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Abstract

We focus on a region that is creative in the sense of Richard Florida. The creative class is broadly composed of existing and candidate entrepreneurs. The general question we analyze concerns the effects of Schumpeterian competition between existing and candidate entrepreneurs on economic growth and innovation policy in this region. We perform four specific tasks. First, when the flow rate of innovation function for the existing entrepreneurs is strictly concave, we delineate the circumstances in which competition between existing and candidate entrepreneurs leads to a unique balanced growth path (BGP) equilibrium. Second, we examine whether it is possible for the BGP equilibrium to involve different levels of R&D expenditures by the existing entrepreneurs. Third, we show how the BGP equilibrium is altered when the flow rate of innovation function for the existing entrepreneurs is constant. Finally, we study the impact that taxes and subsidies on R&D by existing and candidate entrepreneurs have on R&D expenditures and regional economic growth.

Keywords: Creative Class, Creative Destruction, Economic Growth, Innovation Policy, R&D

JEL Codes: R11, O31, O38

1. Introduction

Regional scientists and urban economists are now very familiar with the twin notions of the *creative class* and *creative capital*. This is because of the considerable impact that Richard Florida's two tomes *The Rise of the Creative Class* in 2002 and the *Flight of the Creative Class* in 2005 have had on both academic researchers and policymakers in regions throughout the United States and Western Europe.[4] Florida (2002, p. 68) helpfully explains that the creative class "consists of people who add economic value through their creativity." This class is composed of professionals such as doctors, lawyers, scientists, engineers, university professors, and, notably, bohemians such as artists, musicians, and sculptors. From the perspective of regional economic growth and development, these people are important because they possess creative capital which is the "intrinsically human ability to create new ideas, new technologies, new business models, new cultural forms, and whole new industries that really [matter]" (Florida, 2005a, p. 32).

The creative class deserves to be studied in detail, says Florida, because this group of people gives rise to ideas, information, and technology, outputs that are significant for the growth and development of cities and regions. Therefore, in this era of globalization, regions that want to be successful need to do all they can to attract and retain members of the creative class because this class is the primary driver of regional economic growth.

Several researchers have now documented the salience of the creative class in promoting regional economic growth and development. For instance, in a theoretical paper, Batabyal and Nijkamp (2013) show how the preferences of the creative class affect the properties of the so called constant growth path (CGP) equilibrium in an urban economy. Gabe *et al.* (2013) use

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Also see Florida (2005b, 2014) and Florida *et al.* (2008).

individual-level data from the United States (US) Current Population Surveys and show that in the 2006-2011 time period, relative to other workers, members of the creative class had a lower probability of being unemployed and that the benefit of being employed in a creative occupation rose over time.

Currid-Halkett and Stolarick (2013) complement the first finding in Gabe *et al.* (2013) mentioned in the preceding paragraph. Specifically, these researchers look at regional unemployment variation in the aftermath of the financial crisis in 2007-2008 and show that members of the creative class have a lower likelihood of being unemployed. From this result, these researchers conclude that although creativity definitely influences economic performance, the magnitude of this influence depends on the size of a region. Tiruneh (2014) uses Italian data and demonstrates that along with technology, the creative class in a region has a positive impact on this region's economic development.

Concentrating on Nordic nations, Tohmo (2015) points out that there is a clear positive association between the existing creative class in these nations and the birth rate of high-technology firms. Finally, in a paper that has both theoretical and empirical foci, Buettner and Janeba (2016) contend that in some settings, German cities face strong incentives to attract members of the creative class by providing these members with the appropriate amenities.

Given this review of the literature, it is now essential to emphasize three points. First, the above studies and the work of Eversole (2005), Baumol (2010), Siemiatycki (2013), and Batabyal and Nijkamp (2014) tells us that in regions where the creative class is a dominant part of the overall workforce, there is a clear link between *innovations*, the creative class, and regional economic growth and development. Second, innovative activities and processes are essentially *competitive* in nature and it is this competitive aspect that is related to the insight of

Joseph Schumpeter who argued that growth processes are marked by *creative destruction* in which "economic growth is driven, at least in part, by new firms replacing incumbents and new machines and products replacing old ones" (Acemoglu, 2009, p. 458). Finally, the preceding two points notwithstanding, there are *no* theoretical studies that analyze how Schumpeterian competition between the members of a region's creative class affects either innovation policy or economic growth in this region.[5] Hence, in this paper, we provide the *first* theoretical analysis of the ways in which Schumpeterian creative class competition influences both innovation policy and economic growth in a region that is creative *a la* Richard Florida.[6]

The remainder of this paper is organized as follows. Section 2 describes our theoretical model of a creative region that is adapted from Acemoglu (2009, pp. 472-479) and Acemoglu and Cao (2015). The creative class in this region is broadly composed of existing and candidate entrepreneurs. The key question we analyze concerns the effects of Schumpeterian competition between existing and candidate entrepreneurs for innovation policy and economic growth in this region. The engine of economic growth in our creative region is *process* innovations that lead to *quality* improvements in the inputs or machines that are used to produce a knowledge good such as a smartphone that is also the final consumption good. On the assumption that the flow rate of innovation function for the existing entrepreneurs is strictly concave, section 3 describes the

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The Schumpeterian competition we study is described in detail in section 2 below. Also, note that we are aware of three theoretical papers that study Schumpeterian economic growth in one or more regions. Batabyal and Nijkamp (2014) have used a Schumpeterian growth model to study the circumstances in which there is either too much or too little innovation first in a generic region and then when this region is part of an aggregate economy of $N \geq 2$ regions. Batabyal and Beladi (2016) have analyzed the effects of probabilistic innovations on Schumpeterian economic growth in a creative region. This paper also studies whether there is too much or too little innovation in this same creative region. Batabyal and Yoo (2017) analyze the nature of R&D *per se* and the Schumpeterian economic growth that the conduct of R&D gives rise to in a creative region. Although there is some similarity between the models employed in these three papers and the model employed in our paper, we stress that there is *no* overlap between the questions analyzed in the above three papers and the issues we study in the present paper.

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The existence of this kind of competition in real world settings has been noted by several writers. For instance, if we think of "Silicon Valley" in California as our creative region and individuals who are programmers or computer engineers or applications developers as members of the creative class in this region then the work of Miller and Wortham (2011), Terdiman (2014), and Widdicombe (2014) tells us that there is fierce competition not only between these individuals but also, more generally, for their talents by headhunters and final good producers.

circumstances in which competition between existing and candidate entrepreneurs in the creative class leads to a unique balanced growth path (BGP) equilibrium. Section 4 examines whether it is possible for the BGP equilibrium to involve *different* levels of research and development (R&D) expenditures by the existing entrepreneurs with machines of dissimilar qualities.[7] Section 5 shows how the BGP equilibrium is altered when the flow rate of innovation function for the existing entrepreneurs is *constant*. Section 6 studies the effect that *taxes* and *subsidies* on R&D by existing and candidate entrepreneurs have on R&D expenditures and regional economic growth. Finally, section 7 concludes and then offers two suggestions for extending the research delineated in this paper.

2. The Theoretical Framework

2.1. Preliminaries

Consider an infinite horizon, stylized region that is creative in the sense of Richard Florida. Time is continuous. The representative creative class household in this region displays constant relative risk aversion (CRRA) and its CRRA utility function is denoted by $\int_0^{\infty} \exp(-\rho t)\, [\{C(t)^{1-\theta}\text{-}1\}/(1\text{-}\theta)]dt, \theta \neq 1$, where $C(t)$ is consumption at time t, $\rho > 0$ is the constant time discount rate, and $\theta \geq 0$ is the constant coefficient of relative risk aversion.[8] At any time t, members of the creative class in the region under study possess creative capital and we denote each member and his creative capital by $R(t)$. The population of the creative class is constant and therefore we have $R(t) = R, \forall t$. The available creative capital is supplied inelastically.

The aggregate resource or budget constraint in our creative region at time t is given by

7 See Orman (2015) and Chen *et al.* (2017) for alternate perspectives on innovation and R&D.

8 See Acemoglu (2009, pp. 308-309) for additional details on the properties of the CRRA utility function.

$$C(t) + X(t) + I(t) \leq O(t) \quad (1)$$

where $C(t)$ is consumption, $X(t)$ is total spending on machines, $I(t)$ is total spending on R&D, and $O(t)$ is the output of the single final good for consumption that we shall think of as a knowledge good such as a smartphone. The price of this final good is normalized to unity at all points in time and therefore $O(t)$ denotes both the output and the value of the final good. The reader should note that the machines we have just referred to can also be thought of as inputs or intermediate goods.

There is a continuum of machines that is used to produce the single final good $O(t)$. Each machine line or variety[9] is described by ν where $\nu \in [0,1]$. As noted in the last paragraph of section 1, the source of economic growth in our creative region is *process innovations* that improve the *quality* of existing machines. To this end, let $q(\nu, t)$ denote the quality of the machine of line ν at time t.

The single final good for consumption (the knowledge good) in our creative region or $O(t)$ is produced in accordance with the function

$$O(t) = \frac{1}{1-\beta}\left[\int_0^1 q(\nu, t)^{\beta} x(\nu, t; q)^{1-\beta}\, d\nu\right] R^{\beta}, \quad (2)$$

where R is the creative capital input, $q(\nu, t)$ is the quality of the machine of line ν at time t, $x(\nu, t; q)$ is the total amount of the machine of variety ν and quality q that is used at time t, and $\beta \in (0,1)$ is a parameter of the production function. Let $w > 0$ denote the wage rate or the return to the creative capital input R and let $r > 0$ denote the interest rate.

9 We shall use the words "line" and "variety" interchangeably in the remainder of this paper.

The *quality* improvements in the inputs or machines that arise from the process innovations mentioned above are the result of two types of innovations. The first type of innovation is performed by members of the creative class who we refer to as *existing entrepreneurs*. These are the individuals who have already invented and produced machines that are presently being used to produce the final consumption good. The second type of innovation is performed by the members of the creative class who we call *candidate entrepreneurs*. These are the individuals who are seeking to invent and produce higher qualities of machine lines than the ones that are presently being used to produce the final consumption good. The central feature of the model we employ in this paper is the *Schumpeterian competition* between existing and candidate entrepreneurs in the creative class. This competition is Schumpeterian because for any machine line ν, when a candidate entrepreneur develops a machine of higher quality than the quality that is presently in use to produce the final consumption good, the candidate entrepreneur's higher quality machine *creatively destroys* an existing entrepreneur's now lower quality machine. Next, let us comprehend the R&D process that gives rise to the production of higher quality machines.

2.2. The invention and production of quality machines

Let $q(\nu,t)$ denote the quality of machine line ν at time t. The "quality ladder" for each machine variety is of the form

$$q(\nu,t) = \delta^n q(\nu,s), \forall \nu \; and \; t, \tag{3}$$

where $\delta > 1$ can be thought of as the "ladder" with rungs and n denotes the number of *marginal* innovations on this machine line---or the number of rungs climbed up the ladder---in the time period between $s \le t$ and t. Here, s is the time at which this particular type of machine technology was first invented and $q(\nu,s)$ is its quality at that point in time. An existing entrepreneur has a fully enforced patent on the machines that he has developed. However, this patent leaves open the possibility that a candidate entrepreneur will engage in R&D and thereby "jump over" an existing entrepreneur's machine quality. At time $t = 0$, each machine line begins with some quality $q(\nu, 0) > 0$ and this line is owned by an existing entrepreneur. We suppose that marginal innovations can only be brought about by an existing entrepreneur. In this regard, if an *existing* entrepreneur engages in R&D and spends an amount $i^E(\nu, t)q(\nu, t)$ of the final consumption good for a marginal innovation on a machine of quality $q(\nu, t)$ then this existing entrepreneur generates a flow rate of innovation given by $\phi(i^E)i^E(\nu, t)$ where $\phi'(i^E) > 0$, $\phi''(i^E) < 0$ and this flow rate function $\phi(\cdot)$ satisfies the (Inada like) conditions $lim_{i^E \to 0}\phi'(i^E) = \infty$ and $lim_{i^E \to \infty}\phi'(i^E) = 0$. The result of this R&D and expenditure by an existing entrepreneur is a new machine of quality $\delta q(\nu, t)$.

Candidate entrepreneurs can also engage in R&D with the aim of producing quality machines that will improve upon or jump over the presently used machines of line ν at time t. Suppose that the current quality of a machine of line ν is $q(\nu, t)$. Then, by spending one unit of the final consumption good, a *candidate* entrepreneur can innovate at the flow rate $\eta\{i^C(\nu, t)\}/q(\nu, t)$ where $\eta'\{\cdot\} < 0$ and $i^C(\nu, t)$ denotes the R&D expenditure incurred by the candidate entrepreneur on machine line ν at time t. For machine line ν, we refer to a quality innovation by a candidate entrepreneur that successfully jumps over an existing quality as a *drastic* innovation and a drastic quality innovation creatively destroys the existing quality machine of line ν. Note that whereas candidate entrepreneurs give rise to drastic innovations only, existing entrepreneurs can give rise to both marginal and drastic innovations. However, even though existing entrepreneurs can give rise to both kinds of innovation, in practice, they only generate marginal innovations.[10]

The fact that the $\eta\{\cdot\}$ function described above is strictly decreasing captures the idea that when many candidate entrepreneurs are competitively engaging in R&D to try to creatively destroy the same machine line, there is likely to exist some diminishing returns. Also, given the competitive nature of the interactions between the different candidate entrepreneurs, each one of them is likely to be a "small player." We model this feature of the problem by supposing that the candidate entrepreneurs treat the $\eta\{\cdot\}$ function as exogenous to their individual actions. Like we did for the flow rate function $\phi(\cdot)$ for the existing entrepreneurs, we assume that the $\eta\{\cdot\}$ function for the candidate entrepreneurs also satisfies the (Inada like) conditions $lim_{i^C\to\infty}\eta\{i^C\} = 0$ and $lim_{i^C\to 0}\eta\{i^C\} = \infty$. Finally, a quality innovation by a candidate entrepreneur leads to a new machine of quality $\chi q(\nu, t)$ where $\chi > \delta$. In other words, quality innovations by candidate entrepreneurs are *more drastic* than those undertaken by the existing entrepreneurs.

Once a specific machine of quality $q(\nu, t)$ has been invented, any amount of this machine can be produced at the marginal cost ψ in terms of the final consumption good and, in what follows, to simplify some of the mathematics, we shall utilize the normalization $\psi = 1 - \beta$. Note that the total spending on R&D or $I(t)$ in equation (1) can also be expressed as

$$I(t) = \int_0^1 \{i^E(\nu, t) + i^C(\nu, t)\} q(\nu, t) d\nu, \tag{4}$$

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This is because of Arrow's (1962) replacement effect. Because of the fully enforced patent discussed in the preceding paragraph, an existing entrepreneur is a *monopolist* over his machine lines that are currently in use to produce the final consumption good. Therefore, with a drastic innovation, the new quality innovation would jump over an existing quality machine and the existing entrepreneur would, in effect, be replacing himself. This means that an existing entrepreneur has little incentive to generate drastic innovations and hence such an entrepreneur gives rise to marginal innovations only. In contrast, the market for generating drastic innovations on the part of candidate entrepreneurs is *competitive* because there is free entry. As such, even with drastic innovations, candidate entrepreneurs make zero profit. For additional details on these points, see Acemoglu (2009, pp. 420-422) and Batabyal and Nijkamp (2014, pp. 610-611).

where $q(\nu, t)$ refers to the *highest* quality of machine variety ν at time t.

In the economy of the creative region under study, an *allocation* has four parts to it. First, there are the trajectories of consumption, total spending on machines, and total spending on R&D given by $\{C(t), X(t), I(t)\}_{t=0}^{\infty}$. Second, we have the trajectories of the R&D expenditures undertaken by the existing and the candidate entrepreneurs denoted by $\{i^E(\nu, t), i^C(\nu, t)\}_{\nu\in[0,1],t=0}^{\infty}$. Third, there are the prices and the quantities of the highest quality machines and the net present discounted value of profits from these same machines given by $\{p^x(\nu, t; q), x(\nu, t; q), V(\nu, t; q)\}_{\nu\in[0,1],t=0}^{\infty}$. Finally, there are the trajectories of the interest and the wage rates denoted by $\{r(t), w(t)\}_{t=0}^{\infty}$.

An equilibrium allocation is one in which four properties are satisfied simultaneously. First, the candidate entrepreneurs make R&D decisions to maximize their present discounted value. Second, the existing entrepreneurs select machine prices and the quantities and make R&D decisions to maximize their present discounted value. Third, the representative creative class household chooses consumption to maximize its utility. Finally, all markets clear. It is understood that a BGP is an equilibrium trajectory on which both consumption and the output of the final consumption good grow at a constant rate.

Now, with this theoretical framework in place, our next task is to delineate the circumstances in which competition between existing and candidate entrepreneurs in the creative class leads to a unique balanced growth path (BGP) equilibrium. While undertaking this exercise, we shall adapt some of the results in Peters and Simsek (2009, pp. 275-284) to our analysis of Schumpeterian competition between existing and candidate entrepreneurs in a creative region.

3. The BGP Equilibrium with Creative Class Competition

3.1. Existence

To derive the BGP equilibrium, it will be necessary to make two assumptions about the value function $V(\cdot)$. First, we suppose that this function is independent of whether the underlying value is derived from the activities of the existing or the candidate entrepreneurs. Second, we suppose that this value function is linear in the quality argument and hence we have $V(q) = \omega q$. Modifying equations (8) and (9) in Acemoglu and Cao (2015, p. 262) to our case, we infer that the demand for the highest quality machine of line ν and the monopoly profits of existing entrepreneurs are given by

$$x(\nu, t; q) = qR \tag{5}$$

and

$$\pi(\nu, t; q) = \beta qR, \tag{6}$$

where we have suppressed the dependence of quality q on the machine line ν and time t because this dependence does not arise once the current quality has been controlled for. The value to an existing entrepreneur from being a monopolist or the holder of a fully enforced patent can be written in terms of the value function $V(\cdot)$. This value function satisfies the so called Hamilton-Jacobi-Bellman (HJB) equation given by

$$r(t)V(\nu, t; q) - \dot{V}(\nu, t; q) = \pi(\cdot) + max_{i^E}\{\phi(i^E)V(\nu, t;\ \delta q) - V(\nu, t; q) - i^E q\} -$$
$$i^C\eta(i^C)V(\nu, t; q), \tag{7}$$

where the dot on the $V(\cdot)$ function denotes a time derivative. It should be noted that the existing entrepreneurs take the R&D expenditures i^C of the candidate entrepreneurs in equation (7) as given.

To determine the *optimal* level of R&D expenditures or i^{E*}, the existing entrepreneurs solve a maximization problem. As such, the optimal level i^{E*} can be written as

$$i^{E*} = argmax_{i^E}\{\phi(i^E)V(\nu,t;\delta q) - V(\nu,t;q) - i^E q\}. \tag{8}$$

Now let us focus on the R&D choices of the candidate entrepreneurs or i^C in the equilibrium of interest. In an interior equilibrium, we will have $i^C > 0$ and this means that the free entry condition for the candidate entrepreneurs must hold with equality. This free entry condition is

$$\eta\{i^C\}V(\nu,t;\ \chi q) = q. \tag{9}$$

Equation (9) tells us that spending an amount q gives rise to a flow rate of innovation $\eta\{i^C\}$ and this innovation raises the present quality of machine line ν to χq.

Using our independence and linear functional form assumptions for the value function $V(\cdot)$, we get $V(\nu,t;q) = V(t;q) = \omega(t)q$. We shall soon demonstrate that $\omega(t)$ is constant. Now, observe that equation (8) implies that

$$i^{E*}(t) = argmax_{i^E}\{\phi(i^E)(\delta-1)\omega(t) - i^E\}. \tag{10}$$

Differentiating equation (10) with respect to i^E, the first order necessary condition (FONC) for an optimum is

$$\phi'(i^{E*}(t))(\delta-1)\omega(t) = 1. \tag{11}$$

Because the $\phi(\cdot)$ function is strictly concave, the FONC in equation (11) above is also sufficient for an optimum.

Let us temporarily suppose that a BGP equilibrium exists. Then we know that along this BGP, the interest rate r is constant and all the relevant variables grow at constant rates. To this end, let g_Z denote the growth rate of a generic variable Z. Using equations (2) and (5), we can write the aggregate output of the final consumption good $O(t)$ as

$$O(t) = \frac{1}{1-\beta}\left\{\int_0^1 q(\nu,t)x(\nu,t;q)^{1-\beta}\,d\nu\right\}R^{\beta} = \frac{Q(t)R}{1-\beta}, \tag{12}$$

where $Q(t) = \int_0^1 q(\nu,t)d\nu$ is the average total quality of the machines that are in use. Similarly, we can also express the total spending on machines $X(t)$ as

$$X(t) = \int_0^1 \psi q(\nu,t)x(\nu,t;q)d\nu = (1-\beta)Q(t)R, \tag{13}$$

where $Q(t)$ is as stated right after equation (12). Inspecting equations (12) and (13) we see that both output $O(t)$ and expenditure on machines $X(t)$ are proportional to average total quality $Q(t)$. From this, we infer that $g_O = g_X = g_Q$.

We now want to show that the mathematical expression in the last line of the preceding paragraph implies that consumption $C(t)$ and R&D expenditures $I(t)$ also have to grow at this same rate. To see this, first rewrite the creative region's aggregate resource constraint given in equation (1) as

$$C(t) + I(t) = O(t) - X(t) = \frac{\beta(2-\beta)Q(t)R}{1-\beta}. \tag{14}$$

Next, we differentiate equation (14) with respect to time, remembering that on the BGP, both g_C and g_I are constant. After some steps of algebra, we get

$$g_O = g_C + (g_I - g_C)\left\{\frac{I(t)}{C(t)+I(t)}\right\}. \tag{15}$$

Recall that g_O, g_C, and g_I are all *constant* on the BGP. This fact and the fact that equation (15) holds for all time t tell us that the ratio $I(t)/\{C(t)+I(t)\}$ is also constant along the BGP. From this, it is clear that $C(t)$ and $I(t)$ both grow at the same rate and hence we have

$$g_{BGP} = g_O = g_C = g_I = g_Q. \tag{16}$$

By maximizing the representative creative class household's CRRA utility function with respect to consumption $C(t)$, we obtain the standard Euler equation. This equation tells us that whenever consumption grows at a constant rate, the interest rate r has to be constant. Adapting equation (18) in Acemoglu and Cao (2015, p. 264) to our problem, the transversality condition is $lim_{t\to\infty}\{\exp(-\int_0^t r(s)ds)\int_0^1 V(\nu,t;q)\} = 0$. In addition, using our analysis thus far in this section and modifying equation (4), we can express aggregate R&D expenditures $I(t)$ as

$$I(t) = \{i^{E*}(t) + i^C(t)\}Q(t). \tag{17}$$

We know that both $I(t)$ and $Q(t)$ are growing at the same rate. This tells us that the sum $\{i^{E*}(t) + i^C(t)\}$ is constant.

Next, let us show that the R&D expenditures incurred by the existing and the candidate entrepreneurs, that is, $i^{E*}(t)$ and i^C, are both constant. From the free entry condition for the candidate entrepreneurs given in equation (9), we infer that

$$\eta\{i^C(t)\}V(\nu,t;\chi q) = \eta\{i^C(t)\}\omega(t)\chi q = q. \tag{18}$$

Dividing the RHS of equation (18) by quality q gives us

$$\eta\{i^C(t)\}\omega(t)\chi = 1. \tag{19}$$

Combining equation (19) with the optimality condition in equation (11) for the existing entrepreneurs, we get

$$\eta\{i^C(t)\}\omega(t)\chi = \phi'\big(i^{E*}(t)\big)(\delta-1)\omega(t). \tag{20}$$

We now want to determine the sign of the partial derivative $\partial i^C(t)/\partial i^{E*}(t)$. To do so, we implicitly differentiate both sides of equation (20) and then simplify the resulting expression. This gives us

$$\frac{\partial i^C(t)}{\partial i^{E*}(t)} = \frac{(\delta-1)\phi''(i^{E*}(t))}{\chi\eta'\{i^C(t)\}} > 0, \tag{21}$$

because $\phi''(\cdot) < 0$ and $\eta'\{\cdot\} < 0$. The sign of the derivative in (21) tells us that R&D spending increases by existing entrepreneurs are matched by an increase in R&D spending by the candidate entrepreneurs. We have already noted that on the BGP, the sum of R&D expenditures $i^{E*}(t) + i^C(t)$ has to be constant. Combining this observation with the sign result in (21), we infer that both $i^{E*}(t)$ and $i^C(t)$ have to be *constant*. Therefore, we can now dispense with the time dependence of these two R&D expenditures and simply write $i^{E*}(t) = i^{E*}$ and $i^C(t) = i^C$. The constancy of these two R&D expenditures along with equation (19) tells us that $\omega(t) = \omega$. In turn, this means that the value function $V(\nu, t; q) = \omega(t)q = \omega q$. In other words, this value function depends only on quality q and not on time t.

To find a closed-form expression for ω, let us use the constancy of i^{E*} and i^C and write the HJB equation---equation (7)---as the following differential equation

$$r_{BGP}\omega(t)q - \dot{\omega}(t)q = \beta qR - i^{E*}q + \omega(t)q[(\delta-1)\phi(i^{E*}) - i^C\eta\{i^C\}]. \tag{22}$$

Setting $\dot{\omega}(t) = 0$ and then simplifying the resulting expression for $\omega(t)$, we get

$$\omega(t) = \omega = \frac{\beta R - i^{E*}}{r_{BGP} - (\delta-1)\phi(i^{E*}) + i^C\eta\{i^C\}}. \tag{23}$$

In equation (23), ω is constant because the ratio on the RHS is made up of terms that are themselves all constant.

Having obtained a closed-form expression for ω, we are finally in a position to explicitly specify the properties of the BGP equilibrium that we have been analyzing in this section. Specifically, the BGP equilibrium of interest is described by a system of five equations. These are given by (23),

$$g_{BGP} = \frac{\dot{C}(t)}{C(t)} = \frac{r_{BGP-\rho}}{\theta}, \tag{24}$$

$$(\delta - 1)\omega\phi'(i^{E*}) = 1, \tag{25}$$

$$\chi\omega\eta\{i^C\} = 1, \tag{26}$$

and

$$g_{BGP} = \frac{\dot{Q}(t)}{Q(t)} = (\delta - 1)\phi(i^{E*}) + (\chi - 1)i^C\eta\{i^C\}. \tag{27}$$

The expressions in (25) and (26) have been written as equalities because $i^{E*} > 0$ and $i^C > 0$ in the BGP equilibrium that we are studying.

Equations (23)-(27) constitute a system of five equations in the five unknowns $i^{E*}, i^C, \omega, r_{BGP}$, and g_{BGP}. Therefore, as long as the transversality condition---see the paragraph after equation (16)---is satisfied, there exists a BGP equilibrium with the following three properties. First, the output of the final consumption good (O), consumption by the representative creative class household (C), total R&D expenditures (I), and the average total quality of machines (Q) all grow at a constant rate. Second, our supposition that the value function has the form $V(q) = \omega q$ is valid. Finally, R&D expenditures by the existing and the candidate entrepreneurs (i^{E*}, i^{C}) are positive constants. We now proceed to show that this BGP equilibrium is unique.

3.2. Uniqueness

We begin by reiterating the point that on the BGP under study, $i^{E*} > 0$ and $i^{C} > 0$. This follows not only from equations (11) and (19) but also from the Inada like conditions satisfied by the $\phi(\cdot)$ and the $\eta\{\cdot\}$ functions and described in section 2.2. Using equations (25) and (26), we get

$$\frac{(\delta-1)\phi\prime(i^{E*})}{\chi\eta\{i^{C}\}} = 1. \tag{28}$$

From the equation (16) result that $g_C = g_Q$ on the BGP and equation (27), we get $r_{BGP} = \theta(\chi-1)i^{C}\eta\{i^{C}\} + \theta(\delta-1)\phi(i^{E*}) + \rho$. Substituting this last result and equation (25) into equation (23) gives us

$$\frac{(\delta-1)(\beta R - i^{E*})\phi\prime(i^{E*})}{(\delta-1)(\theta-1)\phi(i^{E*}) + \{\theta(\chi-1)+1\}i^{C}\eta\{i^{C}\} + \rho} = 1. \tag{29}$$

Equations (28) and (29) constitute a system of two equations in the variables i^{E*} and i^{C}. Solving these two equations simultaneously for i^{E*} and i^{C}, we can determine g_{BGP}, r_{BGP}, and ω from the other equations in the system of equations given by (23)-(27). Now, observe that equation (28) leads to the result in (21). This last finding tells us that we can define a function $f(\cdot)$ where

$$i^{C} = f(i^{E*}) \tag{30}$$

and $f'(\cdot) > 0$. In addition and as described in section 2.2, both the $\phi(\cdot)$ and the $\eta\{\cdot\}$ functions satisfy Inada like conditions. Therefore, we get $lim_{i^{E*}\to 0} f(i^{E*}) = 0$ and $lim_{i^{E*}\to\infty} f(i^{E*}) = \infty$.

We now want to ascertain the sign of the derivative di^C/di^{E*}. To determine this sign, let us totally differentiate equation (29) and then simplify the resulting expression. After several steps of algebra, we get

$$\frac{di^C}{di^{E*}} = \frac{(\delta-1)\{(\beta R - i^{E*})\phi''(i^{E*}) - \theta\phi'(i^{E*})}{\{\theta(\chi-1)+1\}[d(\eta\{i^C\}i^C)/di^C]} < 0. \tag{31}$$

The negative sign in (31) follows from the following two observations. First, the function $\phi(\cdot)$ is strictly concave and hence $\phi''(\cdot) < 0$. Second, the product $i^C\eta\{i^C\}$ is assumed to be increasing in i^C. Given the strict inequality in (31), we infer that equation (29) implicitly defines a second function $j(\cdot)$ where

$$i^C = j(i^{E*}) \tag{32}$$

and $j'(\cdot) < 0$. Also, because the $\phi(\cdot)$ and the $\eta\{\cdot\}$ functions satisfy the Inada like conditions discussed in section 2.2, we have $lim_{i^{E*}\to 0} j(i^{E*}) = j(0) > 0$. The differentiability of the $f(\cdot)$ and the $j(\cdot)$ functions tells us that both these functions are continuous. In turn, the continuity of these two functions implies that there must exist a *unique* value of i^C or the R&D expenditures incurred by the candidate entrepreneurs with the property that

$$i^C = f(i^{E*}) = j(i^{E*}). \tag{33}$$

From equation (33) it is clear that in the BGP equilibrium under study, i^{E*} and i^C or the R&D expenditures of the existing and the candidate entrepreneurs are uniquely determined. In addition, we deduce that the interest rate (r_{BGP}), the creative economy's growth rate (g_{BGP}), and the coefficient of the value function (ω) are all uniquely determined. Therefore, we conclude that the BGP equilibrium that we have been studying in this section is *unique*. Our next task is to examine whether it is possible for this BGP equilibrium to involve different levels of R&D expenditures by existing entrepreneurs with machines of dissimilar qualities.

4. R&D Expenditures by the Existing Entrepreneurs

The first point to note is that the optimal level of R&D expenditures by the existing entrepreneurs (i^{E*}) is given by equation (11). Inspecting equation (11), it is clear that i^{E*} is a function of δ and ω but it is not a function of quality (q). In addition, we know from the section 3 analysis that in the BGP equilibrium, the value function is linear and given by $V(q) = \omega q$. These two findings together tell us that the optimal R&D expenditures of the existing entrepreneurs are *independent* of q. Therefore, the simple conclusion we now draw is that in the BGP equilibrium under study here, it is *not* possible for the optimal R&D expenditures of the existing entrepreneurs to vary across machines with different qualities.

Having said this, we should also point out that we have thus far studied a BGP equilibrium in which the value function $V(\cdot)$ is linear. We have not demonstrated that a BGP equilibrium in which the value function is nonlinear does not exist. If such an equilibrium were to exist then we conjecture that in this equilibrium, the independence result stated in the preceding paragraph would not hold. Let us now analyze how the BGP equilibrium discussed in section 3 would be altered when the flow rate of innovation function for the existing entrepreneurs or $\phi(\cdot)$ is constant.

5. The Constancy of the Flow Rate of Innovation

When the flow rate of innovation function is constant, we get $\phi'(\cdot) = 0$. Substituing this result in either equation (8) or (10), we see that the maximization problem faced by the existing entrepreneurs is linear in their optimal R&D spending choice or i^{E*}. This means that in the BGP equilibrium, the value function $V(\cdot)$ will need to have the property that the existing entrepreneurs are indifferent between all possible choices of optimal R&D spending or i^{E*}. When this is the case, all the existing entrepreneurs will typically *not* select the same optimal R&D expenditure i^{E*}. Our last task in this paper is to analyze the effect that taxes and subsidies on R&D by the existing and the candidate entrepreneurs have on R&D expenditures and economic growth in the creative region under study.

6. The Impact of R&D Taxes and Subsidies

6.1. BGP equilibrium with taxes

Suppose that an appropriate regional authority (RA) levies taxes on the R&D expenditures undertaken by the existing and the candidate entrepreneurs. Let us denote these two taxes by τ^E and τ^C respectively. Clearly, these two taxes can be expected to alter the R&D spending decisions of the two types of entrepreneurs in our creative region. With the tax τ^E, equation (11) for the existing entrepreneurs needs to be modified. We now have

$$(\delta - 1)\phi'(i^{E*})\omega(t) = 1 + \tau^E. \tag{34}$$

Similarly, modifying equation (19) for the candidate entrepreneurs, we get

$$\eta\{i^C(t)\}\omega(t)\chi = 1 + \tau^C. \tag{35}$$

Equations (34) and (35) reflect the fact that spending one unit of the final consumption good on R&D costs $1 + \tau^E$ units to the existing entrepreneurs and $1 + \tau^C$ units to the candidate entrepreneurs.

To determine the coefficient $\omega(t)$ of the value function, we have to modify equation (22). This gives us

$$r_{BGP}\omega(t) = \beta R - i^{E*}(1 + \tau^E) + \omega(t)[(\delta - 1)\phi(i^{E*}) - i^C\eta\{i^C\}]. \tag{36}$$

Simplifying equation (36), we get the equation for $\omega(t)$ that we seek. That equation is

$$\omega(t) = \omega = \frac{\beta R - i^{E*}(1+\tau^E)}{r_{BGP} - (\delta-1)\phi(i^{E*}) + i^C \eta\{i^C\}}. \tag{37}$$

Equation (37) tells us that although ω does not depend on the tax on candidate entrepreneurs (τ^C), it does depend directly on the tax on existing entrepreneurs (τ^E).

The BGP equilibrium with the R&D taxes will now be determined by a system of equations similar to equations (23)-(27). Using modified versions of equations (28) and (29), we can, once again, solve for the optimal values of i^{E*} and i^C. The two modified equations are

$$\left(\frac{1+\tau^C}{1+\tau^E}\right) \frac{(\delta-1)\phi'(i^{E*})}{\chi \eta\{i^C\}} = 1 \tag{38}$$

and

$$\frac{(\delta-1)\{\beta R - i^{E*}(1+\tau^E)\}\phi'(i^{E*})}{(\delta-1)(\theta-1)\phi(i^{E*}) + \{\theta(\chi-1)+1\} i^C \eta\{i^C\} + \rho} = 1. \tag{39}$$

Once equations (38) and (39) have been solved simultaneously for the optimal values of i^{E*} and i^C, we can ascertain the BGP growth rate of our creative region's economy from the representative creative class household's Euler equation and the definition of the growth rate given in equation (27). Using the same line of reasoning as that employed in section 3.2 to obtain equations (30) and (32), we infer that with the two taxes in place, equation (38) defines a strictly increasing and differentiable function $f(\cdot)$ where

$$i^C = f(i^{E*}, \tau^E, \tau^C). \tag{40}$$

Similarly, equation (39) defines a strictly decreasing and differentiable function $j(\cdot)$ where

$$i^C = j(i^{E*}, \tau^E). \tag{41}$$

Because differentiability implies continuity, the $f(\cdot)$ and the $j(\cdot)$ functions are continuous and this tells us that for any tax policy (τ^E, τ^C) implemented by the RA in our creative region, there will exist a unique BGP equilibrium with taxes.

6.2. Comparative statics with taxes and subsidies

6.2.1 Tax/subsidy on candidate entrepreneurs

Suppose there is an increase in the R&D tax levied on candidate entrepreneurs (τ^C). One way to interpret this tax on the candidate entrepreneurs is to think of it as a policy that is, in effect, a more stringent patent policy than the patent policy that existed before this increase in τ^C. Since the function $j(i^{E*}, \tau^E)$ in equation (41) does not depend on τ^C, the graph of this function is *unaffected* by this increase. However, the function $f(\cdot)$ in equation (40) depends on both τ^E and τ^C. Now, implicit differentiation of equation (38), keeping the R&D spending by the candidate entrepreneurs i^C fixed, yields

$$\frac{di^{E*}}{d\tau^C}_{i^C\, fixed} = -\frac{\phi'(i^{E*})}{(1+\tau^C)\phi''(i^{E*})} > 0. \tag{42}$$

Equation (42) tells us that the graph of the function $f(\cdot, \tau^E, \tau^C)$ shifts to the *right*. Combining this discussion about how an increase in τ^C affects the graph of the two relevant functions, we see that

$$\frac{di^{E*}}{d\tau^C} > 0 \ and\ \frac{di^C}{d\tau^C} < 0. \tag{43}$$

In other words, an increase in the tax on R&D spending incurred by the candidate entrepreneurs *lowers* their R&D and *increases* the R&D undertaken by the existing entrepreneurs. Alternately, when this R&D tax increase is viewed as a more stringent patent policy, this more stringent patent policy lowers (increases) the R&D undertaken by the candidate (existing) entrepreneurs.

Now note that if τ^C is the tax imposed on the R&D spending of the candidate entrepreneurs then we can interpret $-\tau^C$ as the corresponding subsidy given to these same entrepreneurs. This means that a small increase in the tax τ^C is equivalent to a small decrease in the subsidy $-\tau^C$. So, looked at from the standpoint of a subsidy, the comparative statics results in (43) tell us that an increase in the subsidy $-\tau^C$ on R&D spending undertaken by the candidate entrepreneurs *raises* their R&D and *lowers* the R&D taken on by the existing entrepreneurs.

What is the impact of the increase in τ^C on the BGP growth rate of the economy of our creative region? To answer this question, we differentiate equation (27). This gives

$$\frac{dg_{BGP}}{d\tau^C} = \underbrace{(\chi - 1)\frac{\partial[i^C\eta\{i^C\}]}{\partial i^C}(\frac{di^C}{d\tau^C})}_{-} + \underbrace{(\delta - 1)\phi'(i^{E*})(\frac{di^{E*}}{d\tau^C})}_{+} \gtrless 0. \qquad (44)$$

The sign of the first term on the RHS of equation (44) is negative because this first term records the contribution to economic growth made by the candidate entrepreneurs and this contribution is *lessened* with the tax (τ^C). In contrast, the sign of the second term on the RHS is positive because this second term accounts for the contribution to economic growth made by the existing entrepreneurs and this contribution is *increased* with the tax (τ^C). Putting these two pieces of information together, we see that the total effect of the R&D tax (or subsidy) on the BGP growth rate is ambiguous.

6.2.2 Tax/subsidy on existing entrepreneurs

We now study the impacts of the R&D tax on the existing entrepreneurs in our creative region. Note that equations (38) and (39) are both affected by the tax (τ^E). Differentiating both sides of equation (38) and then simplifying the resulting expression gives us

$$\frac{di^{E*}}{d\tau^E}_{i^C\,fixed} = \frac{\phi\prime(i^{E*})}{(1+\tau^E)\phi\prime\prime(i^{E*})} < 0. \qquad (45)$$

So, for a fixed level of R&D spending by the candidate entrepreneurs, the existing entrepreneurs respond to the tax τ^E by lowering their R&D spending. This means that the graph of the upward sloping $f(\cdot)$ function shifts to the *left*. Next, we totally differentiate both sides of equation (39). This gives us

$$\frac{di^{E*}}{d\tau^E}_{i^C\,fixed} = \frac{(\delta-1)i^{E*}\phi'(i^{E*})+1}{\frac{\partial}{\partial i^{E*}}\left[\frac{(\delta-1)\{\beta R - i^{E*}(1+\tau^E)\}\phi'(i^{E*})}{\Delta(i^{E*},i^C)}\right]}\Delta(i^{E*},i^C), \qquad (46)$$

where the function $\Delta(i^{E*},i^C) = (\delta-1)(\theta-1)\phi(i^{E*}) + \{1+\theta(\chi-1)\}i^C\eta\{i^C\} + \rho$.

Recall from the discussion in section 6.1 that the $j(\cdot,\tau^E)$ function is strictly decreasing. Knowing this, we infer that the sign of the derivative $\frac{\partial[\cdot]}{\partial i^{E*}}$ in the denominator on the RHS of equation (46) is negative. Given this last finding, equation (39) tells us that for a given level of R&D spending by the candidate entrepreneurs (i^C), R&D spending by the existing entrepreneurs (i^{E*}) is *decreasing* in the R&D tax (τ^E) levied on the existing entrepreneurs. In symbols, we have $\frac{di^{E*}}{d\tau^E}_{i^C\,fixed} < 0$. Put differently, the graph of the strictly decreasing function $j(\cdot,\tau^E)$ shifts to the *left*. The discussion thus far tells us that the total impact of the tax τ^E on the R&D

spending of the candidate entrepreneurs is *indeterminate*. Therefore, the result that is analogous to (43) in section 6.2.1 is

$$\frac{di^{E*}}{d\tau^E} < 0 \; and \; \frac{di^C}{d\tau^E} \gtreqless 0. \tag{47}$$

It is informative to comprehend why the impact of the tax τ^E on R&D spending by the candidate entrepreneurs is indeterminate. Consider a given level of i^C. Then, equation (27) tells us that lower R&D spending by the existing entrepreneurs will reduce the growth rate of the economy of our creative region. When this happens, the representative creative class household's Euler equation says that the interest rate will also fall. This falling interest rate will make innovations now more appealing to entrepreneurs because of the reduced discounting of future profits. As such, this first effect tends to *increase* the R&D spending (i^C) of the candidate entrepreneurs. However, recall that the point of the Schumpeterian competition between the existing and the candidate entrepreneurs is to enable a candidate entrepreneur to "jump over" or creatively destroy an existing entrepreneur and take this individual's place as the producer of a machine that is used to produce the final consumption good. In this regard, the tax τ^E diminishes the value of becoming an existing entrepreneur. This second effect tends to *decrease* R&D expenditures by the candidate entrepreneurs. Because these two effects go in opposite directions, the total impact of the tax τ^E on R&D spending by the candidate entrepreneurs is indeterminate.

As in section 6.2.1, when τ^E is the tax imposed on the R&D spending of existing entrepreneurs, we can interpret $-\tau^E$ as the corresponding subsidy given to these same entrepreneurs. In other words, a small increase in the tax τ^E is equivalent to a small decrease in the subsidy $-\tau^E$. So, looked at from the perspective of a subsidy, the comparative statics results in (47) imply that an increase in the subsidy $-\tau^E$ on R&D spending undertaken by existing entrepreneurs *raises* their R&D and has an ambiguous impact on the R&D undertaken by the candidate entrepreneurs.

Consistent with the analysis in section 6.2.1, we can again ask what the impact of the increase in τ^E is on the BGP growth rate of the economy of our creative region. In symbols, we want to know the sign of the derivative $dg_{BGP}/d\tau^E$. We claim that an increase in the tax on the R&D of existing entrepreneurs *lowers* the growth rate of the economy of our creative region or $dg_{BGP}/d\tau^E < 0$. To demonstrate the validity of our claim, we proceed with a proof by contradiction. We begin by focusing on equation (37) which specifies the coefficient ω of the value function $V(\cdot)$. Inspection of equation (37) shows that, *inter alia*, ω depends on the exogenous tax τ^E and on the three endogenous variables i^{E*}, i^C, and r_{BGP}. Now, if we use the representative creative class household's Euler equation to substitute the value of the BGP growth rate g_{BGP} for the BGP interest rate r_{BGP} in equation (37), we get

$$\omega(i^{E*}, i^C, g_{BGP};\ \tau^E) = \frac{\beta R - i^{E*}(1+\tau^E)}{\theta g_{BGP} + \rho - (\delta - 1)\phi(i^{E*}) + i^C \eta\{i^C\}}. \tag{48}$$

To make further progress, we will need to totally differentiate equation (48). This gives us the following derivative

$$\frac{d\omega(i^{E*}, i^C, g_{BGP};\tau^E)}{d\tau^E} = \frac{\partial\omega}{\partial\tau^E} + \frac{\partial\omega}{\partial i^{E*}}\frac{\partial i^{E*}}{\partial\tau^E} + \frac{\partial\omega}{\partial i^C}\frac{\partial i^C}{\partial\tau^E} + \frac{\partial\omega}{\partial g_{BGP}}\frac{\partial g_{BGP}}{\partial\tau^E}. \tag{49}$$

We can immediately simplify two of the partial derivatives in equation (49). Specifically, from equation (48) we get $\partial\omega/\partial\tau^E < 0$. Also, the envelope theorem[11] tells us that $\partial\omega/\partial i^{E*} = 0$.

To continue the proof, suppose our claim that $dg_{BGP}/d\tau^E < 0$ is false and that $dg_{BGP}/d\tau^E > 0$. Keeping equation (27) and the result that $\partial i^{E*}/\partial\tau^E < 0$ from (47) in mind, we reason that the BGP growth rate g_{BGP} can only increase if the candidate entrepreneurs respond to the tax τ^E by substantially increasing their R&D spending i^C. In symbols, we need to have

$$\frac{\partial g_{BGP}}{\partial\tau^E} > 0 \ \Rightarrow\ \frac{\partial i^C}{\partial\tau^E} > 0. \tag{50}$$

Because the product $i^C\eta\{i^C\}$ is assumed to be increasing in i^C, from equation (48) we infer that $\partial\omega/\partial g_{BGP} < 0$ and that $\partial\omega/\partial i^C < 0$. As such, equations (49) and (50) together tell us that if g_{BGP} is to go up then the following result must hold

$$\frac{d\omega(i^{E*},i^C,g_{BGP};\tau^E)}{d\tau^E} = \underbrace{\frac{\partial\omega}{\partial\tau^E}}_{-} + \underbrace{\frac{\partial\omega}{\partial i^C}}_{-}\underbrace{\frac{di^C}{d\tau^E}}_{+} + \underbrace{\frac{\partial\omega}{\partial g_{BGP}}}_{-}\underbrace{\frac{dg_{BGP}}{d\tau^E}}_{+} < 0. \tag{51}$$

Next, we rewrite equation (35) which tells us how the candidate entrepreneurs set their R&D spending. This gives us

$$\chi\omega(i^{E*},i^C,g_{BGP};\ \tau^E)\eta\{i^C\} = 1+\tau^C. \tag{52}$$

Totally differentiating equation (52), we get

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See theorem A.31 in Acemoglu (2009, pp. 914-915) for additional details on the envelope theorem.

$$\chi\eta'\{i^C\}\omega(i^{E*}, i^C, g_{BGP};\ \tau^E)\frac{di^C}{d\tau^E} + \chi\eta\{i^C\}\frac{d\omega(i^{E*}, i^C, g_{BGP}; \tau^E)}{d\tau^E} = 0. \tag{53}$$

Because $\eta'\{i^C\} < 0$, we can use this result to rewrite equation (53) in a more convenient form. That form is

$$\frac{d\omega(i^{E*}, i^C, g_{BGP}; \tau^E)/d\tau^E}{di^C/d\tau^E} = -\frac{\omega(i^{E*}, i^C, g_{BGP}; \tau^E)\eta'\{i^C\}}{\eta\{i^C\}} > 0. \tag{54}$$

However, equation (54) clearly contradicts the result, from equations (50) and (51), that

$$\frac{d\omega(i^{E*}, i^C, g_{BGP,}\ \tau^E/d\tau^E}{di^C/d\tau^E} = \underbrace{\frac{\partial\omega/\partial\tau^E}{di^C/d\tau^E}}_{(-)} + \underbrace{\frac{\partial\omega}{\partial\tau^E}}_{(-)} + \underbrace{(\frac{\partial\omega/\partial g_{BGP}}{di^C/d\tau^E})}_{(-)}\underbrace{(\frac{dg_{BGP}/d\tau^E}{di^C/d\tau^E})}_{(+)} < 0. \tag{55}$$

Therefore, we conclude that $dg_{BGP}/d\tau^E < 0$.

To intuitively see why the growth rate of the economy of our creative region cannot increase with the tax τ^E, note that when the existing entrepreneurs reduce their spending on R&D, higher economic growth can come about only if there is increased R&D by the candidate entrepreneurs. However, candidate entrepreneurs will increase their spending on R&D if and only if as a result of this increase, the future *value* of being an existing entrepreneur *rises*. This is what equation (54) tells us. In symbols, i^C will go up only if ω also goes up.

Now suppose that the equilibrium value function (proxied by ω) goes up. Then, from the standpoint of the existing entrepreneurs, in equilibrium, a higher value function can exist simultaneously with higher growth and replacement rates[12] only if their economic rewards are also higher. However, higher taxes do not raise but instead lower the economic rewards accruing to existing entrepreneurs. Put differently, in the presence of the tax τ^E, an increase in the R&D spending of the candidate entrepreneurs is *not* sufficient for the growth rate of the creative region to rise.

From the perspective of the RA, the finding in the preceding paragraph points to a clear asymmetry in the growth effects of innovation policy. In particular, a tax on the R&D of the candidate entrepreneurs may or may not stimulate the growth rate of the economy of the creative region. However, a tax on the R&D undertaken by the existing entrepreneurs will definitely lower this same growth rate. This concludes our analysis of Schumpeterian creative class competition, innovation policy, and regional economic growth.

7. Conclusions

In this paper, we concentrated on a region that was creative in the sense of Richard Florida. Broadly speaking, the creative class was composed of existing and candidate entrepreneurs. The general question we analyzed concerned the impacts of Schumpeterian competition between existing and candidate entrepreneurs for economic growth and innovation policy in the region under study. We performed four specific tasks. First, when the flow rate of innovation function for the existing entrepreneurs was strictly concave, we described the circumstances in which competition between existing and candidate entrepreneurs led to a unique balanced growth path (BGP) equilibrium. Second, we examined whether it was possible for the BGP equilibrium to involve different levels of R&D expenditures by the existing

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This replacement refers to the replacement of existing entrepreneurs by candidate entrepreneurs as a result of the Schumpeterian competition between them. Alternately, we can also think of this replacement as an outcome of the creative destruction of lower quality machines by higher quality ones.

entrepreneurs. Third, we showed how the BGP equilibrium was altered when the flow rate of innovation function for the existing entrepreneurs was constant. Finally, we studied the impact that taxes and subsidies on R&D by existing and candidate entrepreneurs had on R&D expenditures and on regional economic growth.

The analysis in this paper can be extended in a number of different directions. Here are two suggestions for augmenting the research described here. First, suppose that the $\eta\{\cdot\}$ function that was assumed to be strictly decreasing and differentiable in the present paper is not strictly decreasing but constant so that we have $\eta\{i^C\} = \hat{\eta}$, a constant. This means that there are no externalities in the economy emanating from the R&D undertaken by the candidate entrepreneurs. It would be interesting to analyze the effects of the R&D taxes and subsidies in this particular case. Second, it would also be useful to analyze a multi-region model of Schumpeterian competition between the creative classes in different regions to ascertain what kinds of spatial interactions between different creative regions can be studied in a theoretically meaningful manner. Studies that incorporate these aspects of the problem into the analysis will increase our understanding of the nexuses between Schumpeterian competition in the creative class in one or more regions and economic growth in these same regions.

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