A NOTE ON SCHUMPETERIAN COMPETITION IN THE CREATIVE CLASS AND INNOVATION POLICY

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Abstract
We study innovation policy in a region in which the members of the creative class engage in Schumpeterian competition and thereby extend aspects of the recent analysis in Batabyal and Yoo (2017). Using the language of these researchers, the creative class is broadly composed of existing and candidate entrepreneurs. In contrast to these researchers, we suppose that R&D by candidate entrepreneurs does not generate any negative externalities. In this setting, we analyze the impact that taxes and subsidies on R&D by existing and candidate entrepreneurs have on R&D expenditures and regional economic growth.
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1. Introduction

We begin with the definitions of two concepts---the creative class and creative capital---that are now very familiar to and much studied by both regional scientists and urban economists. Richard Florida (2002, p. 68) helpfully explains that the creative class "consists of people who add economic value through their creativity." This class is made up of professionals such as doctors, lawyers, scientists, engineers, university professors, and, notably, bohemians such as artists, musicians, and sculptors. From the standpoint of regional economic growth and development, these people are significant 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, 2005, p. 32).

Several researchers have now documented the salience of the creative class in promoting regional economic growth and development. In a recent paper, Batabyal and Yoo (2017) (hereafter B&Y) summarize the literature on the creative class and make three salient points. First, B&Y note 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, B&Y contend that innovative activities and processes are essentially competitive in nature and that this competitive aspect 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, B&Y point out that the preceding two points notwithstanding, there are no theoretical studies that examine how Schumpeterian competition between the members of a region's creative class affects both innovation policy and economic growth in this region.

Given this state of affairs, B&Y provide what they claim is the first theoretical analysis of the ways in which Schumpeterian competition in the creative class affects innovation policy and economic growth in a region that is creative in the sense of Richard Florida. B&Y broadly divide the creative class they study into existing and candidate entrepreneurs. A key assumption made by B&Y in their analysis is that negative externalities accompany the R&D

undertaken by the candidate entrepreneurs. The justification for this assumption is the idea that when many candidate entrepreneurs are competitively attempting to come up with quality improvements in the inputs called machines that are used to produce a final consumption good such as a camera, diminishing returns are likely to exist. This notwithstanding, we contend that R&D by the candidate entrepreneurs may but does not have to be accompanied by the presence of negative externalities.

As such, our central objective in this note is to first suppose that R&D by the candidate entrepreneurs does not generate any negative externalities and to then study the impact that taxes and subsidies on R&D by the existing and the candidate entrepreneurs have on R&D expenditures and economic growth in a creative region. In the course of our analysis, we shall make use of the basic point that a subsidy can be thought of as a negative tax and that a tax can be thought of as a negative subsidy. The remainder of this note is arranged as follows. Section 2 describes the model employed by B&Y. Section 3 highlights the ways in which the balanced growth path (BGP) equilibrium with taxes and subsidies studied by B&Y changes when the R&D conducted by the candidate entrepreneurs generates no negative externalities. Section 4 studies how the comparative statics results about the effects of taxes and subsidies on R&D and economic growth obtained by B&Y change when, once again, no negative externalities arise from the R&D conducted by the candidate entrepreneurs. Section 5 concludes and then offers two suggestions for extending the research delineated in this note.

2. The Model

2.1. Preliminaries

Consider an infinite horizon, continuous-time, stylized region that is creative in the sense of Richard Florida. 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. At any time t, members of the creative class possess creative capital and we denote each member and her creative capital by $R(t)$. The population of the creative class is constant and therefore we have $R(t) = R, \forall t$. The existing creative capital is supplied inelastically.

The aggregate resource constraint at time t is given by

$$C(t) + X(t) + I(t) \leq O(t), \tag{1}$$

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 and the value of the single final consumption good such as a camera. The machines we have just referred to are essential inputs in the production of the final good.

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

The single final good or $O(t)$ is produced in accordance with the function

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

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

The *quality* improvements in the machines that arise from the process innovations mentioned above are the outcome of two types of innovations. The first type of innovation is performed by members of the creative class known 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 known as *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 good. The basic feature of the model employed by B&Y is the *Schumpeterian competition* between the existing and the candidate entrepreneurs. This competition is Schumpeterian because for any machine line v, when a candidate entrepreneur develops a machine of higher quality than the quality that is presently in use to produce the final 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 invention and production of higher quality machines.

2.2. The ontogenesis of quality machines

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

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

where $\delta > 1$ is 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 $s \leq t$ and t. Here, s is the time at which this particular type of machine technology was first invented and $q(v,s)$ is its quality at that point in time. An existing entrepreneur has a fully enforced patent on the machines that she has developed. Even so, this patent leaves open the possibility that a candidate entrepreneur will engage in R&D and "jump over" an existing entrepreneur's machine quality. At time $t = 0$, each machine line begins with some quality $q(v,0) > 0$ and this line is owned by an existing entrepreneur. Marginal innovations can only be brought about by an existing entrepreneur. If an *existing* entrepreneur engages in R&D and spends an amount $i^E(v,t)q(v,t)$ of the final consumption good for a marginal innovation on a machine of quality $q(v,t)$ then this existing entrepreneur gives rise to the flow rate of innovation $\phi(i^E)i^E(v,t)$ where $\phi'(i^E) > 0$, $\phi''(i^E) < 0$ and this flow rate function $\phi(\cdot)$ satisfies the 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 $\delta q(v,t)$.

Candidate entrepreneurs can also conduct R&D with the aim of producing quality machines that will improve upon the presently used machines of line v at time t. Assume that the current quality of a machine of line v is $q(v,t)$. Then, by spending one unit of the final consumption good, a *candidate* entrepreneur can innovate at the flow rate $\eta\{i^C(v,t)\}/q(v,t)$ where $\eta'\{\cdot\} < 0$ and $i^C(v,t)$ is the R&D expenditure incurred by the candidate entrepreneur on machine line v at time t. For machine line v, a quality innovation by a candidate entrepreneur that jumps over an existing quality is a *drastic* innovation and a drastic quality innovation creatively destroys the existing quality machine of line v. Whereas candidate entrepreneurs give rise to drastic innovations only, existing entrepreneurs can give rise to marginal and to drastic innovations. However, even though existing entrepreneurs can give rise to both kinds of innovation, in practice, they only generate marginal innovations.[1]

The key point to note is the B&Y assumption that the $\eta\{\cdot\}$ function is *strictly decreasing*. This assumption captures the idea that the competitively undertaken R&D by the candidate entrepreneurs is subject to diminishing returns and hence leads to negative externalities. This is the assumption that we dispense with in section 4 by supposing that $\eta\{i^C\} = \tilde{\eta}$, where $\tilde{\eta}$ is

[1] This is because of a phenomenon known as Arrow's (1962) replacement effect. See Acemoglu (2009, pp. 420-422) and Batabyal and Yoo (2017) for additional details.

a positive constant. Also, note that the candidate entrepreneurs treat the $\eta\{\cdot\}$ function as exogenous to their decision-making. The $\eta\{\cdot\}$ function for the candidate entrepreneurs satisfies the 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 $\chi q(v,t)$ where $\chi > \delta$. Put differently, quality innovations by candidate entrepreneurs are *more* drastic than those undertaken by the existing entrepreneurs.

Once a specific machine of quality $q(v,t)$ has been inented, any amount of this machine can be produced at the marginal cost ψ in terms of the final good and, in the remainder of this note, we shall use the normalization $\psi = 1-\beta$. Observe that the total spending on R&D or $I(t)$ in (1) can also be expressed as

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

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

In our creative region, a so called *allocation* has four parts. First, there are the time paths 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 time paths of the R&D expenditures by the existing and the candidate entrepreneurs denoted by $\{i^E(v,t),i^C(v,t)\}_{v\in[0,1],t=0}^{\infty}$. 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 $\{p^x(v,t;q),x(v,t;q),V(v,t;q)\}_{v\in[0,1],t=0}^{\infty}$. Finally, there are the time paths 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 concurrently. First, the candidate entrepreneurs make R&D decisions to maximize their present discounted value. Second, the existing entrepreneurs choose machine prices and quantities and make R&D decisions to maximize their present discounted value. Third, the representative creative class household chooses consumption to maximize utility. Finally, all markets clear. It is understood that a balanced growth path (BGP) is an equilibrium time path on which both consumption and the output of the final good grow at a constant rate.

Now, with this description of the model in place, our next task is to delineate the ways in which taxes and subsidies on R&D by the existing and the candidate entrepreneurs influence R&D expenditures and regional economic growth with the assumption that the R&D conducted by the candidate entrepreneurs does *not* generate negative externalities. While performing this exercise, we follow B&Y and adapt some of the results in Peters and Simsek (2009, pp. 275-284) to our analysis of Schumpeterian competition in the creative class that broadly consists of existing and candidate entrepreneurs.

3. The BGP Equilibrium with no Negative Externalities

Suppose that an apposite regional authority (RA) levies taxes on the R&D expenditures undertaken by the existing and the candidate entrepreneurs. Denote these two taxes by τ^E and τ^C respectively. B&Y show that in the presence of these two taxes, a unique BGP equilibrium exists in our creative region and that this equilibrium satisfies three properties. First, the output of the final 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, the value function is explicitly a function of machine quality q and it has the linear form $V(q)=\omega q$. Finally, R&D expenditures by the existing and the candidate entrepreneurs (i^{E*},i^C) are positive. We now demonstrate how the BGP equilibrium studied by B&Y changes when R&D conducted by the candidate entrepreneurs does *not* generate negative externalities or when $\eta\{i^C\}=\tilde{\eta}$, a constant.

Modifying equations (34), (35), and (37) in B&Y, we get

$$(\delta-1)\phi'(i^{E*})\omega(t)=1+\tau^E, \tag{5}$$

$$\chi\tilde{\eta}\omega(t) = 1 + \tau^{C}, \tag{6}$$

and

$$\omega(t) = \omega = \frac{\beta R - i^{E*}(1+\tau^{E})}{r_{BGP} - (\delta-1)\phi(i^{E*}) + i^{C}\tilde{\eta}}, \tag{7}$$

where r_{BGP} denotes the interest rate in the BGP equilibrium. The BGP equilibrium growth rate of the economy of our creative region is now given by modifying equation (27) in B&Y. This gives us

$$g_{BGP} = (\delta - 1)\phi(i^{E*}) + (\chi - 1)i^{C}\tilde{\eta}. \tag{8}$$

We now want to ascertain the equilibrium R&D expenditures by the existing and the candidate entrepreneurs or (i^{E*}, i^{C}). To this end, let us use (6) to eliminate one equation from the system of equations given by (5), (6), and (7). We get

$$(\delta - 1)\phi'(i^{E*})\left(\frac{1+\tau^{C}}{\chi\tilde{\eta}}\right) = 1 + \tau^{E}, \tag{9}$$

and

$$\omega = \left(\frac{1+\tau^{C}}{\chi\tilde{\eta}}\right) = \frac{\beta R - i^{E*}(1+\tau^{E})}{\{\theta(\chi-1)+1\}i^{C}\tilde{\eta} + (\theta-1)(\delta-1)\phi(i^{E*}) + \rho}, \tag{10}$$

where we have substituted for g_{BGP} from (8) in the representative creative class household's so called Euler equation---see equation (24) in B&Y---to obtain the denominator in the right-hand-side (RHS) of equation (10).

Equations (9) and (10) give us a system of two equations that can be solved to obtain the two unknowns i^{E*} and i^{C}. In this regard, note that we can solve equation (9) directly for i^{E*} or the equilibrium spending on R&D by the existing entrepreneurs. This is because inspection of (9) reveals that this equation gives us i^{E*} as a function of exogenous parameters only. Once we have obtained the equilibrium value of i^{E*}, we can substitute this value in equation (10) to give us the equilibrium value of i^{C} or the optimal value of the spending on R&D by the candidate entrepreneurs.

We conclude this section with two observations. First, the main impact of the $\eta\{i^{C}\} = \tilde{\eta}$ assumption is to simplify some of the mathematical analysis conducted by B&Y. Second, when the R&D of the candidate entrepreneurs generates no negative externalities, the BGP equilibrium values of i^{E*} and i^{C} are both *different* from the values obtained by B&Y and easier to solve for. We now proceed to study how the comparative statics results about the effects of taxes and subsidies on R&D spending and economic growth obtained by B&Y change when there are no negative externalities from the R&D conducted by the candidate entrepreneurs.

4. Comparative Statics with Taxes and Subsidies

Recall that the taxes on R&D spending by the existing and the candidate entrepreneurs are denoted by τ^{E} and τ^{C} respectively. Now, let us first consider the impact of these two taxes on the R&D spending of the existing entrepreneurs. B&Y show that a tax on R&D by the existing (candidate) entrepreneurs lowers (raises) the amount of R&D they conduct. To see what happens when $\eta\{i^{C}\} = \tilde{\eta}$, we work with equation (9). Totally differentiating this equation and then simplifying the resulting expression, we get

$$\frac{di^{E*}}{d\tau^{E}} = \left\{\frac{\chi\tilde{\eta}}{1+\tau^{C}}\right\}\left\{\frac{1}{(\delta-1)\phi''(i^{E*})}\right\} < 0 \tag{11}$$

and

$$\frac{di^{E*}}{d\tau^{C}} = -\left\{\frac{1}{1+\tau^{C}}\right\}\left\{\frac{\phi'(i^{E*})}{\phi''(i^{E*})}\right\} > 0. \tag{12}$$

Comparing (11) and (12) with the previously stated result obtained by B&Y, we see that the absence of negative externalities does *not* change the impact that these two taxes have on the R&D spending of the existing entrepreneurs. Specifically, in both the B&Y paper and in the present note, R&D spending by the existing entrepreneurs goes *down* when the R&D tax is imposed on them and it goes *up* when the R&D tax is imposed on the candidate entrepreneurs.

Let us now analyze the impact of the two taxes on the R&D spending undertaken by the candidate entrepreneurs. To this end, suppose τ^C increases by a small amount. Then (10) tells us that i^{E*} goes up. However, when i^{E*} goes up, (10) tells us that for a given value of i^C, the left-hand-side (LHS) of this equation rises and the RHS falls. This means that in order to satisfy (10), i^C must go down. Therefore, we get

$$\frac{di^C}{d\tau^C} < 0. \tag{13}$$

To determine the impact that the tax τ^E has on R&D spending i^C, observe that equation (10) can be simplified to give us

$$\omega[\{\theta(\chi-1)+1\}\tilde{\eta}di^C + (\delta-1)(\theta-1)\phi'(i^{E*})di^{E*}] = -(1+\tau^E)di^{E*} - i^{E*}d\tau^E. \tag{14}$$

We now substitute equations (9), (11), and (12) in the above equation. After several steps of algebra, we get

$$\omega\{\theta(\chi-1)+1\}\tilde{\eta}di^C = -\left\{i^{E*} + \frac{\theta\phi'(i^{E*})}{\phi''(i^{E*})}\right\}d\tau^E. \tag{15}$$

It is not possible to sign the expression in the curly brackets on the RHS of (15) without making further assumptions about the flow rate of innovation function $\phi(\cdot)$. Therefore, as in B&Y, once again, the impact of the tax τ^E on R&D spending by the candidate entrepreneurs is ambiguous. In symbols, we have

$$\frac{di^C}{d\tau^E} \gtreqless 0. \tag{16}$$

Comparing (13) and (16) with equations (43) and (47) in B&Y, we see that the B&Y results are *unchanged*. In other words, whether or not the R&D undertaken by the candidate entrepreneurs generates negative externalities, R&D spending by the candidate entrepreneurs goes *down* when the R&D tax is imposed on them and there is an ambiguous impact on this same R&D spending when the tax is imposed on the existing entrepreneurs.

Now note that if τ^E or τ^C is the tax imposed on the R&D spending of either the existing or the candidate entrepreneurs then we can interpret $-\tau^E$ or $-\tau^C$ as the corresponding subsidy given either to the existing or to the candidate entrepreneurs. This means that a small increase in the tax τ^E or τ^C is equivalent to a small decrease in the subsidy $-\tau^E$ or $-\tau^C$. So, looked at from the standpoint of a subsidy, the comparative statics results in (11) and (12) tell us that an increase in the subsidy $-\tau^E$ $(-\tau^C)$ on R&D spending undertaken by the existing entrepreneurs raises (lowers) their R&D. Next, consider the R&D undertaken by the candidate entrepreneurs. Now, the results in (13) and (16) are of interest. Once again, looking at the comparative statics impacts from the perspective of a subsidy, (13) tells us that an increase in the subsidy $-\tau^C$ raises the R&D undertaken by the candidate entrepreneurs and an increase in the subsidy $-\tau^E$ has an ambiguous impact on the R&D undertaken by the same candidate entrepreneurs. In sum, whether or not the R&D conducted by the candidate entrepreneurs generates negative externalities, the comparative statics results involving the two taxes and the subsidies obtained by B&Y do *not* change.

Since the comparative statics results with the two taxes and the subsidies are the same as those obtained by B&Y, intuitively speaking, it follows that the impact of the two taxes on the growth rate of the economy of our creative region in the BGP equilibrium (g_{BGP}) is also unchanged. Specifically, using the methodology of B&Y, it can be shown that a tax on the R&D performed by the candidate entrepreneurs has an *ambiguous* impact on g_{BGP} but a tax on the R&D of existing entrepreneurs *lowers* g_{BGP}. This concludes our analysis of Schumpeterian competition in the creative class and innovation policy.

5. Conclusions

In this note, we studied innovation policy in a region in which the members of the creative class engaged in Schumpeterian competition and thereby extended aspects of the recent analysis in Batabyal and Yoo (2017). Using the language of these researchers, the creative class was broadly composed of existing and candidate entrepreneurs. In contrast to these researchers, we supposed that the R&D conducted by the candidate entrepreneurs did not generate any negative externalities. In this setting, we analyzed the impact that taxes and subsidies on R&D by the existing and the candidate entrepreneurs had on R&D expenditures and regional economic growth.

The analysis in this note can be extended in a number of different directions. Here are two suggestions for extending the research described here. First, one could analyze a social planner's problem in which the planner maximizes the utility of the representative creative class household. The objective here would be to shed light on the temporal behavior of this household's optimal consumption. Second, it would also be useful to analyze whether there are circumstances in which a social planner selects a higher growth rate than the rate that arises in a BGP equilibrium. Studies that integrate these aspects of the problem into the analysis will increase our understanding of the connections between Schumpeterian competition in a region's creative class and economic growth in this same region.

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