Managi (2007) argue for the decoupling of economic development from the consumption of finite resources through the implementation of a circular economy. Moreover, Brock and Taylor (2010) analyze the relationship between an economic growth model and the environmental Kuznets curve from the perspective of sustainable growth.[1]

In the fifth basic environmental plan approved by Japan's cabinet in April 2018, the Ministry of the Environment advocated for a *circulating and ecological economy* (The Ministry of the Environment, 2018). According to this perspective, a circular and symbiotic society would aim to become self-reliant and decentralized to maximize each of its regions' vitality, while maximizing their use of regional resources (such as natural scenery) to them to complement and support each other according to their specific characteristics.

Natural capital (such as clean air and landscape, forests, and oceans) is one of the critical aspects of a circular economy. Natural capital has a significant impact on people's housing choices because, as population increases, so do waste and pollution, while the benefits derived from natural capital decrease. Managi and Kumar (2018) present a framework for quantifying the value of natural capital in the context of the Inclusive Wealth Index.

This paper clarifies the link among migration, congestion effects, and the technological level of waste management under the assumption that players receive utility from consump-

[1]Tsurumi and Managi (2010) presents the theoretical framework of the EKC. Mayer et al. (2019) analyzes the relationship between carbon dioxide emissions and economic growth in the UK using long-term data from 1751 to 2016 and presents results that support the existence of an EKC.

tion and natural capital population growth. We introduce utility from natural capital declines with population growth into a new economic geography model by Krugman (1991), Forslid and Ottaviano (2003) and Pflüger (2004).

We applied this new economic geography model to analyze the benefits of living in rural areas, linking them to natural capital. This attempt is essential in considering a circulating and ecological economy. Our findings revealed that the long-term population-distribution pattern varied greatly depending on the congestion effect of natural capital and the technological level of waste disposal. In particular, full agglomeration equilibria appeared stable for higher technological levels of waste management (lower congestion effects), interior asymmetric equilibria were stable for intermediate technological levels (intermediate congestion effects), and the symmetric dispersion equilibrium was stable for lower technological levels (higher congestion effects).

Current policy focuses on conducting a circular economy at the domestic level. The concept of circular economy is used worldwide to refer to the following types of trade: trade of materials and waste for recycling and energy recovery and trade of secondary raw materials and second-hand goods for refurbishment and remanufacturing (Shinkuma and Managi, 2011; Lacy and Rutqvist, 2015; Valles, 2016). Some researchers have argued that the import of second-hand goods in developing countries may prevent their transition to an energy-efficient, low-carbon economy because of slow market changes. However, others have refuted this notion (Higashida and Managi, 2014). Kellenberg (2012) suggests that differences in environmental standards play an essential role in some countries' international waste trade flows.

This study suggests that technological advances in waste management may solve the problem of population clustering. However, Managi et al. (2014) suggests that policies that subsidize green technologies may be ineffective. By contrast, other studies have shown that well-designed policies can promote technological progress (Somanathan et al., 2014).

Several studies have been conducted on trade openness, economic development, and the environment. Managi et al. (2009) estimated the overall impact of trade openness on environmental quality and found that trade's benefits to the environment vary depending on the pollutant and the country. They also suggest that the impact is vital in the long term even though it is weak in the short term.

The structure of our paper is as follows. The next section presents the basic setting of the model. In section 3, we analyze the long run mobility of skilled labor (human capital owners). Further, section 4 shows the application of our model for waste management. Finally, in section 5 we present our closing arguments.

2 The model

Our basic framework follows Pflüger (2004)'s model, with the upper-tier utility being quasi-linear. Consider that the world is composed of two regions ($r \in \{1, 2\}$), two production factors (unskilled and skilled labor) two sectors (manufacturing and agriculture). Unskilled labor is intersectionally mobile and interregionally immobile, and each region r has the quantity L_r. Skilled labor is interregionally mobile and the quantity in the region r is K_r, and we assume $K_1 + K_2 = K$. This mobility setting is called the Footloose Entrepreneur model developed by Forslid and Ottaviano (2003).

Each household has the following preferences:

$$U = \mu \ln M + A + \Xi_r, \mu > 0, r \in \{1, 2\}, \tag{1}$$

$$M = \left[\int_0^{n_r} q(i_r)^\rho di_r + \int_0^{n_s} q(i_s)^\rho di_s \right]^{\frac{1}{\rho}}, \tag{2}$$

$$\Xi_r = \ln N_r (L_r + K_r)^{-k}, k > 0, \tag{3}$$

where M is the manufacturing aggregate, the consumption of the agricultural good, $q(i_r)$ is the consumption quantity of the variety produced at home i_r, $q(i_s)$ is that at the other region, n_r is the number of varieties produced at home, n_s is that at the other region, $\rho \in (0, 1)$ is the parameter of the elasticity of substitution $\sigma = 1/(1-\rho)$, $\sigma \in (1, \infty)$. Ξ_r is the utility from natural capital N_r in the region $r \in \{1, 2\}$, and the setting in (3) implies that natural capital is the club good with contagion effect from the regional population.

The budget constraint is given as follows:

$$\int_0^{n_r} p(i_r)q(i_r)di_r + \int_0^{n_s} p(i_s)q(i_s)di_s + A = y, \tag{4}$$

$p(i_r)$ is the price of the variety i_r. The utility maximization problem is given by

$$\max \mu \ln M + y - \left[\int_0^{n_r} p(i_r)q(i_r)di_r + \int_0^{n_s} p(i_s)q(i_s)di_s\right] + \Xi_r. \tag{5}$$

We get the following solutions:

$$M = \frac{\mu}{P}, \tag{6}$$

$$A = y - \mu, \tag{7}$$

$$q(i_r) = \mu \frac{p(i_r)^{-\sigma}}{P_r^{1-\sigma}}, \tag{8}$$

$$q(i_s) = \mu \frac{\tau p(i_s)^{-\sigma}}{P_r^{1-\sigma}}, \tag{9}$$

$$V_r = \mu(\ln \mu - 1) + y - \mu \ln P_r + \Xi_r, \tag{10}$$

where V_r is the indirect utility in the region r and τ is the parameter of the iceberg transport costs. That is, the consumer needs τ units of an imported variety to consume one unit of them. Trade freeness is defined as $\tau^{1-\ sigma}$. P_r is the perfect CES price index as follows:

$$P_r = \left[n_r p_r^{1-\sigma} + n_s(\tau p_s)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \tag{11}$$

Firms use both skilled and unskilled labor to produce manufacturing goods. We assume that the fixed labor input in manufacturing production is F units and that the marginal labor input is ρ units. The profit for the representative firm in the region r is

$$\Pi_r = p_r q_r - (F + \rho) w_r q_r. \tag{12}$$

The equilibrium price of the manufacturing goods is 1. The output of each firm located in region r is given by the following equation:

$$q_r = \frac{\mu(L_r + K_r)}{n_r + \phi n_s} + \frac{\phi\mu(L_s + K_s)}{\phi n_r + n_s}. \tag{13}$$

The zero profit condition is given by:

$$\sigma F w_r = q_r. \tag{14}$$

Using (14) and $F n_r = K_r$, the wage of skilled labor in the region 1 is given as follows:

$$w_1 = \frac{\mu}{\sigma}\left[\frac{\eta_1 + \lambda}{\lambda + \phi(1-\lambda)} + \frac{\phi[\eta_2 + (1-\lambda)]}{\phi\lambda + (1-\lambda)}\right], \tag{15}$$

and that in the region 2 is given by

$$w_2 = \frac{\mu}{\sigma}\left[\frac{\phi(\eta_1 + \lambda)}{\lambda + \phi(1-\lambda)} + \frac{\eta_2 + (1-\lambda)}{\phi\lambda + (1-\lambda)}\right], \tag{16}$$

where

$$\lambda = \frac{K_1}{K}, 1 - \lambda = \frac{K_2}{K}, \eta_r = \frac{L_r}{K}, \tag{17}$$

λ is the share of skilled workers (human capital) in region 1. η_r is the ratio of unskilled workers (labor) to the total of skilled workers. λ is an endogenous variable and η_r is an exogenous variable.

3 Long run equilibrium

Here, we analyze the mobility of skilled labor (human capital owners) in the long run. The replicator dynamics of λ is given by

$$\dot{\lambda} = \lambda(1-\lambda)[V_1 - V_2]. \tag{18}$$

The steady state corresponding to an interior stationary point is λ that satisfies $\Delta V = V_1 - V_2 = 0$ and the corner stationary points $\lambda = 0, 1$. The difference in indirect utility is given by

$$\Delta V = w_1 - w_2 - \mu \ln \frac{P_1}{P_2} + \Xi_1 - \Xi_2. \tag{19}$$

Here,

$$\Xi_1 - \Xi_2 = \ln \frac{\frac{N_1}{(\eta_1+\lambda)^k}}{\frac{N_2}{[\eta_2+(1-\lambda)]^k}}. \tag{20}$$

We assume that exogenous conditions are symmetric in each region, $L_1 = L_2 = L$, and $N_1 = N_2 = N$. Therefore, we can rewrite equation (19) as follows:

$$\begin{aligned}\Delta V(\lambda) = {} & \frac{(1-\phi)\mu}{\sigma}\left[\frac{\eta+\lambda}{\lambda+\phi(1-\lambda)} - \frac{\eta+(1-\lambda)}{\phi\lambda+(1-\lambda)}\right] \\ & + \frac{\mu}{\sigma-1}\ln\frac{\lambda+\phi(1-\lambda)}{(1-\lambda)+\phi\lambda} + k\ln\frac{\eta+(1-\lambda)}{\eta+\lambda}.\end{aligned} \tag{21}$$

The difference in indirect utility when the agglomeration to region 2 occurs ($\lambda = 0$) is given by

$$\Delta V(0) = \frac{(1-\phi)\mu}{\sigma}\left[\frac{\eta}{\phi} - (\eta+1)\right] + \frac{\mu}{\sigma-1}\ln\phi + k\ln\frac{\eta}{\eta+1}. \tag{22}$$

The difference in indirect utility when the agglomeration to region 1 occurs ($\lambda = 1$) is given by

$$\Delta V(1) = \frac{(1-\phi)\mu}{\sigma}\left[\eta + 1 - \frac{\eta}{\phi}\right] + \frac{\mu}{\sigma - 1}\ln\frac{1}{\phi} + k\ln\frac{\eta}{\eta+1}. \tag{23}$$

From (22) and (23),we obtain the following proposition regarding the critical level of the congestion effect that the full agglomeration equilibria $\lambda = 0, 1$ are stable.

Proposition 1 *The necessary and sufficient condition that* $\lambda = 0, 1$ *are stable is given by*

$$k < k_s,$$

where

$$k_s = \left[\ln\frac{\eta+1}{\eta}\right]^{-1}\left[\frac{(1-\phi)\mu}{\sigma}\left[\eta + 1 - \frac{\eta}{\phi}\right] + \frac{\mu}{\sigma-1}\ln\frac{1}{\phi}\right].$$

Proof. Because $\Delta V(0) = -\Delta V(1)$, the necessary and sufficient condition that $\lambda = 0, 1$ are stable is $V(0) = -V(1) < 0$. We can rearrange (22) as follows:

$$\begin{aligned}
\Delta V(0) &< 0, \\
\frac{(1-\phi)\mu}{\sigma}\left[\frac{\eta}{\phi} - (\eta+1)\right] + \frac{\mu}{\sigma-1}\ln\phi + k\ln\frac{\eta+1}{\eta} &< 0, \\
k\ln\frac{\eta+1}{\eta} < \frac{(1-\phi)\mu}{\sigma}\left[\eta+1-\frac{\eta}{\phi}\right] + \frac{\mu}{\sigma-1}\ln\frac{1}{\phi}&, \\
k < \left[\ln\frac{\eta+1}{\eta}\right]^{-1}\left[\frac{(1-\phi)\mu}{\sigma}\left[\eta+1-\frac{\eta}{\phi}\right] + \frac{\mu}{\sigma-1}\ln\frac{1}{\phi}\right] &:= k_s.
\end{aligned}$$

■

We call k_s the "sustain point" which denotes the critical level of the congestion effect that corner equilibria $\lambda = 0, 1$ are stable. We can obtain the following proposition regarding the critical level of the congestion effect that the symmetric equilibrium $\lambda = 0.5$ is stable.

Proposition 2 *The necessary and sufficient condition that symmetric interior equilibrium* $\lambda^* = 1/2$ *is stable is given by*

$$k > k_b,$$

where

$$k_b = \frac{(2\eta+1)\mu(1-\phi)\left[2\eta(\sigma-1)(\phi-1)+3\sigma\phi+\sigma-2\phi\right]}{(\sigma-1)\sigma(\phi+1)^2},$$

and the no-black-hole-condition is given by

$$\frac{\phi}{1-\phi} > \frac{2\eta(\sigma-1)}{3\sigma-2}.$$

Proof. The necessary and sufficient condition that $\lambda = 1/2$ is stable is as follows:

$$\left.\frac{d\Delta V(\lambda)}{d\lambda}\right|_{\lambda=1/2} < 0. \tag{24}$$

We can rearrange (24) as follows:

$$-\frac{\mu(\phi-1)\left(\phi^2-\frac{1}{2}(\phi-1)^2+1\right)\left(\eta(\phi-1)+\phi\right)}{\sigma\left(\frac{\phi-1}{2}+1\right)^2\left(\frac{\phi}{2}+\frac{1}{2}\right)^2} - \frac{k(2\eta+1)}{\eta^2+\eta+\frac{1}{4}} + \frac{\mu(\phi-1)(\phi+1)}{(\sigma-1)\left(\frac{\phi-1}{2}+1\right)\left(\frac{\phi-1}{2}-\phi\right)} < 0,$$

$$k > \frac{(2\eta+1)\mu(1-\phi)\left[2\eta(\sigma-1)(\phi-1)+3\sigma\phi+\sigma-2\phi\right]}{(\sigma-1)\sigma(\phi+1)^2} := k_b.$$

■

We call k_b the "break point," which means the congestion effect's critical level that symmetric equilibrium $\lambda = 0.5$ is stable. To clarify the implications of the above proposition, we performed a numerical plot. Figure 1 shows the replicator dynamics $\dot{\lambda}(\lambda)$ for different levels of congestion effects and for parameter values $\rho = 2/3$, $\sigma = 3$, $\tau = 1.2$, $\mu = 0.3$. We can summarize the results of the numerical plotting as follows:

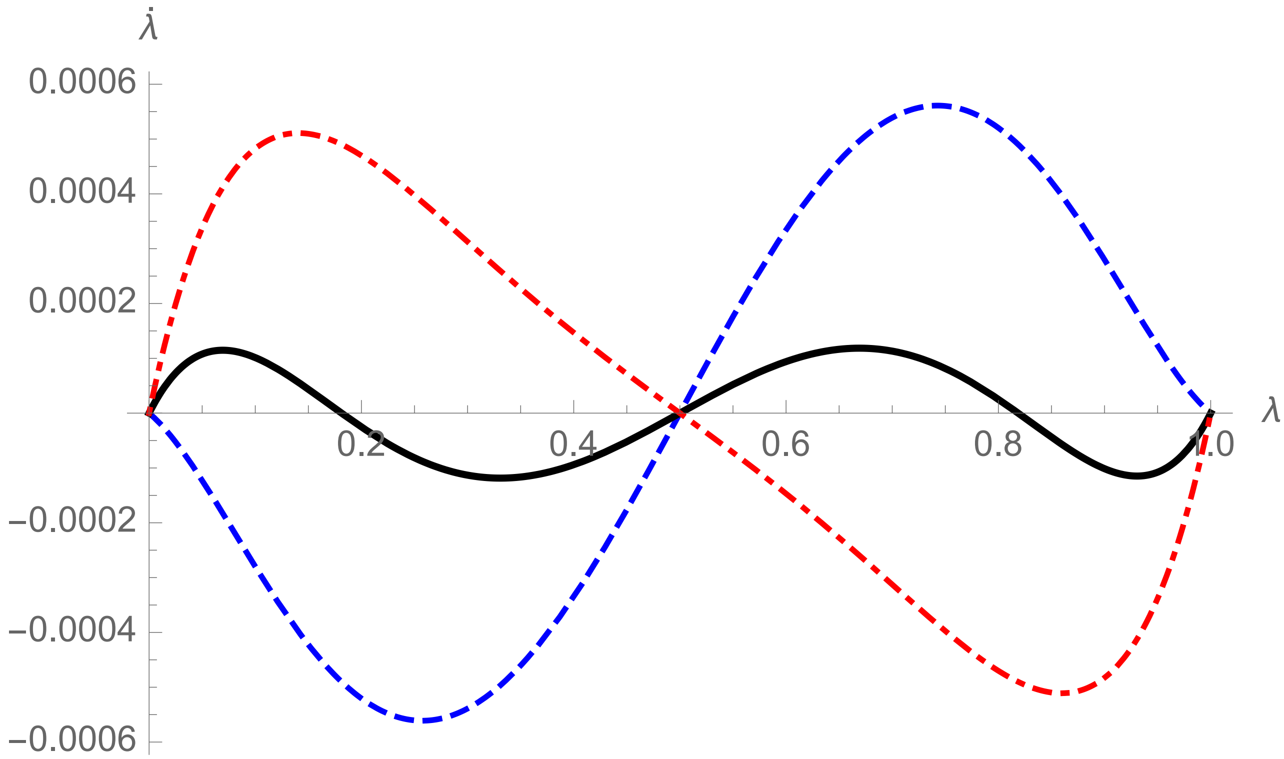

Figure 1: Comparison of replicator dynamics with respect to k

Notes: The figure shows the numerical plot of $\dot{\lambda}(\lambda)$ with low k (dashed line), intermediate k (thick line) and high k (dot-dashed line) with the parameter values $\rho = 2/3$, $\sigma = 3$, $\tau = 1.2$, $\mu = 0.3$, $K = L = 1$, $k = 0.07; 0.075; 0.08$.

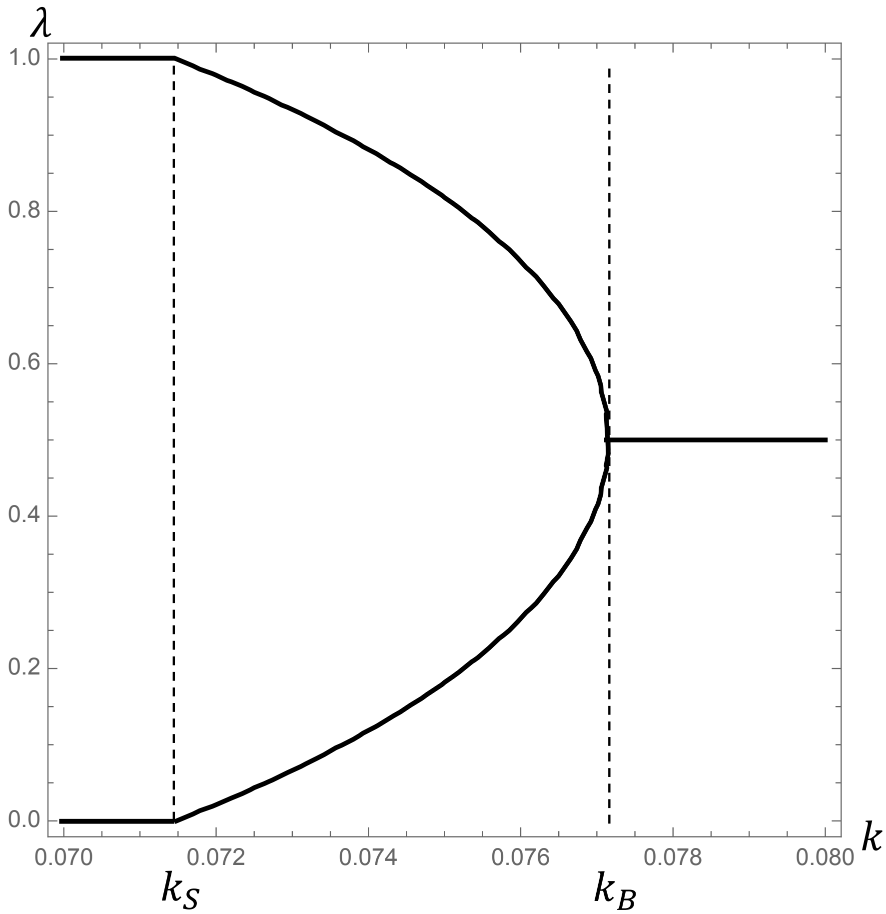

Figure 2: Bifurcation diagram

Notes: The figure shows the bifurcation diagram of λ and k with the parameter values $\rho = 2/3$, $\sigma = 3$, $\tau = 1.2$, $\mu = 0.3$, $K = L = 1$.

Result 1 *The symmetric equilibrium $\lambda = 0.5$ is stable when the congestion effect is large, internal asymmetric equilibria $\lambda \in (0, 0.5)$, and $\lambda \in (0.5, 1)$ are stable when the congestion effect is intermediate, and the full agglomeration equilibria $\lambda = 0, 1$ are stable when the congestion effect is small.*

For small congestion effects (as indicated by the dashed line in Figure 1), the agglomeration equilibria $\lambda = 0, 1$ are stable. Conversely, for high congestion effects (as drawn as the dot-dashed line in Figure 1), the dispersed equilibrium $\lambda = 0.5$ is stable. This result implies that when the congestion effect is small, the marginal benefit of aggregation exceeds the marginal cost and aggregation is stable, while when the congestion effect is large, the marginal benefit of aggregation is less than the marginal cost and dispersion is stable. In fact, when k is intermediate (thick line in Figure 1), the imperfectly aggregation equilibria $\lambda \in (0, 0, 5)$ and $\lambda \in (0.5, 1)$ are stable. Such equilibria are realistic. We assume that the congestion effect on natural capital can be an intermediate to explain a real-world agglomeration pattern under our model.

Figure 2 shows the stable equilibria in the corresponding bifurcation program. The model indicates supercritical pitchfork bifurcation for the congestion effect. When the congestion effect is lower than the sustain point k_s, full agglomeration equilibria are stable. When the congestion effect is between sustain point k_s and break point k_b, the internal asymmetric equilibria are stable. When the congestion effect is larger than the break point k_b, the symmetric equilibrium is stable.

4 Waste management

This section introduces waste for Ξ. We suppose the benefit from natural capital is as follows:

$$\Xi_r = \frac{N}{\Omega_r^k}. \tag{25}$$

Here, Ω_r is the aggregate waste in region r. We assume Ω_r as follows:

$$\Omega_r = (L_r + K_r)^{1/\omega}, \tag{26}$$

where $\omega > 0$ is the parameter for waste disposal technology. Here, the technology level is higher (ω is larger) and the environmental burden of a growing population can be diminished further. We can rearrange (26) as follows:

$$\Omega_1 = K^{1/\omega}(\eta + \lambda)^{1/\omega}, \tag{27}$$

$$\Omega_2 = K^{1/\omega}(\eta + 1 - \lambda)^{1/\omega}, \tag{28}$$

Substituting (27) and (28) into (25), we obtain as follows:

$$\Xi_1 = \frac{N}{K^{k/\omega}(\eta + \lambda)^{k/\omega}}, \tag{29}$$

$$\Xi_2 = \frac{N}{K^{k/\omega}(\eta + 1 - \lambda)^{k/\omega}}. \tag{30}$$

The replicator dynamics of λ is given by

$$\dot{\lambda} = \lambda(1 - \lambda)\Delta V(\lambda),$$

where

$$\begin{aligned}\Delta V(\lambda) = &\frac{(1-\phi)\mu}{\sigma}\left[\frac{\eta + \lambda}{\lambda + \phi(1-\lambda)} - \frac{\eta + (1-\lambda)}{\phi\lambda + (1-\lambda)}\right] \\ &+ \frac{\mu}{\sigma - 1}\ln\frac{\lambda + \phi(1-\lambda)}{(1-\lambda) + \phi\lambda} + \frac{k}{\omega}\ln\frac{\eta + (1-\lambda)}{\eta + \lambda}.\end{aligned} \tag{31}$$

As in the analysis of the previous section, we can derive the sustaining point and break point for the technological level of waste management (k/ω).

Proposition 3 *The necessary and sufficient condition that the symmetric equilibrium* $\lambda =$

0.5 *is stable is* $\omega < \omega_b$ *and the necessary and sufficient condition that the full agglomeration equilibria* $\lambda = 0$ *and* 1 *are stable is* $\omega > \omega_s$. *Here,* ω_b *and* ω_s *are as follows:*

$$\omega_b = \frac{k(\sigma-1)\sigma(\phi+1)^2}{(2\eta+1)\mu(1-\phi)\left[2\eta(\sigma-1)(\phi-1)+3\sigma\phi+\sigma-2\phi\right]}, \tag{32}$$

$$\omega_s = \frac{k\ln\frac{\eta+1}{\eta}}{\frac{(1-\phi)\mu}{\sigma}\left(\eta+1-\frac{\eta}{\phi}\right)+\frac{\mu}{\sigma-1}\ln\frac{1}{\phi}}. \tag{33}$$

The proof of Proposition 3 is the same as Proposition 1 and Proposition 2. Proposition 3 shows that the technological level of waste management ω has opposite properties to the congestion effect k. Figure 3 shows the numerical plots of the dynamics of λ for different technological levels of waste management. The results imply that a high level of waste management technology generates agglomeration. On the other hand, a low level generates dispersion. We can summarize the results of the numerical plot as follows:

Result 2 *The symmetric equilibrium* $\lambda = 0.5$ *is stable when the technological level of waste management* ω *is low, internal asymmetric equilibria* $\lambda \in (0, 0.5)$, *and* $\lambda \in (0.5, 1)$ *are stable when the level is intermediate, and the full agglomeration equilibria* $\lambda = 0, 1$ *are stable when the level is high.*

The mechanism underlying these results is as follows: For lower levels of ω, the marginal cost of increasing waste from agglomeration is more extensive than the marginal benefit, dispersion is more attractive. For higher ω, the marginal cost is lower than the marginal benefit, and agglomeration is more attractive.

As history has shown, as cities have grown over time, they have developed complex waste management technological innovations. In the *Edo* Era, between the 17th and 19th centuries, Tokyo adopted a sophisticated waste management system (Hoshino, 2008). In addition, Tokyo's population density increased rapidly during this period. This suggests the development of a positive feedback phenomenon through a cycle of population growth,

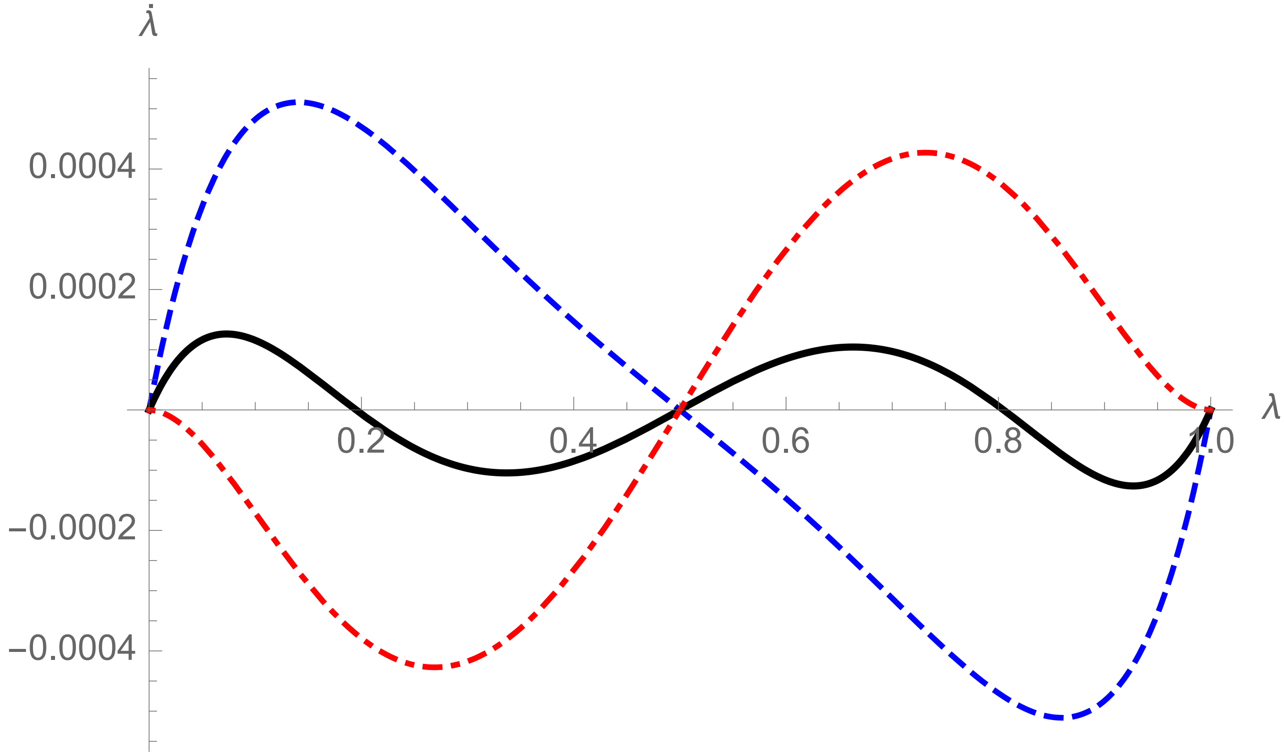

Figure 3: Comparison of replicator dynamics with respect to ω

Notes: The figure shows the numerical plot of $\dot{\lambda}(\lambda)$ with low ω (dashed line), intermediate ω (thick line) and high ω (dot-dashed line) with the parameter values $\rho = 2/3$, $\sigma = 3$, $\tau = 1.2$, $\mu = 0.3$, $k = 1$, $\omega = 12.5; 13.3; 14$.

technological innovation in waste management systems, and population density.[2] This cycle of population density increases and technological progress could potentially lead to a circular economy in cities.

We can also apply this model to the discussion of balanced national development and the redistribution of wealth. Let us assume that income inequality exists between urban and rural areas and that an income redistribution policy is implemented. This policy would reduce income inequality and the indirect effect of migration between regions in response to the policy. If higher taxes were imposed on high-income areas (urban), there would be incentives to move from urban to rural areas. This implies that inter-regional income redistribution policies could reduce the skewness of population distribution to some extent.

5 Concluding remarks

This study extended the new economic geography model to analyze the link between natural capital and waste management. We found that long-term population distribution patterns vary depending on the congestion effect of natural capital and waste management technological level. Specifically, full agglomeration equilibrium is realized in the long term for higher technological levels of waste management (lower congestion effects), the interior asymmetric equilibrium is realized for intermediate technological levels (intermediate congestion effects), and the symmetric dispersion equilibrium is realized for lower technological levels (higher congestion effects).

As discussed in the section 4, technological innovation in waste management and agglomeration can be interdependent. To analyze this in a future study, we would need to apply a theoretical model in which technological innovation and agglomeration are endogenized (Baldwin, 2001; Martin and Ottaviano, 2001; Fujita and Thisse, 2003; Hirose, 2008). In addition, NIMBY (not in my back yard) problems are an important issue (Dear, 1992). By

[2]Baldwin (2001); Martin and Ottaviano (2001) have shown that agglomeration promotes technological innovation and increases the rate of economic growth.

extending our framework to endogenize the establishment of cross-regional waste disposal sites, we could analyze NIMBY waste problems.[3]

We could also apply the analytical framework of this study to infectious diseases. Urban residents are at a higher risk of contracting infectious diseases, compared with rural residents. To avoid the risk of infection, urban residents have are incentive to move to rural areas. However, those who move from cities to rural areas are stigmatized. The stronger this stigma is, the incentive to migrate from urban to rural areas becomes weaker.[4] This analysis is beyond the scope of this paper and will be the subject of a future study.

[3]To analyze NIMBY and waste management, various issues should be considered, including radioactive waste management (Benjamin and Wagner, 2006), illegal dumping (Matsumoto and Takeuchi, 2011), and disaster waste(Ishimura et al., 2021).

[4]Katafuchi et al. (2020) and Kurita and Managi (2020) analyze the stigma of going out during the COVID-19 pandemic.

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