Creative Capital, Information and Communication Technologies, and Economic Growth in Smart Cities[1]

by

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Abstract

We analyze the connections between creative capital, information and communication technologies (ICTs), and economic growth in a stylized smart city A. We first describe our model and then derive analytic expressions for three growth related metrics. Second, we use these metrics to show that the economy of smart city A converges to a balanced growth path (BGP) and then we compute the growth rate of output per effective creative capital unit on this BGP. Third, we compute the BGP values of ICT and skills per effective creative capital unit. Fourth, we study how heterogeneity in initial conditions affects outcomes on the BGP by introducing a second smart city B into the analysis. At time $t=0$, two key savings rates in city A are twice as large as in city B. In this setting, we compute the ratio of the BGP value of income per effective creative capital unit in city A to its value in city B. Finally, for the same values of the four savings rates, we compute the ratio of the BGP value of skills per effective creative capital unit in city A to its value in city B.

Keywords: Creative Capital, Economic Growth, Information and Communication Technology, Smart City

JEL Codes: R11, O33

1. Introduction

1.1. A definition

In contemporary times, the notion of a smart city has become popular among both regional scientists and urban planners. Therefore, we begin by defining what we mean by the term smart city in this paper. There are two key parts to this definition. First, a smart city is a vision of urban development whose objective is to utilize information and communication technologies (ICTs) to effectively manage a city's assets and thereby improve its performance. As noted by Paskaleva (2009) and Herrschel (2013), examples of such assets include, but are not limited to, transportation systems, hospitals, power plants, and electronic governance. Second, following the work of Shapiro (2006) and Winters (2011), a smart city is also a metropolitan area in which a large share of the adult population has a college degree.

Given the present-day popularity of the concept of smart cities, there now exists a fairly substantial literature that has studied the working of smart cities from a variety of perspectives. As such, we now briefly review this burgeoning literature before proceeding to the specifics of our paper.

1.2. Review of the literature

Shapiro (2006) uses a neoclassical city growth model to show that 60 percent of the employment growth effect of college graduates in a smart city is due to enhanced productivity growth. The remaining 40 percent is caused by the rise in the quality of life of the city residents. Focusing on the city of Boston in the United States, Fu (2007) shows that human capital externalities are salient across census blocks. This notwithstanding, Fu points out that the impact of human capital depth decays rapidly beyond three miles from block centroids and hence it is appropriate to refer to the localities within cities where this limited effect occurs as "smart café cities."

O'Connell (2008) examines the nexus between environmental concerns and the adoption of smart growth policies in a sample of cities in the United States. On the basis of surveys in 340 cities, he contends that the smart growth movement is a product of the environmental concerns of what he calls the "new political culture" and that these concerns are more likely to influence the adoption of land preserving rather than land use intensifying policies. Sudekum (2010) studies human capital externalities in western German regions and points out that relative to other cities,"skilled cities" in western Germany grow faster. In addition, cognitive skills appear to be a key factor in urban performance.

Why are smart cities in the United States growing relatively rapidly? Winters (2011) conducts an empirical analysis of this question and makes two worthwhile points. First, he argues that smart cities are growing in part because people migrating into such cities tend to stay there upon the completion of their education. Second, he notes that the growth of smart cities is largely attributable to population redistribution within the same state and that this phenomenon has little impact on population growth at the state level. Bakici *et al.* (2013) and Zygiaris (2013) both focus on Barcelona and study the extent to which this city has become "smart" by conforming to the so called Smart City Reference Model. It is noted that being smart does not only involve a greater reliance on the use of ICTs but also the use of a more general strategy that pays attention to smart districts within a city, the use of living labs, and the provision of electronic services.[4]

Sounding a cautionary tone, Viitanen and Kingston (2014) use evidence from Birmingham, Glasgow, and Manchester in the United Kingdom to argue that the use of a digital consumer

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[4] These features are closely related to the recently studied notion of "urban buzz." See Arribas-Bel *et al.* (2016) for more details.

experience to define the "intelligent systems" in these smart cities has essentially left behind parts of these same cities and their populations. Taking a different approach, Steenbruggen *et al.* (2015) argue that the use of digital data in general and mobile phone data in particular can be used to develop innovative applications for the improved management of smart cities.[5]

Even though the above discussed studies have certainly advanced our understanding of smart cities, three points are now worth emphasizing. First, the extant literature on smart cities is overwhelmingly either empirical or based on case studies. Second, this literature has paid virtually no attention to the working of smart cities from a *theoretical* standpoint. Finally, even though smart cities clearly possess an abundance of what Richard Florida (2002, 2005)[6] has called creative capital, there are *no* theoretical studies that link the use of creative capital and ICTs to economic growth in a smart city.

Given this lacuna in the literature, in this paper, we *theoretically* analyze the connections between creative capital, ICTs, and economic growth in a stylized smart city called city A. We first delineate our dynamic model which is adapted from Mankiw *et al.* (1992) and then derive closed-form expressions for three growth related metrics. Second, we use these metrics to show that the economy of smart city A converges to a balanced growth path (BGP) and then we compute the growth rate of output per effective creative capital unit on this BGP. Third, we compute the BGP

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See Caragliu *et al.* (2011) for additional details on these issues.

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The urbanist Richard Florida has successfully popularized the twin concepts of the *creative class* and *creative capital* to regional scientists and to urban planners. In this regard, 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 the growth and development of smart cities, 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).

values of ICT and skills per effective creative capital unit. Fourth, we study how heterogeneity in initial conditions affects outcomes on the BGP by introducing a second smart city B into the analysis. At time $t=0$, two key savings rates in city A are assumed to be twice as large as in city B. In this setting, we compute the ratio of the BGP value of income per creative capital unit in city A to its value in city B. Finally, for the same values of the four savings rates, we compute the ratio of the BGP value of skills per creative capital unit in city A to its value in city B.

The rest of this paper is organized as follows. Section 2 describes our theoretical model of smart city A in detail. Section 3.1 derives analytic expressions for three growth related metrics. Section 3.2 first uses these metrics to demonstrate that the economy of smart city A converges to a BGP and then calculates the growth rate of output per effective creative capital unit on this BGP. Section 3.3 computes the BGP values of ICT and skills per effective creative capital unit. Section 4.1 begins the study of heterogeneity in initial conditions. Specifically, this section first introduces a second smart city B into the analysis. At time $t=0$, two key savings rates in city A are set twice as large as in city B. In this setting, this section computes the ratio of the BGP value of income per creative capital unit in city A to its value in city B. For the values of the four savings rates in section 4.1, section 4.2 calculates the ratio of the BGP value of skills per creative capital unit in city A to its value in city B. Section 5 concludes and then discusses two ways in which the research described in this paper might be extended.

2. The Theoretical Framework

Consider a stylized smart city that we denote by A. At any time t, this city produces a knowledge good such as a laptop computer or a smartphone whose output is denoted by $Q(t)$. This knowledge good is also the final consumption good whose price is normalized to unity at all points in time. The inputs used to produce this knowledge good include ICTs denoted by $C(t)$ and creative capital units denoted by $R(t)$. The total amount of *skills* or *smartness* possessed by the individual creative capital units is denoted by $S(t)$.[7] In addition to the ICTs in our smart city, we suppose that there also exists a different kind of technology and that this technology augments or makes more productive the individual creative capital units. Let us denote this creative capital augmenting technology in our smart city by $A(t)$ and let $A(t)R(t)$ represent an *effective* creative capital unit.

The production function for the output $Q(t)$ of the knowledge good is given by the Cobb-Douglas form

$$Q(t)=C(t)^{\alpha}S(t)^{\beta}\{A(t)R(t)\}^{1-\alpha-\beta}, \tag{1}$$

where the parameters $\alpha>0$, $\beta>0$, and $\alpha+\beta<1$. The dynamics of the four inputs that are used to produce the knowledge good are given by the differential equations

$$\dot{A}(t)=gA(t), \tag{2}$$

$$\dot{R}(t)=nR(t), \tag{3}$$

$$\dot{C}(t)=\sigma_c Q(t)-\delta C(t), \tag{4}$$

and

$$\dot{S}(t)=\sigma_s Q(t)-\delta S(t), \tag{5}$$

where a dot on top of a variable on the left-hand-side (LHS) of equations (2)-(5) indicates a time

[7] We shall use the terms *skills* and *smartness* interchangeably in the remainder of this paper.

derivative. As far as the signs of the three coefficients g, n, and δ are concerned, we have $g>0$, $n>0$, and $\delta>0$.

Of particular importance for our subsequent analysis are the coefficients $\sigma_c \in (0,1)$ and $\sigma_s \in (0,1)$. Specifically, σ_c (σ_s) is the *constant* fraction of the output of the final consumption good that is *saved* to create more ICTs (skills) in smart city A. The initial values of the four inputs $A(0)$, $C(0)$, $R(0)$, and $S(0)$ are given and they are all positive. Finally, let the values of output, ICTs, and skills per effective creative capital unit (sometimes called the intensive values) be given by $q(t) \equiv Q(t)/A(t)R(t)$, $c(t) \equiv C(t)/A(t)R(t)$, and $s(t) \equiv S(t)/A(t)R(t)$. This concludes the description of our stylized smart city. We now proceed to derive analytic expressions for three growth related metrics and these metrics are $q(t)$, $\dot{c}(t)$, and $\dot{s}(t)$.

3. One Smart City

3.1. Three growth metrics

3.1.1. An expression for q(t)

We begin by deriving an expression for output per effective creative capital unit or $q(t)$ as a function of ICTs per effective creative capital unit $c(t)$ and skills per effective creative capital unit $s(t)$. Substituting equation (1) into the definition of $q(t)$, we get

$$q(t) = \frac{C(t)^{\alpha} S(t)^{\beta} \{A(t)R(t)\}^{1-\alpha-\beta}}{A(t)R(t)}. \qquad (6)$$

Now using the definitions of $c(t)$ and $s(t)$ given above, we can rewrite equation (6) as

$$q(t)=\frac{\{A(t)R(t)c(t)\}^{\alpha}\{A(t)R(t)s(t)\}^{\beta}\{A(t)R(t)\}^{1-\alpha-\beta}}{A(t)R(t)}. \tag{7}$$

Canceling the term $A(t)R(t)$ from the numerator and the denominator of equation (7), we obtain the expression for $q(t)$ that we seek. Specifically, we get

$$q(t)=c(t)^{\alpha}s(t)^{\beta}. \tag{8}$$

3.1.2. An expression for dc(t)/dt

Differentiating both sides of the defining equation for $c(t)$ as a function of time t, we get

$$\dot{c}(t)=\frac{\dot{C}(t)A(t)R(t)-C(t)\{\dot{A}(t)R(t)+A(t)\dot{R}(t)\}}{\{A(t)R(t)\}^{2}}. \tag{9}$$

Using the definition $c(t)\equiv C(t)/A(t)R(t)$ we can simplify equation (9) to give us

$$\dot{c}(t)=\frac{\dot{C}(t)}{A(t)R(t)}-\{\frac{\dot{A}(t)}{A(t)}+\frac{\dot{R}(t)}{R(t)}\}c(t). \tag{10}$$

Substituting from equations (2), (3) and (4) into equation (10) and then simplifying, we get

$$\dot{c}(t) = \sigma_c q(t) - (g+n+\delta)c(t). \tag{11}$$

Let us now substitute the value of $q(t)$ from equation (8) into equation (11). This gives us the expression for $\dot{c}(t)$ that we seek. Specifically, we get

$$\dot{c}(t) = \sigma_c c(t)^{\alpha} s(t)^{\beta} - (g+n+\delta)c(t). \tag{12}$$

3.1.3. An expression for ds(t)/dt

Differentiating both sides of the defining equation for skills per effective creative capital unit or $s(t)$ as a function of time t, we get

$$\dot{s}(t) = \frac{\dot{S}(t)A(t)R(t) - S(t)\{\dot{A}(t)R(t) + A(t)\dot{R}(t)}{\{A(t)R(t)\}^2}. \tag{13}$$

Using the definition $s(t) \equiv S(t)/A(t)R(t)$, equation (13) can be simplified to

$$\dot{s}(t) = \frac{\dot{S}(t)}{A(t)R(t)} - \{\frac{\dot{A}(t)}{A(t)} + \frac{\dot{R}(t)}{R(t)}\}s(t). \tag{14}$$

Substituting from equations (2), (3), and (5) into equation (14) and then simplifying, we get

$$\dot{s}(t) = \sigma_s q(t) - (g+n+\delta)s(t). \tag{15}$$

Let us now substitute the value of $q(t)$ from equation (8) into equation (15). This gives us the expression for $\dot{s}(t)$ that we seek. That expression is

$$\dot{s}(t)=\sigma_s c(t)^{\alpha}s(t)^{\beta}-(g+n+\delta)s(t). \tag{16}$$

This completes the derivation of analytic expressions for $q(t)$, $\dot{c}(t)$, and $\dot{s}(t)$. Our next task is to show that the economy of smart city A converges to a BGP and to then compute the growth rate of output per creative capital unit on this BGP.

3.2. Convergence to a BGP

To show that smart city A converges to a BGP, we must first understand the properties of the set of points in (c,s) space where $\dot{c}(t)=0$ and $\dot{s}(t)=0$. To this end, let us first work with equation (12). To obtain the $\dot{c}(t)=0$ locus, we set the right-hand-side (RHS) of this equation equal to zero and then perform several steps of algebra to isolate $c(t)$. This gives us

$$c(t)=\{\frac{\sigma_c}{g+n+\delta}\}^{\frac{1}{1-\alpha}}s(t)^{\frac{\beta}{1-\alpha}}. \tag{17}$$

We can now use equation (17) to compute the first and the second derivatives of $c(t)$ with respect to $s(t)$. Doing this, we infer that $dc(t)ds(t)>0$ and that $d^2c(t)/ds(t)^2<0$. These last two results together tell us that the $\dot{c}(t)=0$ locus is upward sloping and *concave* in (c,s) space.

Next, we work with equation (16). To find the $\dot{s}(t)=0$ locus, we set the RHS of this equation equal to zero and then isolate $s(t)$. We get

$$c(t) = \{\frac{g+n+\delta}{\sigma_s}\}^{\frac{1}{\alpha}} s(t)^{\frac{1-\beta}{\alpha}}. \tag{18}$$

Once again, we use equation (18) to ascertain the first and the second derivatives of $c(t)$ with respect to $s(t)$. Completing the necessary computations, we see that $dc(t)ds(t)>0$ and that $d^2c(t)/ds(t)^2>0$. On the basis of the signs of these two derivatives, we deduce that the $\dot{s}(t)=0$ locus is upward sloping and *convex* in (c,s) space.

Let us now put the above information about the $\dot{c}(t)=0$ and the $\dot{s}(t)=0$ loci together in a phase diagram. This is shown in figure 1. This figure clearly demonstrates that the economy of smart

Figure 1 about here

city A converges to a stable BGP at the point marked E. Inspection of this figure leads to three additional results. First, if we exclude the origin where $c=s=0$, we see that the stable BGP at point E is *unique*. Second, $c(t) \equiv C(t)/A(t)R(t)$ is constant on the BGP. This tells us that the ICT per creative capital unit or $C(t)/R(t)=c(t)A(t)$ must be growing at the *same* rate as the creative capital augmenting technology, which is g. Third, skills or smartness per effective creative capital unit or $s(t) \equiv S(t)/A(t)R(t)$ is also constant on the BGP. Therefore, skills per creative capital unit or $S(t)/R(t)=s(t)A(t)$ must also be growing at the *same* rate as the creative capital enhancing technology, which is, once again, g.

Our final task in this section is to compute the growth rate of output per creative capital unit on the above described BGP. To do so, we divide both sides of the production function given in equation (1) by $R(t)$. This yields

$$\frac{Q(t)}{R(t)} = \{\frac{C(t)}{R(t)}\}^{\alpha}\{\frac{S(t)}{R(t)}\}^{\beta} A(t)^{1-\alpha-\beta}. \tag{19}$$

We already know that the ratios $C(t)/R(t)$, $S(t)/R(t)$, and the creative capital augmenting technology $A(t)$ all grow at rate g on the BGP. In addition, the production function in equation (1) displays constant returns to scale. These last two points together tell us that the output of the knowledge good per creative capital unit in smart city A also grows at rate g on the BGP. We now proceed to compute the BGP values of ICT and skills per effective creative capital unit in terms of the savings rates σ_c, σ_s, and the other parameters of our model.

3.3. BGP values of c(t) and s(t)

Let us denote the two BGP values we seek by c^{BGP} and s^{BGP} respectively. Solving equations (17) and (18) simultaneously, we can write

$$\{s^{BGP}\}^{\frac{1-\beta}{\alpha}-\frac{\beta}{1-\alpha}} = \{\frac{\sigma_c}{g+n+\delta}\}^{\frac{1}{1-\alpha}}\{\frac{\sigma_s}{g+n+\delta}\}^{\frac{1}{\alpha}}. \tag{20}$$

Note that the exponent on s^{BGP} in equation (20) simplifies to $(1-\alpha-\beta)/\{\alpha(1-\alpha)\}$. Therefore, raising both sides of equation (20) to the reciprocal of this simplified exponent, we get our desired expression for s^{BGP} as a function of σ_c, σ_s, and the other parameters of the problem. Specifically, that expression is

$$s^{BGP} = \sigma_c^{\frac{\alpha}{1-\alpha-\beta}} \sigma_s^{\frac{1-\alpha}{1-\alpha-\beta}} \{\frac{1}{g+n+\delta}\}^{\frac{1}{1-\alpha-\beta}}. \tag{21}$$

To find the corresponding expression for c^{BGP}, we substitute the expression for s^{BGP} from equation (21) into equation (17). This gives us

$$c^{BGP} = \sigma_c^{\frac{1}{1-\alpha}} \{\frac{1}{g+n+\delta}\}^{\frac{1}{1-\alpha}} [\sigma_c^{\frac{\alpha}{1-\alpha-\beta}} \sigma_s^{\frac{1-\alpha}{1-\alpha-\beta}} \{\frac{1}{g+n+\delta}\}^{\frac{1}{1-\alpha-\beta}}]^{\frac{\beta}{1-\alpha}}. \tag{22}$$

After several steps of straightforward but tedious algebra, equation (22) can be simplified to

$$c^{BGP} = \sigma_c^{\frac{1-\alpha-\beta+\alpha\beta}{(1-\alpha)(1-\alpha-\beta)}} \sigma_s^{\frac{\beta}{1-\alpha-\beta}} \{\frac{1}{g+n+\delta}\}^{\frac{1-\alpha-\beta+\beta}{(1-\alpha)(1-\alpha-\beta)}}. \tag{23}$$

The exponent on σ_c in equation (23) can be simplified because $(1-\alpha-\beta+\alpha\beta) = (1-\alpha)(1-\beta)$. Using this simplification, we get the sought after expression for c^{BGP} as a function of σ_c, σ_s, and the other parameters of the problem. That expression is

$$c^{BGP}=\sigma_c^{\frac{1-\beta}{1-\alpha-\beta}}\sigma_s^{\frac{\beta}{1-\alpha-\beta}}\left\{\frac{1}{g+n+\delta}\right\}^{\frac{1}{1-\alpha-\beta}}. \tag{24}$$

Our next task is to study the impact of heterogeneity in certain initial conditions on the BGP values of some key variables.

4. Two Smart Cities

4.1. Ratio of BGP value of income per effective creative capital unit in city A to city B

To study the effect of heterogeneity, we now focus on two smart cities. These two cities are city A—which we have been studying thus far—and a second smart city B. Smart city B is different from smart city A in two key ways. Specifically, both σ_c and σ_s are twice as large in city A as in city B. To conduct the analysis below in an analytically tractable manner, we will need to make two assumptions. As such, we first assume that apart from the two differences in cities A and B that we have just mentioned, these two cities are identical in all other respects. Second, we assume that $\alpha=1/3$ and $\beta=1/2$ in the remainder of this paper.

Note that because the creative capital augmenting technology $A(t)$ is the same in both the cities under study, we can compare the output of the final consumption good per effective creative capital unit. Using equation (8), the ratio of the output of the knowledge good on the BGP in smart city A to that in smart city B is given by

$$\frac{q_A^{BGP}}{q_B^{BGP}} = \{\frac{c_A^{BGP}}{c_B^{BGP}}\}^{\alpha}\{\frac{s_A^{BGP}}{s_B^{BGP}}\}^{\beta}. \tag{25}$$

We know that $\alpha = 1/3$ and that $\beta = 1/2$. Therefore, substituting these two values in equations (24) and (21), we get

$$c^{BGP} = \sigma_c^3 \sigma_s^3 \{\frac{1}{g+n+\delta}\}^6 \tag{26}$$

and

$$s^{BGP} = \sigma_c^2 \sigma_s^4 \{\frac{1}{g+n+\delta}\}^6. \tag{27}$$

Now, substituting equations (26) and (27) into equation (25) and then simplifying, we obtain

$$\frac{q_A^{BGP}}{q_B^{BGP}} = \{\frac{\sigma_{cA}\sigma_{sA}}{\sigma_{cB}\sigma_{sB}}\}\{\frac{\sigma_{cA}\sigma_{sA}^2}{\sigma_{cB}\sigma_{sB}^2}\}. \tag{28}$$

By assumption, we have $\sigma_{cA}=2\sigma_{cB}$ and $\sigma_{sA}=2\sigma_{sB}$. Except for these two key differences, the economies of smart cities A and B are identical in every other way. Therefore, substituting these assumptions about the two savings rates in equation (28), we get $q_A^{BGP}/q_B^{BGP}=32$.

The above result clearly shows one powerful way in which initial differences in the two savings rates in the two smart cities matter. Specifically, we see that even though smart city A saves only twice the amount that smart city B does to create more ICTs and skills, this 2-fold initial difference between the two cities leads to a *32-fold* difference in the BGP output per effective creative capital unit between these same two cities. Put differently, relatively *small* initial differences in the two savings rates translate into a substantially *magnified* impact on the BGP values of output per effective creative capital unit.

One way of measuring the extent to which a city is smart is to look at the skills or smartness possessed by the various creative capital units in this city. It is also true that actual cities generally differ in the extent to which they are smart and that this difference can be attributed to differential skill acquisition processes. Therefore, consistent with the comparative exercise carried out in this section, we can ask how initial differences in σ_c and σ_s across the two cities A and B affect the ratio of the BGP value of skills per effective creative capital unit in these same cities. We now proceed to answer this question.

4.2. Ratio of BGP value of skills per effective creative capital unit in city A to city B

We begin by noting that we are able to compare the amount of skills per effective creative capital unit in the two smart cities because the creative capital augmenting technology $A(t)$ is, once again, the same in both cities. Using equation (27), the BGP ratio of skills (or smartness) in city A

to those in city B is given by

$$\frac{s_A^{BGP}}{s_B^{BGP}} = \frac{\sigma_{cA}^2 \sigma_{sA}^4}{\sigma_{cB}^2 \sigma_{sB}^4}. \tag{29}$$

As in section 4.1, we suppose that $\sigma_{cA}=2\sigma_{cB}$ and that $\sigma_{sA}=2\sigma_{sB}$. Substituting these four values into equation (29), we get $s_A^{BGP}/s_B^{BGP}=64$.

The above result shows a second powerful way in which initial differences in the two savings rates in the two smart cities influence BGP outcomes. Specifically, we see that even though smart city A saves only twice the amount that smart city B does to create more ICTs and skills, this 2-fold initial difference between the two cities leads to a *64-fold* difference in the BGP value of skills per effective creative capital unit between these same two cities. Consistent with the finding in section 4.1, once again we see that relatively *small* initial differences in the two savings rates translate into a substantially *magnified* effect on the BGP values of skills or smartness per effective creative capital unit.

The policy implications of the comparative exercises in this and the preceding section for smart cities are threefold. First, for a given smart city, all else being equal, increasing the fraction of the output of the final consumption good that is used to generate more ICTs and skills in the creative capital units *now* will yield greatly magnified benefits in terms of increased output and skills per effective creative capital unit *later*. Second, consider a smart city that is lagging another smart city in terms of output and skills per effective creative capital unit. For such a city to get ahead, it will need to *increase* the two constant fractions of output or, equivalently, the two savings rates denoted by σ_c and σ_s. Finally, the size of the *magnification effect* on output and skills that we have been discussing thus far can be easily computed by a policymaker in a smart city for the general case of a $m-$fold *initial* difference between the relevant savings rates in any two smart cities. To this end, suppose that we have $\sigma_{cA}=m\sigma_{cB}$ and $\sigma_{sA}=m\sigma_{sB}$ where m is an arbitrary positive integer that is greater than two. In this case, straightforward computations show that $q_A^{BGP}/q_B^{BGP}=m^5$ and that $s_A^{BGP}/s_B^{BGP}=m^6$. This completes our discussion of the connections between creative capital, ICTs and economic growth in smart cities.

5. Conclusions

In this paper, we examined the nexuses between creative capital, ICTs, and economic growth in a stylized smart city A. We first described our model and then derived closed-form expressions for three growth related metrics. Second, we used these metrics to show that the economy of smart city A converged to a BGP and then we computed the growth rate of output per effective creative capital unit on this BGP. Third, we computed the BGP values of ICT and skills per effective creative capital unit. Fourth, we studied how heterogeneity in initial conditions influenced outcomes on the BGP by introducing a second smart city B into the analysis. At time $t=0$, two key savings rates in city A were twice as large as in city B. In this setting, we calculated the ratio of the BGP value of income per effective creative capital unit in city A to its value in city B. Finally, for the same values of the four savings rates, we computed the ratio of the BGP value of skills per effective creative capital unit in city A to its value in city B.

The analysis in this paper can be extended in a number of different directions. In what follows, we suggest two possible extensions. First, it would be useful to analyze economic growth in two or more heterogeneous smart cities when these cities are linked to each other either via trade over space or through the harmonization of, for instance, tax policy. Second, it would be helpful to embed the economies of smart cities of the sort studied in this paper in a stochastic environment and then analyze the impact that uncertainty in the temporal evolution of ICTs and/or skills has on the growth prospects of these economies. Studies that analyze these aspects of the underlying problem will provide additional insights into the nexuses between alternate spatial, fiscal, and temporal factors on the one hand and economic growth in smart cities on the other.

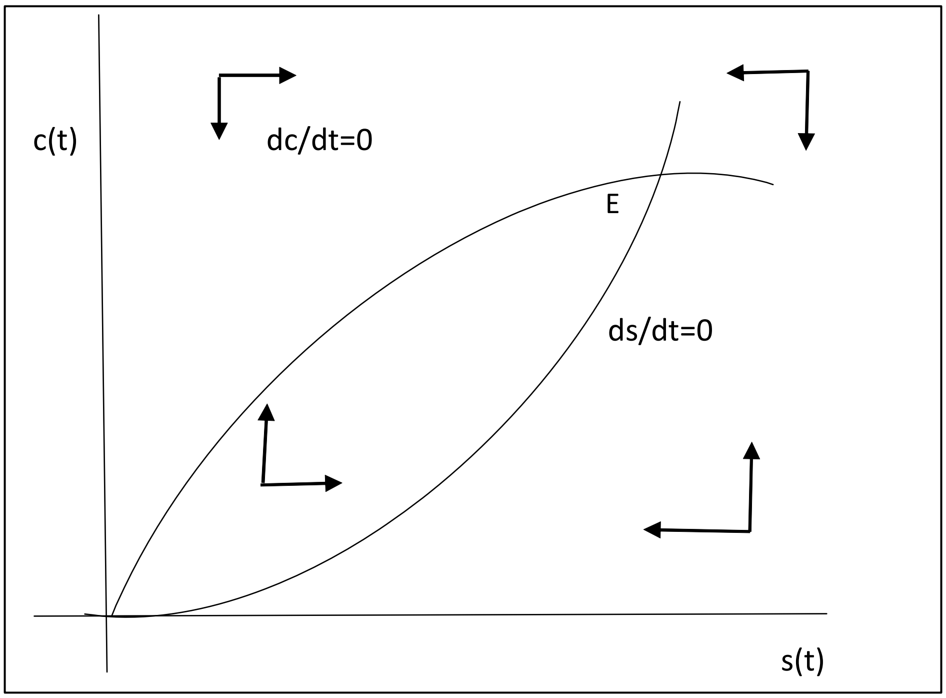

Figure 1: Economy of smart city A converges to a BGP

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