Cultural Transmission, Education-Promoting Attitudes, and Economic Development*

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Abstract

This study emphasises the interdependence between physical capital formation and the cultural transmission of human capital-promoting attitudes and values. It demonstrates how this interdependence establishes a powerful propagation mechanism that generates multiple, divergent paths of economic development. It also highlights the role of physical capital formation in expanding the conditions that are propitious to path-dependency in models of cultural transmission: Even in the absence of a cultural complementarity, the long-run equilibrium is sensitive to the initial distribution of cultural attitudes among the population, as long as the combined effects of physical capital formation and social segregation permeate the process of cultural transmission.

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1 Introduction

The idea that cultural change and economic performance are mutually dependent is by no means a new one. Karl Marx's view was that cultural traits are mere by-products of the prevailing economic/material conditions, whereas Max Weber surmised that the prevailing culture is a significant determinant of economic change. Can the idea of an interrelation between culture and economic activity be pertinent to the role of human capital for economic growth and development?

According to Lucas (1993), features such as significant improvements in educational attainment and human capital, which distinguish countries that have achieved and sustained high levels of economic development, should not be merely viewed as the explanatory factors behind their economic success. Instead, these *"are additions to the list of events we want to explain, not themselves explanations"* (Lucas 1993, p. 252). Motivated by this assertion, van Hoorn (2016) employed an empirical study to argue that cultural traits such as attitudes, values and social norms, have a significant impact on people's views on the importance of education and, therefore, their propensity towards human capital-promoting activities.[1] Given these arguments, the aim of this study is to shed more light on the interplay between economic growth and the cultural transmission of education-promoting attitudes and values; to identify some new mechanisms that underlie this interplay; and to offer new insights not only into the process of economic development but also into the process of cultural transmission itself.

Although human capital has been a cornerstone of our understanding of economic growth, the current literature lacks a body of systematic work that delves deeper into the behavioural and cultural traits that influence people's propensity towards human capital-promoting activities, as well as the implications of these factors for economic development.[2] One notable exception is the work of Doepke and Zilibotti (2008) who argued that the two-way causal effects between economic progress and the interegenerational transmission of occupational choice-related and work ethic-related preferences can account for the

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[1] In fact, Bisin and Verdier (2001) had already alluded to the significance of these factors, by referring to *"the relevance of the endogeneity of various elements of preferences, as, for example (…) the perceived importance of education"* (Bisin and Verdier 2001, p. 299) as a means of motivating their influential work on intergenerational preference transmission.

[2] Doepke and Zilibotti (2017) present an analysis of human capital formation in a cultural transmission framework that adopts different types of altruism and different styles of parenting. The intersection between economic growth and the cultural transmission of factors associated with entrepreneurship is investigated in models by Doepke and Zilibotti (2014); Klasing (2014); Klasing and Milionis (2014); and Chakraborty *et al.* (2016).

socioeconomic and structural transformations that coincided with the Industrial Revolution in Britain.[3] While their intention was to provide a theoretical underpinning for phenomena and developments that are particular to the Industrial Revolution, one can hardly dispute with the idea that the underlying principle, which views economic progress as being inherently linked to the cultural traits that encourage people to undertake human capital-promoting activities, is also pertinent to more recent circumstances and events.

Consider the case of East and West Germany for example. In spite of their reunification more than two decades ago, and the ensuing adjustment of their formal institutions, significant economic disparities between them seem to be persistent (Uhlig 2008; Smolny 2009). Seeking to identify factors that could account for the differing economic fortunes between East and West Germany, van Hoorn and Maseland (2010) argued that Germany's division generated differences in *"values and attitudes that continue to feed differences in economic performance"* (van Hoorn and Maseland 2010, p. 791). Their empirical results showed that West Germans' greater esteem for higher academic education is among those persistent and significant cultural differences between the two regions.

In a similar vein, the empirical study of Desdoigts (1999) showed that human capital accounts for differences in economic development between East Asia and Africa, more than any other institution-related variable. He attributed this outcome to the persistent cultural heritage of Confucianism, whose ingredients of *"self-cultivation and self-improvement (…) make sure that people put a high value on education"* (Desdoigts 1999, p. 317).[4]

Since the interplay between economic progress and the cultural evolution of attitudes on the importance of education possesses a broader explanatory power, which applies to more recent observations of divergent economic performance among different regions, the objective of this study is to embed these characteristics in a theory of 'modern' economic growth, i.e., a theory whose point of departure is the endogenous growth paradigm. I

[3] There is additional historical evidence that supports the link between economic progress and culturally-induced improvements in human capital. Becker and Woessman (2009) proposed the view that the increased literacy among Protestants, which was induced by Luther's stipulation that all Christians should be able to read the Bible by themselves, triggered improvements in human capital that contributed to the economic progress of Protestant regions. In fact, their empirical results showed that this mechanism accounts for the entire difference in economic prosperity between Protestant and Catholic regions in Prussia during the 19th century. Other economic historians argue that the European Enlightenment – an intellectual movement that, among other things, attached prominence to the importance of knowledge, its advancement, and to its diffusion – was important in laying the foundations of Western Europe's economic progress from the early 19th century onwards (Mokyr 2012), which, in turn, paved the way for the change in those attitudes and norms that supported the establishment of a more extensive education system, thus leading to widespread improvements in human capital (Carl 2009).

[4] See Manz *et al*. (2006) and Tabellini (2010) for further evidence on the importance of cultural factors for economic development.

construct a model that integrates the accumulation of both human and physical capital with an explicit process for the cultural transmission of a behavioural trait that embodies people's attitudes towards human capital-promoting activities. The cultural transmission process draws on Bisin and Verdier (2001), i.e., young generations are inculcated with education-promoting attitudes, either by their parents (direct transmission) or by imitating role models (oblique transmission).[5] Based on the notion of 'neighbourhood effects', for which Borjas (1995) and Patacchini and Zenou (2011) offer empirical support, I adapt this process by considering a scenario where, due to self-selection and social segregation, the parents' social environment, as well as their interests and activities, affect the likelihood that their children will find suitable role models to motivate them into the adoption of human capital-promoting attitudes. Physical capital, together with the time/effort devoted by young individuals, is an input to the human capital technology, thus it increases the return to education and motivates altruistic parents to intensify their efforts to instil the education-inducing cultural trait in their children. At the same time, an increase in the population share of those individuals who have been inculcated with the education-inducing trait, promotes physical capital formation through its positive effect on productivity, saving and investment.

In terms of economic growth and development, the model's analysis and results highlight the powerful propagation mechanism that is prompted by the interdependence between physical capital accumulation and the cultural transmission of human capital-promoting attitudes. As a result, the long-run equilibrium is characterised by multiple, divergent paths of economic development, which establish persistent differences in income per capita, due to the (either virtuous or vicious) circles of mutually-reinforcing processes of economic change and culturally-induced evolution in attitudes towards education. While this description echoes the underlying ideas of Doepke and Zilibotti (2008), my focus, set-up and mechanisms differ in comparison. Their study is focused at circumstances that surrounded the Industrial Revolution, for which the key elements are the cultural factors behind occupational choice and the work ethic, structural transformation and the lack of financial deepening. My study draws on the paradigm of modern economic growth, thus its key

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[5] This setting is, in fact, consistent with existing empirical evidence. For example, evidence for the impact of parenting on educational outcomes is provided by Astone and McLanahan (1991) and Brown and Iyengar (2008), to name but a few, whereas other empirical studies suggest that such educational outcomes are also affected by role models (e.g., Beaman *et al.* 2012; Macours and Vakis 2014). In their empirical study, Patacchini and Zenou (2011) take a broader view of cultural transmission and show that both its aspects – direct and oblique – are relevant in explaining differences in educational attainment. It should also be noted that Becker and Tomes (1986) cited "motivation" as one of the channels through which parents can influence their children's human capital and, therefore, future earnings.

elements are the impact of physical capital on the return to education, the endogenous distribution of different education-related cultural traits among the population, as well as the implications of this distribution for aggregate productivity, aggregate investment and the accumulation of (both human and physical) capital.

In order to check the robustness of the proposed mechanism, I also examine the outcomes that transpire when either the distribution of different attitudes towards education is fixed among the population, or when this distribution does change endogenously, but cultural transmission is not affected by the formation of physical capital. Under such circumstances, path-dependent outcomes do not materialise, i.e., the long-run equilibrium is invariant to initial conditions. This establishes that, indeed, the interdependence between economic and cultural factors fosters the emergence of multiple paths of economic development.

In terms of the conditions that underpin the process of cultural change, this study reveals that, as long as physical capital formation influences the process of cultural transmission – in this context, through its effect on the return to education – the circumstances under which the initial distribution of cultural traits (e.g., attitudes, values, norms etc.) among the population matters for the long-term establishment of these traits, are broader than has hitherto been assumed. While path-dependent outcomes in existing models of cultural transmission typically require some sort of cultural complementarity (Bisin and Verdier 2001, 2008) – i.e., when parental efforts towards the cultural instruction of children are intensified, following an increase in the share of the population who carry the behavioural trait that parents seek to diffuse – in my model, such outcomes can emerge even in the absence of this complementarity. Instead, the initial distribution of cultural attitudes among the population may still determine the long-run equilibrium, as long as the combined effects of physical capital formation and social segregation permeate the process through which parents try to instil these attitudes in their children.

In order to facilitate its exposition, the remainder of this study is structured as follows: Section 2 outlines the results from the relevant literature. In Section 3, I discuss the characteristics of the model, while in Section 4 I derive its equilibrium. Section 5 provides the characterisation of the model's dynamics, while Section 6 presents some further analysis which aims at establishing the robustness of the proposed mechanisms. In Section 7, I investigate how similar outcomes emerge under alternative set-ups, while Section 8 concludes.

2 Literature Review

Although this study shares elements and ideas with the existing literature on the economics of cultural transmission, its results, mechanisms and implications differ. To clarify this, the current section summarises the results of previous studies on related themes.

Patacchini and Zenou (2011) show, theoretically and empirically, that the parents' involvement in their offspring's education is increasing in the quality of the neighbouring environment. They also establish that, when parents are highly educated, parental involvement is more important for children's educational outcomes, whereas community effects are more important for the educational outcomes of children from low-educated families. Using different frameworks, both Klasing (2014) and Doepke and Zilibotti (2014) demonstrate how the cultural transmission of attitudes towards risk and patience can affect the dynamics of occupational choice, and determine long-run growth through its effect on the number of individuals who opt for high-return, but riskier, entrepreneurial projects. In a similar vein, Klasing and Milionis (2014) focus on the cultural aspects regarding time preference and their implications for innovation-driven growth, through their impact on occupational choices between skilled and unskilled labour. The comparison between a culturally homogeneous economy and an economy where the dynamics of cultural transmission converge to a unique stable equilibrium of a culturally heterogeneous population, reveals that the growth rates of the two economies may actually converge if, in addition to altruism, cultural instruction is motivated by parents' innate desire for children who share their own cultural traits. In Chakraborty *et al.* (2016), culturally-induced stagnation (a zero growth equilibrium where entrepreneurs do not adopt more advanced technologies) can be escaped by means of policies that may induce either a shift in aggregate productivity, or lower transferability of existing human capital across technologies. When this happens, long-run growth is not sensitive to cultural characteristics. Doepke and Zilibotti (2017) construct a theory where parents have both altruistic and paternalistic motives in relation to their offspring's risk and time preferences. They use it to explain the shift of parenting practices (from authoritarian to permissive) in the process of economic development.

Contrary to these studies, my framework pinpoints the role of investment and physical capital accumulation, and its impact on the cultural change that determines the distribution of diverse education-related traits among the population, as a key factor in explaining differences in long-term economic performance, by means of multiple, path-dependent outcomes. Furthermore, it highlights a new mechanism whereby differences in the distribution of cultural traits among the population can be amplified in the long-run, as a result of the combined effect of physical capital accumulation and social segregation on the process of cultural transmission.

Several of this study's elements, which touch upon the role of parental characteristics for children's attitudes to education and educational outcomes, are consistent with ideas and results from the existing literature. This applies, for example, to parents' desire to instil education-promoting attitudes in their children (Patacchini and Zenou 2011). It also applies to the impact of parents' education on children's educational attitudes and achievements – an impact that emanates from the adoption of appropriate parenting practices (e.g., Fischer 1982; Lareau 1989; Cochran and Gunnarsson 1990; Huang *et al.* 2005; Morawska *et al.* 2009; Egalite 2016) and the important role of parents' social relations and networks (e.g., Riley 1990; Teachman *et al.* 1997; Cochran and Niego 2002; Sheldon 2002; Curry and Holter 2019).

3 The Economy

I consider an infinite horizon economy in which time is measured in discrete periods, indexed by $t = 0,1,2,...$. This economy is populated by a sequence of overlapping generations of individuals who live for three periods. Henceforth, the first period of an individual's lifetime will be referred to as *youth*, whereas the two subsequent periods of maturity will be referred to as *middle age* (the second period) and *old age* (the third and final period of her lifespan). In terms of demographics, each adult gives birth to one young individual during middle age. Thus, the population mass of each age cohort is constant over time. Without loss of generality, each age cohort's population mass is also normalised to 1.

Let us consider a person who is born in period t. When young, she is endowed with a unit of time and decides how much of it will be allocated to activities that will facilitate the formation of her human capital (e.g., studying, educational attainment etc.). Such activities are costly however, in the sense that they entail a direct loss of utility due to the effort devoted to them. This loss of utility need not be solely associated with physical strain; it also captures the mental and psychological strain of educational activities, e.g., stress, pressure, and the frustration emanating from some loss of leisure activities. The utility cost is not uniform across the whole population of young individuals though. Instead, there are two personality traits, indexed by $i=\{x,v\}$, that distinguish individuals according to the different utility costs they experience, for given levels of educational effort. Particularly, an individual who devotes $e_{i,t}$ units of time for human capital-promoting activities, faces a utility cost

$$\Psi_i(e_{i,t})=\frac{\psi_i e_{i,t}}{1-e_{i,t}}, \quad \psi_i>0, \tag{1}$$

where

$$\psi_i=\begin{cases}\underline{\psi} & \text{if} \quad i=x \\ \overline{\psi} & \text{if} \quad i=v\end{cases}, \quad \overline{\psi}>\underline{\psi}. \tag{2}$$

In essence, we can think of a Type- x individual as one who, in comparison to a Type- v individual, incurs less utility loss from spending a given amount of time in human capital-promoting activities, either because she has greater aspirations for her future standards of living, or because she assigns a greater value to the knowledge gained through the process of education.

Another important issue is that each young individual's trait is not exogenous. On the contrary, it will be determined endogenously through a process of intergenerational cultural transmission. This process will be formalised at a later point of the analysis. For now, it is instructive to specify the process through which effort in education is transformed into units of human capital. In addition to education investment by the young, I follow others (e.g., Rebelo 1991) in assuming that physical capital is also an input of the human capital technology. This is meant to capture the contribution of educational facilities, equipment, labs, libraries etc. Formally, for a young Type- i person, human capital will be determined according to

$$h_{i,t+1}=Be_{i,t}^{\beta}k_{h,t}, \quad B>0, \ 0<\beta\leq 1, \tag{3a}$$

where $k_{h,t}$ is the amount of capital (per person) that is employed as an input to the education sector. It should be noted that, by taking explicit account of the effort that young individuals devote in their education, this study follows the approach of Glomm and Ravikumar (1992) and Blackburn and Cipriani (2002) among others.

An alternative assumption concerning the contribution of physical capital to education and knowledge could be based on the idea of an aggregate-wide externality in the manner of

Frankel (1962) and Romer (1986). In this case, the human capital technology would take the form

$$h_{i,t+1} = Be_{i,t}^{\beta}\overline{k}_t , \tag{3b}$$

where $\overline{k}_t$ is the average stock of capital per person. Although the subsequent analysis will follow the specification in (3a), the adoption of the alternative specification in (3b) would have no bearing on the model's mechanisms, results and implications.

During the first period of maturity, the middle-aged individual supplies her human capital (i.e., her efficient labour) to output-producing firms in exchange for the competitive wage rate w_{t+1}. She decides how much of her labour income to consume and how much to save in order to finance her consumption expenditures during old age – a period during which she does not have any other source of income because she does not possess the ability to work when old. Using $c_{i,t+1}$ to denote middle age consumption, and $d_{i,t+2}$ to denote old age consumption of a Type-i individual who was born in period t, her budget constraints are given by

$$c_{i,t+1} = w_{t+1}h_{i,t+1} - s_{i,t+1} , \tag{4}$$

and

$$d_{i,t+2} = (1+r_{t+2})s_{i,t+1} , \tag{5}$$

respectively. Note that $s_{i,t+1}$ denotes the saving of a Type-i individual while r_{t+2} is the market interest rate.

In addition to the choice regarding her intertemporal consumption profile, the middle-aged individual is also endowed with a unit of time and chooses how much of it will be dedicated to inculcate her offspring with attitudes that are conducive to the young individual's willingness to invest in human capital formation. This is done through a process of cultural instruction, involving socialisation and nurturing, whereby parents may seek to instil aspirations, habits, values and attitudes – in general, the characteristics that can affect their children's perceptions, hence inducing them to devote more effort towards educational activities. In other words, each parent's effort will be directed towards attempts to ingrain the x trait into her offspring, irrespective of whether she, herself, grew up as a Type-x or a Type-v individual when young. This latter assumption follows the cultural transmission set-up of Patacchini and Zenou (2011). As they point out, *"education is not…a trait that is horizontally differentiated (so that it is a matter of taste which trait is considered better) but a trait…that it is* *vertically differentiated (so that everybody agrees that more education is better than less"* (Patacchini and Zenou 2011, p. 988).

As we shall see later, the parent's incentive to engage in this type of direct cultural transmission stems from the idea that a middle-aged person is altruistic, but not in a paternalistic manner.[6] Each parent cares about her child's human capital and, therefore, her objective is to have her offspring instilled with the behavioural trait that induces more willingness to engage in educational activities. This is meant to capture the idea that parents care about the future prospects (e.g., income; social status) of their children.[7] In this respect, my framework deviates from the notion of paternalistic altruism that is employed by Bisin and Verdier (2001), and adopts an idea that is conceptually closer to the approach of Becker (1976).[8] Despite the fact that parents of both types try to encourage the same behavioural trait, the process of cultural transmission differs between households of different types. The sources of such differences are twofold and relate to the external aspects that permeate the cultural transmission process. The detailed characteristics of this process are discussed in the following section.

3.1 The Process of Intergenerational Cultural Transmission

The framework under which young individuals adopt either the v or the x traits draws on Bisin and Verdier (2001), albeit suitably adapted to accommodate the idea that, irrespective of their own type, parents care about the human capital of their offspring, therefore they strive to instil in their children the behavioural characteristics associated with the x trait. Let us consider a Type-i parent. By devoting $\gamma_{i,t+1} \in [0,1]$ units of time, she can be successful in having the x trait instilled into her offspring, with probability $z(\gamma_{i,t+1}) \in [0,1]$ where $z' > 0$. Doing so, however, entails a loss of utility (due to her effort towards socialisation and nurturing), captured by

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[6] Paternalistic altruism applies when parents make a subjective evaluation of what contributes to their children's well-being, based on their own preferences.

[7] One could think of a scenario in which parents wish to instil their own trait in their children. In terms of this study, Type-v parents would devote effort to socialise their children towards attaching more weight to leisure and less towards education, i.e., these parents would nurture their offspring towards choices that will effectively undermine their future prospects. This is a scenario that goes beyond the concepts, ideas, mechanisms and implications of this study.

[8] The adoption of this type of (impure) altruism in OLG models of economic growth is quite common in the literature. See Galor and Weil (2000) among others.

$$\Phi_i(\gamma_{i,t+1}) = \frac{f_{i,t+1}\gamma_{i,t+1}}{1-\gamma_{i,t+1}}. \tag{6}$$

The term $f_{i,t+1}$ includes both the innate and the external characteristics that determine how costly (in terms of utility) is a parent's effort in trying to improve the chances that her offspring adopts the x trait. This is a source of differentiation between Type-x and Type-v parents. To formalise this idea, henceforth I will be using $\eta_{t+1} \in [0,1]$ to denote the fraction of middle-aged parents who adopted the x trait when they were young. Given this, it is assumed that

$$f_{i,t+1} = [1-\zeta_i(\eta_{t+1})]\varphi_i = \begin{cases} [1-\zeta_x(\eta_{t+1})]\underline{\varphi} & \text{if} \quad i = x \\ [1-\zeta_v(\eta_{t+1})]\overline{\varphi} & \text{if} \quad i = v \end{cases}, \tag{7}$$

where $\overline{\varphi} > \underline{\varphi} > 0$, $0 \leq \zeta_v(\eta_{t+1}) < \zeta_x(\eta_{t+1}) \leq 1$, and $\zeta_x' > \zeta_v' > 0$. The assumption $\overline{\varphi} > \underline{\varphi}$ captures the Type-x parent's innate ability to achieve a given probability of success in transmitting the x trait to her offspring at a lower utility cost compared to a Type-v parent – an outcome attributed to her own abilities and experiences relating to the process that induced her to adopt the x trait when she, herself, was young. Indeed, a report by the National Academies of Sciences, Engineering and Medicine (2016) argues that parenting attitudes and practices are partly shaped by parents' experiences of their own childhood, whereas other studies show that more educated parents have a better understanding of effective parenting practices towards child development, in general, and student achievement, in particular (e.g., Huang *et al.* 2005; Morawska *et al.* 2009; Egalite 2016) as well as a greater involvement in their children's education due to the confidence in their own skills and success in education (e.g., Lareau 1989). The assumption $\zeta_x', \zeta_v' > 0$ captures an intragenerational externality, according to which a larger number of Type-x individuals results in an expanded set of parenting knowledge and practices, as well as experiences on what induced them to adopt the x trait when they, themselves, were young. These are shared with other parents (e.g., through networking and social interactions), thus generating a positive learning externality that can facilitate all parents in their efforts to instil the behavioural characteristics associated with the x trait in their own children. Several empirically-based arguments support this assumption, as researchers have argued that social networks can facilitate parents in adapting their parenting attitudes and practices through discussions and advice on childrearing, instrumental assistance and informational support (e.g., Riley 1990; Cochran and Niego 2002), whereas other studies emphasise the manner through which the impact of social networks on parenting affects children's educational outcomes (e.g., Sheldon 2002; Curry and Holter 2019). The assumptions $0 \le \zeta_v(\eta_{t+1}) < \zeta_x(\eta_{t+1}) \le 1$ and $\zeta'_x > \zeta'_v > 0$ capture the idea that the benefit from this externality is less pronounced for Type-v parents. As a means of justifying these assumptions, I appeal to the idea that, due to self-selection and social segregation, the networking opportunities and social interactions of Type-v parents with Type-x ones are limited, thus mitigating the extent to which they can benefit from the previously described mechanism. Once more, this is an idea that finds empirical support. Some researchers argue that the extent of social relationships and networks, which among other things can help improve parenting practices towards desirable child development outcomes, are constrained by such factors as low levels of education (e.g., Fischer 1982; Cochran and Gunnarsson 1990). Similarly, the empirical analysis of Teachman *et al.* (1997) employs social relations among parents as a proxy of social capital and shows that its interaction with other characteristics (such as parents' income and level of education) has a significant effect on children's educational outcomes.

Now let us consider what happens in the event that, despite her efforts, the parent is not successful in inculcating her offspring with the desired personality trait directly. In this case, the young individual's type will be determined through the oblique transmission, whereby she will adopt the lifestyle choices of a role model who she picks out of the population of middle-aged individuals. Following Bisin and Verdier (2002), she will adopt one of the two traits with a probability that is increasing in the share of the middle-aged population who possess the same trait. Formally, $n_i(\eta_{t+1}) \in [0,1]$ $(n'_i > 0)$ denotes the probability that a young individual who grows up with a Type-i parent, adopts the x trait through the oblique transmission. Once more, this external effect is a source of differentiation between Type-x and Type-v households, in the sense that $n_x(\eta_{t+1}) > n_v(\eta_{t+1})$ and $n'_x > n'_v$. In order to justify this assumption, I appeal again to the idea that Type-x parents are more likely to have a network and interact with other middle-aged individuals of the same type. Hence, their offspring will have more opportunities, compared to young individuals who grow up in households with Type-v parents, for aspiring to role models who will induce them to adopt the x trait. This assumption is consistent with arguments and results from the existing literature. According to Conrad and Niego (2002) highly educated parents are more likely to form social ties with likeminded people, with whom their children can interact and identify them as positive role models. A similar view is promoted by Egalite (2016) who argues that, with regard to their children's attitudes on education, parents with high levels of education "*can also use their (…) cohesive social network of well-educated individuals*" (Egalite 2016, p.72). This network can instil in children "*the specific behaviors, patterns of speech, and cultural references that are valued by the educational and professional elite*" (Egalite 2016, p.72).[9]

Since the sources of the two external effects that permeate the process of cultural transmission are similar, henceforth I will set $\zeta_i(\eta_{t+1}) = n_i(\eta_{t+1})$ for $i = \{x, v\}$. It should be noted that, apart from its conceptual relevance, this assumption serves another, more technical purpose. As we shall see during the model's solution, this assumption will render the optimal choices for $\gamma_{i,t+1}$ independent of η_{t+1}. Hence, it will allow me to show that multiple, path-dependent equilibria, for which the existing distribution of different attitudes towards education is critical, can emerge despite the absence of cultural complementarities, i.e., circumstances where the equilibrium solution for $\gamma_{i,t+1}$ is increasing in η_{t+1}. Of course, this setting also rules out cultural substitution, i.e., when $\gamma_{i,t+1}$ is decreasing in η_{t+1} – a case where, as it is well-known from the analysis of Bisin and Verdier (2001, 2008), the process of cultural transmission generates forces that rule out multiple equilibria.

In what follows, I will be using $\pi_{i,t+1}$ to denote the overall probability that a young individual, growing up with a Type-i parent, adopts the behavioural attributes of a Type-x person. Given that this probability must incorporate all the elements of cultural transmission, it follows that

$$\pi_{i,t+1} = z(\gamma_{i,t+1}) + [1 - z(\gamma_{i,t+1})] n_i(\eta_{t+1}) . \tag{8}$$

By the law of large numbers, the share of the population who will grow up to maturity having adopted the x trait is given by

$$\eta_{t+2} = \pi_{x,t+1}\eta_{t+1} + \pi_{v,t+1}(1 - \eta_{t+1}) . \tag{9}$$

3.2 Production Technology and Preferences

In the previous part of the analysis, I indicated that individuals enjoy utility from the consumption of the economy's homogeneous good during the two periods of their maturity,

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[9] In Section 7.2 I remove the sources of differentiation related to the oblique transmission and the effort cost of socialisation, i.e., $\varphi_i = \varphi \ \forall i = \{x, v\}$, $n_x(\bullet) = n_v(\bullet)$, $\zeta_x(\bullet) = \zeta_v(\bullet)$, $n'_x = n'_v$ and $\zeta'_x = \zeta'_v$. Instead, I consider a version of the model where Type-x and Type-v parents are differentiated only in terms of the likelihood to inculcate their children with the x trait through the direct transmission.

as well as from the human capital of their offspring. They also face the utility costs associated with their efforts in forming their own human capital (when young) and nurturing their children towards the adoption of the x trait (when middle-aged). These characteristics can be summarised by the following lifetime utility function of a Type-i individual who is born in period t:

$$U_{i,t} = -\Psi_i(e_{i,t}) + \frac{\ln(c_{i,t+1}) + \pi_{i,t+1}h^{\sigma}_{x,t+2} + (1-\pi_{i,t+1})h^{\sigma}_{v,t+2} - \Phi_i(\gamma_{i,t+1})}{1+\rho} + \frac{\ln(d_{i,t+2})}{(1+\rho)^2}, \tag{10}$$

where $\sigma > 0$ and $\rho > 0$ is the rate of time preference. The underlying (impure) altruism, captured by the direct presence of the child's human capital on the parent's utility in (10), is not an alien assumption. On the contrary, the same assumption has been adopted by several existing studies (e.g., Borjas 1992; Galor and Weil 2000).

Recall that individuals who are born in period t will be employed when middle-aged, by firms that produce and supply the economy's homogeneous good. These firms are perfectly competitive and their total mass is normalised to 1. They employ units of physical capital, purchased by financial intermediaries, and human capital, supplied by middle-aged individuals, in order to produce y_{t+1} units of output under a Cobb-Douglas technology[10]

$$y_{t+1} = Ak^{a}_{y,t+1}(\Omega_{t+1}H_{t+1})^{1-a}, \quad A > 0,\ 0 < a < 1, \tag{11}$$

where $k_{y,t+1}$ is the amount of the economy's capital employed by private sector firms, H_{t+1} is the stock of human capital (efficient labour) used in production, and Ω_{t+1} is another factor affecting labour productivity (in addition to human capital).

At this point, I shall introduce a technical device to simplify the analysis of the model's equilibrium dynamics. Specifically, it is assumed that

$$\Omega_{t+1} = \frac{1}{mk_t}, \tag{12}$$

where $k_t = k_{y,t} + k_{h,t}$ is the capital stock in period t. The technical details are clarified in Footnote 14. It should be noted, however, that there are intuitive and empirically relevant arguments to support the specification in (12). For example, it could capture the adverse impact of pollution on the workers' health stock and, therefore, their productivity (e.g., Hanna and Oliva 2015). From a modelling perspective, the use of this formulation as a means of capturing the adverse impact of pollution in models of economic growth is by no means new.

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[10] I assume that physical capital depreciates completely during a period.

On the contrary, similar formulations in capturing the negative effect of pollution on productivity have been adopted Day (1982), Smulders and Gradus (1996) and Kijima *et al.* (2010) among others.

4 Equilibrium

The maximisation problem of a Type-i individual will be solved by backward induction. I shall begin by considering the optimal choices for consumption and saving, as well the optimal choice regarding her child's cultural instruction, made during the individual's middle age. Subsequently, I will take account of these choices when determining the optimal education effort – a choice made when the same individual is young.

Given the above, the middle-aged person will choose $s_{i,t+1}$ and $\gamma_{i,t+1}$ in order to maximise her utility function in (10) subject to Eq. (4)-(8), while taking w_{t+1}, r_{t+2} and η_{t+1} as given. The first order conditions from this problem are given by

$$\frac{1}{w_{t+1}h_{i,t+1}-s^*_{i,t+1}}=\frac{1}{(1+\rho)s^*_{i,t+1}}, \tag{13}$$

and

$$z'(\gamma^*_{i,t+1})(h^{\sigma}_{x,t+2}-h^{\sigma}_{v,t+2})=\frac{\varphi_i}{(1-\gamma^*_{i,t+1})^2} \ . \tag{14}$$

The condition in Eq. (13) is the familiar Euler equation: At the optimum, the individual should be indifferent about changes in the intertemporal consumption profile that are realised through changes in saving behaviour. The condition in Eq. (14) reveals that, at the optimum, the middle-aged parent's effort in inducing her offspring to adopt the desired personality trait, is the one that equates the marginal benefits and marginal costs (in terms of utility) from the process of cultural instruction. Note that the benefit is proportional to the human capital increment resulting from the young individual's adoption of the x trait, whereas the cost depends on the innate characteristics that distinguish Type-x and Type-v parents, in terms of the effort they need to devote in order to achieve a given probability of success in inculcating their children with the behavioural attributes attached to a Type-x individual. As I argued previously, the assumption $\zeta_i(\eta_{t+1})=n_i(\eta_{t+1})$ means that η_{t+1} is neither a cultural substitute nor a cultural complement to $\gamma^*_{i,t+1}$. Thus, it allows me to focus on the role of economic conditions (captured by the stock of physical capital) in governing the dynamics of cultural transmission, as well as the manner through which the population distribution of cultural attitudes matters for the long-term equilibrium. Note that this restriction will be relaxed in Section 6 by modifying the model to induce a cultural complementarity (i.e., a case where $\gamma^{*}_{i,t+1}$ would be an increasing function of η_{t+1}), as a means of establishing the relevance of the mechanisms that this study proposes.

The Euler equation in (13) can be solved to yield the optimal saving function

$$s^{*}_{i,t+1} = \frac{w_{t+1}h_{i,t+1}}{2+\rho}, \tag{15}$$

whereas mild conditions can be applied to the function $z(\gamma_{i,t+1})$ in order to ensure the uniqueness of the solution that can be derived from Eq. (14). Substituting (15) in (4) and (5), and the resulting demand functions, together with $\gamma^{*}_{i,t+1}$, in the lifetime utility function of Eq. (10), yields

$$U_{i,t} = -\Psi_i(e_{i,t}) + p\ln(h_{i,t+1}) + V_i^{*}, \tag{16}$$

where $p \equiv \frac{1}{1+\rho}\left(1+\frac{1}{1+\rho}\right)$ is a composite term, and

$$V_i^{*} = p\ln\left(\frac{w_{t+1}}{2+\rho}\right) + \frac{\ln(1+\rho)}{1+\rho} + \frac{\pi^{*}_{i,t+1}h^{\sigma}_{x,t+2} + (1-\pi^{*}_{i,t+1})h^{\sigma}_{v,t+2} - \Phi_i(\gamma^{*}_{i,t+1})}{1+\rho} + \frac{\ln(1+r_{t+2})}{(1+\rho)^2}, \tag{17}$$

where $\pi^{*}_{i,t+1} = z(\gamma^{*}_{i,t+1}) + [1-z(\gamma^{*}_{i,t+1})]n_i(\eta_{t+1})$. Given these, the young individual chooses her optimal effort towards her own education so as to maximise the utility function in (16) subject to (1) and (3a), while taking $k_{h,t}$ as given. The first order condition associated with this problem is

$$\frac{p\beta}{e^{*}_{i,t}} = \frac{\psi_i}{(1-e^{*}_{i,t})^2}. \tag{18}$$

At the optimum, the individual balances the marginal benefit and the marginal cost associated with her educational activities. The former is related to the increase of consumption intertemporally, due to higher disposable income during maturity – an effect that (i) is more pronounced if the education technology is more responsive to an individual's effort, and (ii) appropriately discounted to account for the individual's underlying impatience. The utility cost is determined by the innate characteristics that distinguish young individuals who have adopted either the x or the v trait.

The expression in (18) can be used to establish the existence of a unique, time-invariant equilibrium $e_i^* \in (0,1)$. To see this, define $\varepsilon(e_{i,t}) = \frac{p\beta}{e_{i,t}} - \frac{\psi_i}{(1-e_{i,t})^2}$ and check that $\lim_{e_{i,t}\to 0} \varepsilon(e_{i,t}) = +\infty$, $\lim_{e_{i,t}\to 1} \varepsilon(e_{i,t}) = -\infty$ and $\varepsilon' < 0$. Furthermore, it is $\frac{\partial\varepsilon(\bullet)}{\partial\psi_i} < 0$ – a result that, combined with (2) and $\varepsilon' < 0$, allows us to infer that

$$e_i^* = \begin{cases} \overline{e} & \text{if} \quad i = x \\ \underline{e} & \text{if} \quad i = v \end{cases}, \text{ such that } \overline{e} > \underline{e}, \tag{19}$$

where $\overline{e}, \underline{e} \in (0,1)$ are composite parameter terms. Substituting (19) in Eq. (3a), it follows that

$$h_{i,t+1} = \begin{cases} h_{x,t+1} = B\overline{e}^{\beta} k_{h,t} & \text{if} \quad i = x \\ h_{v,t+1} = B\underline{e}^{\beta} k_{h,t} & \text{if} \quad i = v \end{cases}, \tag{20}$$

and

$$h_{x,t+1} - h_{v,t+1} = Bk_{h,t}(\overline{e}^{\beta} - \underline{e}^{\beta}) > 0, \tag{21}$$

hence verifying the original conjecture of the analysis, as this is summarised in

Proposition 1. *Type-x individuals devote more effort towards education when young, thus their human capital when middle-aged is higher compared to the human capital of Type-v individuals.*

Proof. See the results in (19) and (21). ■

The intuition is straightforward. It rests with the idea that, due to the characteristics associated with the x trait, mainly that educational activities are less strenuous and, therefore, less costly in terms of utility loss, young individuals of this type are willing to provide a greater amount of time, compared to Type-v individuals, in activities that facilitate the formation of human capital.

The accumulation of physical capital takes place as follows. In every period, middle-aged individuals deposit their savings to financial intermediaries. These are perfectly competitive firms whose role is to collect all the saving deposits (denoted S_{t+1}) and use them as inputs in a technology that transforms units of output into units of physical capital, according to

$$k_{t+2} = k_{y,t+2} + k_{h,t+2} = S_{t+1}. \tag{22}$$

Using Eq. (15), aggregate saving is

$$S_{t+1} = \eta_{t+1} s^*_{x,t+1} + (1-\eta_{t+1}) s^*_{v,t+1} = \frac{w_{t+1}[\eta_{t+1} h_{x,t+1} + (1-\eta_{t+1}) h_{v,t+1}]}{2+\rho}. \tag{23}$$

i.e., the sum of the saving deposits of both Type-x and Type-v individuals. Naturally, the equilibrium wage rate corresponds to the marginal product of effective labour in the production technology. That is,

$$w_{t+1} = (1-a) A k^a_{y,t+1} \Omega^{1-a}_{t+1} H^{-a}_{t+1}. \tag{24}$$

In order to avoid mathematical complications that will add nothing of significance to the model's implications, I will adopt a simple rule for the allocation of physical capital across the education and final goods sectors. Specifically, it is assumed that the human capital technology employs a fraction $\tau \in (0,1)$ of the physical capital stock and the remaining fraction is employed by final goods firms. It follows that

$$k_{h,t} = \tau k_t \text{ and } k_{y,t} = (1-\tau) k_t. \tag{25}$$

A possible scenario behind the specification in (25) is related to public investment in education. For example, every period the government levies a tax from financial intermediaries, i.e., the firms that process the transformation of savings into units of physical capital. The tax takes the form of a fixed fraction $\tau \in (0,1)$ of the physical capital stock that financial intermediaries produce. This capital is then used by the government as an input in the education technology.[11] Alternatively, however, I could have adopted the specification in (3b), in which case (25) would be redundant. The results and implications would have remained qualitatively intact.

Taking account of the share of each group (Type-x and Type-v) in the total population of middle-aged individuals, the stock of human capital is $H_{t+1} = \eta_{t+1} h_{x,t+1} + (1-\eta_{t+1}) h_{v,t+1}$. Substituting this, together with (12), (20), (23), (24) and (25), in Eq. (22) yields

$$k_{t+2} = g k^a_{t+1} [\eta_{t+1} (\overline{e}^\beta - \underline{e}^\beta) + \underline{e}^\beta]^{1-a}, \tag{26}$$

where $g \equiv \frac{(1-a) A (1-\tau)^a}{2+\rho} \left(\frac{B\tau}{m} \right)^{1-a}$ is a composite parameter term. The result in Eq. (26) allows us to link the distribution of behavioural traits among the population, with the process of capital formation. This is done through

[11] We can think of τ as a tax rate on financial intermediaries. Furthermore, given that $k_{h,t}$ is the public input towards education and that τk_t are total revenues, the expression $k_{h,t} = \tau k_t$ in (25) is effectively a balanced budget condition.

Proposition 2. *A higher population share of Type-x individuals is favourable to the accumulation of physical capital.*

Proof. Using Eq. (26), it is straightforward to establish that $\frac{\partial k_{t+2}}{\partial \eta_{t+1}} > 0$. ■

In terms of intuition, a larger number of Type-x individuals will raise the aggregate stock of human capital, simply because these are the people who were willing to dedicate more time towards their education when they were young. Consequently, aggregate productivity and income will be higher as well. Since individuals save a fraction of their income during the first period of maturity, aggregate saving and, therefore, physical capital investment will be positively related to η_{t+1}.

Now, let us derive and analyse the equilibrium solution for a parent's effort to inculcate her offspring with the Type-x attributes. To do this, I follow others (e.g., Bisin and Verdier 2001) in employing the following functional form for $z(\gamma_{i,t+1})$:

$$z(\gamma_{i,t+1}) = \gamma_{i,t+1}. \tag{27}$$

Substituting (22), (25) and (27) in Eq. (14) yields

$$(B\tau k_{t+1})^{\sigma}(\overline{e}^{\beta\sigma} - \underline{e}^{\beta\sigma}) = \frac{\varphi_i}{(1-\gamma^{*}_{i,t+1})^2}. \tag{28}$$

Defining the composite term $\mu_i \equiv \sqrt{\frac{\varphi_i}{(B\tau)^{\sigma}(\overline{e}^{\beta\sigma} - \underline{e}^{\beta\sigma})}}$, and taking account of $\overline{\varphi} > \underline{\varphi}$, it follows that

$$\mu_i = \begin{cases} \underline{\mu} & \text{if} \quad i = x \\ \overline{\mu} & \text{if} \quad i = v \end{cases}, \text{ such that } \overline{\mu} > \underline{\mu}, \tag{29}$$

where $\overline{\mu}, \underline{\mu} > 0$ are composite parameter terms. Given these and the non-negativity constraint on $\gamma_{i,t+1}$, the solution of Eq. (28) yields

$$\gamma^{*}_{i,t+1} = \max\left\{0, 1 - \frac{\mu_i}{k^{\omega}_{t+1}}\right\} \equiv \gamma_i(k_{t+1}), \tag{30}$$

where $\omega \equiv \frac{\sigma}{2}$. The result in Eq. (30) allows us to derive implications on how economic resources, captured by the stock of physical capital, impinge on parental decisions regarding the process of cultural instruction. These implications are summarised in

Lemma 1. *There exist* $\underline{k} > 0$ *and* $\overline{k} > 0$, *such that* $\underline{k} < \overline{k}$ *and*

i. $\gamma_v(k_{t+1}) = 0$, $\gamma_x(k_{t+1}) = 0$ *if* $k_{t+1} \leq \underline{k}$;

ii. $\gamma_v(k_{t+1}) = 0$, $\gamma_x(k_{t+1}) = 1 - \dfrac{\underline{\mu}}{k_{t+1}^{\omega}} > 0$ *if* $\underline{k} < k_{t+1} \leq \overline{k}$;

iii. $\gamma_v(k_{t+1}) = 1 - \dfrac{\overline{\mu}}{k_{t+1}^{\omega}} > 0$, $\gamma_x(k_{t+1}) = 1 - \dfrac{\underline{\mu}}{k_{t+1}^{\omega}} > 0$ *if* $k_{t+1} > \overline{k}$.

Furthermore, it is $\gamma_x(k_{t+1}) \geq \gamma_v(k_{t+1})$ *and* $\gamma_v', \gamma_x' \geq 0$.

Proof. Defining $\underline{k} \equiv \underline{\mu}^{1/\omega}$ and $\overline{k} \equiv \overline{\mu}^{1/\omega}$, all these results follow from the expressions in (29) and (30). ■

Irrespective of her type, the parent's effort to increase the probability that her offspring adopts the x trait, is increasing in the economy's stock of physical capital. This is because the capital stock determines the productivity of the human capital technology, through the process of public investment in education. Parents who care about their children's human capital, will be more willing to use the process of cultural instruction – thus inducing their children to exert more effort towards educational activities – because public spending in education improves the return to human capital investment.

An important result relates to the possibility of corner solutions in the determination of $\gamma_{i,t+1}^*$. Indeed, if the level of physical capital is not sufficient, the return to education is so low that the utility cost of engaging in the process of socialisation and nurturing, with the purpose of instilling the x trait in her child, is always greater than the expected benefit, which is measured in terms of the expected increase of the child's human capital.[12] Naturally, this is a scenario where the parent will not devote any effort at all, whereas the young individual's type will be determined solely through the oblique transmission mechanism. Note that the threshold level of capital, below which corner solutions materialise, differs between Type-x and Type-v parents. Specifically, the stock of capital necessary to induce Type-v parents to exert any effort in inculcating their offspring with the x trait is higher. This emanates from

[12] For sufficiently low values of the capital stock, the expressions in (14) and (28) become strict inequalities for every possible value of $\gamma_{i,t+1}$. The complementary slackness condition implies that $\gamma_{i,t+1}^* = 0$ in this case.

the innate characteristics that differentiate Type-x and Type-v parents. Due to $\underline{\varphi} < \overline{\varphi}$, the former group of parents require less effort to achieve the same probability of success in inducing their children to adopt their own attitudes and behaviour, compared to the latter group who try to induce attitudes and behavioural patterns to which they, themselves, did not actually abide as young individuals.

At this point, it should be noted that the introduction of diminishing returns to physical capital in the educational technology would have no bearing on the results. For example, replacing (3a) with $h_{i,t+1} = Be_{i,t}^{\beta} k_{h,t}^{b}$ ($0 < b < 1$) will leave (29), (30) and, therefore, Lemma 1 unaffected. The only change will occur with the presence of b in the composite parameter terms $\mu_i \equiv \sqrt{\dfrac{\varphi_i}{(B\tau^b)^{\sigma}(\overline{e}^{\beta\sigma} - \underline{e}^{\beta\sigma})}}$ and $\omega \equiv \dfrac{\sigma b}{2}$.

Recall that the external effects that permeate the process of cultural transmission are captured by a function $n_i(\eta_{t+1})$, such that $n_i' > 0$ and $n_x(\eta_{t+1}) > n_v(\eta_{t+1})$. As in other analyses (e.g., Bisin and Verdier 2001), I shall be using the specific functional form

$$n_x(\eta_{t+1}) = \eta_{t+1}, \tag{31}$$

to capture the external effects that apply to the cultural transmission process for a young individual who grows up with parents of the same type (i.e., Type-x). In order to capture the idea that (for the reasons detailed in Section 3) these external characteristics are less effective for a young individual who grows up with a Type-v parent, I shall employ

$$n_v(\eta_{t+1}) = \theta\eta_{t+1}, \tag{32}$$

where $\theta \in (0,1)$ is a parameter that quantifies the extent to which the external effects of the cultural transmission process differ between Type-x and Type-v households. The arguments that were used previously to justify the differences captured by θ indicate that a possible interpretation for this parameter is that lower values of θ capture a higher degree of social segregation between the two types of households.[13] This may be the outcome of several mechanisms (e.g., self-selection, neighbourhood effects) that emanate from the differences in socioeconomic characteristics between these two types, thus restricting Type-v parents' social networking with Type-x ones. Earlier, I elaborated on the empirical relevance of these social class-related and education-related restrictions for the link between parenting and children's

[13] An assumption similar to $n_v(\eta_{t+1}) < \eta_{t+1}$ (in this model, due to $\theta \in (0,1)$) is adopted by Sáez-Martí and Sjögren (2008). In their model, they interpret it as a negative bias towards a cultural trait. A similar interpretation in this study's context would be that young people who grow in Type-v households may have a negative predisposition against a cultural trait with which they do not have any direct familiarity through their parental environment.

educational outcomes (e.g., Fischer 1982; Cochran and Gunnarsson 1990; Teachman *et al.* 1997; Conrad and Niego 2002; Egalite 2016).

Combining Eq. (8), (27) and (30)-(32) results in

$$\pi_{x,t+1} = \gamma_x(k_{t+1}) + [1-\gamma_x(k_{t+1})]\eta_{t+1}, \tag{33}$$

and

$$\pi_{v,t+1} = \gamma_v(k_{t+1}) + [1-\gamma_v(k_{t+1})]\theta\eta_{t+1}. \tag{34}$$

We can substitute (33) and (34) in Eq. (9) and manipulate algebraically in order to get

$$\eta_{t+2} = \eta_{t+1} + (1-\eta_{t+1})\{\eta_{t+1}[\gamma_x(k_{t+1}) - (1-\theta)] + (1-\theta\eta_{t+1})\gamma_v(k_{t+1})\}. \tag{35}$$

Earlier, we established that a larger number of Type-x individuals facilitates the process of capital accumulation. As it turns out, the link between the stock of physical capital and the share of the population who adopt the x trait is two-way causal, given that the stock of physical capital may facilitate the process of cultural transmission. I formalise the latter idea through

Proposition 3. *As long as* $k_{t+1} > \underline{k}$, *a higher physical capital stock shifts the distribution of traits among the population, in favour of Type-*x.

Proof. It follows from Lemma 1 and $\frac{\partial \eta_{t+2}}{\partial \gamma_x(k_{t+1})}, \frac{\partial \eta_{t+2}}{\partial \gamma_v(k_{t+1})} > 0$. ■

This is of course an intuitive result. As long as the effect of the physical capital stock on the human capital technology is sufficiently strong, the increased return to the young individuals' human capital motivates (either some or all) parents to exert more effort towards the cultural instruction of their offspring. Consequently, a higher fraction of young individuals will adopt the x trait.

Of course, there are several alternative scenarios that could result in a qualitatively similar outcome. Some of these are formally analysed in Section 7 where, in addition to its role as an input of production, physical capital reduces the marginal cost of effort – either in education (by the young) or socialisation (by parents). Alternatively, the presence of physical capital in the human capital technology could reflect the remuneration of those middle-aged workers who act as teachers and whose services are included as inputs in the process of education.

5 Capital Accumulation and the Formation of Cultural Attitudes towards Education

In the previous section, I showed that as long as the capital stock is below a threshold which, in turn, depends on the specific type of parents, there are corner solutions where $\gamma_i^* = 0$. I also established that the forces determining capital accumulation and the intergenerational transmission of attitudes towards human capital-promoting activities are two-way causal. Now, let us examine how the combination of these characteristics determine the joint dynamics of k_t and η_t. The underlying sources of these dynamics can be summarised by combining Lemma 1 together with Eq. (26) and Eq. (35), expressed one period backward. That is[14]

$$k_{t+1} = F(k_t, \eta_t) = g k_t^a [\eta_t (\overline{e}^\beta - \underline{e}^\beta) + \underline{e}^\beta]^{1-a}, \tag{36}$$

and

$$\eta_{t+1} = \Gamma(k_t, \eta_t) = \begin{cases} \eta_t - (1-\eta_t)\eta_t(1-\theta) & \text{if} \quad k_t \le \underline{k} \\ \eta_t + (1-\eta_t)\eta_t[\gamma_x(k_t) - (1-\theta)] & \text{if} \quad \underline{k} < k_t \le \overline{k} \\ \eta_t + (1-\eta_t)\{\eta_t[\gamma_x(k_t) - (1-\theta)] + (1-\theta\eta_t)\gamma_v(k_t)\} & \text{if} \quad k_t > \overline{k} \end{cases}. \tag{37}$$

Now, consider the expression $\gamma_x(k_t) - (1-\theta)$. Taking account of (29) and (30), it is straightforward to establish that this expression is positive if and only if $k_t > \left(\dfrac{\mu}{\theta}\right)^{1/\omega} \equiv \tilde{k}$. Since $\theta \in (0,1)$, it is $\tilde{k} > \underline{k}$. However, the comparison between $\tilde{k}$ and $\overline{k}$ is not equally unambiguous. Specifically, whether $\tilde{k} > \overline{k}$ or $\tilde{k} < \overline{k}$ depends on whether $\theta < \tilde{\theta}$ or $\theta > \tilde{\theta}$ respectively, where $\tilde{\theta} \equiv \overline{\mu}^{-1}\underline{\mu}$. For now, I will focus on the case where the condition $\theta < \tilde{\theta}$ holds.

A look at the expression in (37) reveals that, as long as $k_t \le \overline{k}$ holds, $\eta_{t+1} - \eta_t \le 0 \ \forall t$. Hence, a steady state solution $\eta_{t+1} = \eta_t = \hat{\eta}$ for the fraction of the population who possess the

[14] At this point where more results are collected, I can clarify the technical reasons behind the use of the assumption in Eq. (12). Suppose that Ω was a fixed parameter, instead of being generated by $\Omega_t = (mk_{t-1})^{-1}$ according to (12). In this case, Eq. (36) would be replaced by $k_{t+1} = g k_t^a (\Omega k_{t-1})^{1-a} [\eta_t(\overline{e}^\beta - \underline{e}^\beta) + \underline{e}^\beta]^{1-a} = F(k_t, k_{t-1}, \eta_t)$. In other words, Eq. (36) would be a second order difference equation in k which, together with Eq. (37), would result in a quite complicated dynamical system to analyse mathematically and to illustrate graphically. Of course, this added mathematical complication would be meaningful had Eq. (12) eliminated a critical mechanism that qualitatively works differently to what we have seen so far. But this is not the case here. On the contrary, both k_{t-1} and k_t have a positive effect on k_{t+1}, meaning that the normalisation in Eq. (12) is an innocuous way to simplify the exposition of the model's results without blurring the main forces at work.

x trait is $\hat{\eta}_1 = 0$ which, given (36), leads to the following steady state solution $k_{t+1} = k_t = \hat{k}$ for the stock of physical capital:

$$\hat{k}_1 = g^{\frac{1}{1-a}} \underline{e}^{\beta}. \tag{38}$$

Similarly, for $k_t \geq \tilde{k}$ the expression in (37) reveals that $\eta_{t+1} - \eta_t \geq 0 \; \forall t$. Therefore, the steady solution $\eta_{t+1} = \eta_t = \hat{\eta}$ is $\hat{\eta}_2 = 1$ which corresponds to the following steady state solution $k_{t+1} = k_t = \hat{k}$ for the physical capital stock:

$$\hat{k}_2 = g^{\frac{1}{1-a}} \overline{e}^{\beta}, \tag{39}$$

where $\hat{k}_2 > \hat{k}_1$ by virtue of (19).

Nevertheless, under the condition $\theta < \tilde{\theta}$ we have $\tilde{k} > \overline{k}$. Therefore, it is instructive to analyse the dynamics of η_t when $\overline{k} < k_t < \tilde{k}$. Combining (30) and (37), it can be established that there exist

$$\breve{\eta}(k_t) = \frac{k_t^{\omega} - \overline{\mu}}{\underline{\mu} - \theta\overline{\mu}}, \tag{40}$$

and $\breve{k} \equiv [(1-\theta)\overline{\mu} + \underline{\mu}]^{1/\omega}$, such that $\breve{k} \in (\overline{k}, \tilde{k})$ and

$$\eta_{t+1} - \eta_t \begin{cases} \leq 0 & \text{if} \quad k_t < \breve{k} \quad \text{and} \quad \eta_t \geq \breve{\eta}(k_t) \\ > 0 & \text{if} \quad k_t < \breve{k} \quad \text{and} \quad \eta_t < \breve{\eta}(k_t). \\ \geq 0 & \text{if} \quad k_t \geq \breve{k} \end{cases} \tag{41}$$

Obviously, if there is a steady state solution $\hat{k}$ on the interval $\overline{k} < k_t < \breve{k}$, then this solution must satisfy $\breve{\eta}\left(\hat{k}\right) = \widehat{\eta}\left(\hat{k}\right) = \hat{\eta}$, where $\widehat{\eta}(k_t)$ is derived from (36) after applying $k_{t+1} = k_t$ and solving for η_t. That is,

$$\widehat{\eta}(k_t) = \frac{k_t - g^{1/(1-a)} \underline{e}^{\beta}}{g^{1/(1-a)} (\overline{e}^{\beta} - \underline{e}^{\beta})}. \tag{42}$$

Now consider $\hat{k}_1 < \overline{k} \Leftrightarrow g^{\frac{1}{1-a}} \underline{e}^{\beta} < \overline{\mu}^{1/\omega}$ and check that $\breve{\eta}\left(\overline{k}\right) = 0$, $\breve{\eta}\left(\breve{k}\right) = 1$, $\widehat{\eta}\left(\overline{k}\right) \in (0,1)$ and $\breve{\eta}', \widehat{\eta}' > 0$. It follows that, by virtue of the single crossing property, $\widehat{\eta}\left(\breve{k}\right) < 1 \Leftrightarrow \breve{k} < \hat{k}_2 \Leftrightarrow [(1-\theta)\overline{\mu} + \underline{\mu}]^{1/\omega} < g^{\frac{1}{1-a}} \overline{e}^{\beta}$ is sufficient for the existence of steady state solutions $k_{t+1} = k_t = \hat{k}_3 \in (\overline{k}, \breve{k})$ and $\eta_{t+1} = \eta_t = \hat{\eta}_3 \in (0,1)$.

The preceding analysis can be utilised in order to provide a formal statement regarding the conditions under which multiple steady state equilibria exist. This is done by means of

Lemma 2. *Suppose that* $\theta < \tilde{\theta}$, $g^{\frac{1}{1-a}} \underline{e}^{\beta} < \overline{\mu}^{1/\omega}$ *and* $[(1-\theta)\overline{\mu} + \underline{\mu}]^{1/\omega} < g^{\frac{1}{1-a}} \overline{e}^{\beta}$ *hold. Then there exist three pairs of steady state equilibria* $(\hat{k}_1, \hat{\eta}_1)$, $(\hat{k}_2, \hat{\eta}_2)$ *and* $(\hat{k}_3, \hat{\eta}_3)$, *such that* $\hat{k}_1 < \hat{k}_3 < \hat{k}_2$ *and* $\hat{\eta}_1 < \hat{\eta}_3 < \hat{\eta}_2$.

Proof. It follows from the preceding analysis. ■

As for the stability properties of the steady state equilibria, these are presented in

Lemma 3. *The equilibrium pairs* $(\hat{k}_1, \hat{\eta}_1)$ *and* $(\hat{k}_2, \hat{\eta}_2)$ *are stable, whereas the equilibrium pair* $(\hat{k}_3, \hat{\eta}_3)$ *is unstable.*

Proof. See the Appendix. ■

In order to understand the forces that drive the economy's dynamics and its long-term prospects, given a pair of initial conditions (k_0, η_0), we shall make use of all the results derived so far, together with the phase diagrams in Figures 1 and 2. To begin with, consider a scenario with the same initial value η_0 but two different possible initial values for the stock of physical capital. At point *A*, the physical capital stock has the tendency to increase during the initial stages, but the share of the population who adopt the x trait gradually declines. This is because the physical capital stock is still not sufficient to induce high enough effort on cultural instruction by parents. Thus, the fraction of young individuals who adopt the behavioural characteristics that are conducive to educational activities declines over time – a process that is exacerbated by the fact that, as η_t falls, the external part of the cultural transmission process becomes weaker as well. Given the gradual fall in η_t, the decline in the aggregate level of human capital will become so pronounced that the process of physical capital accumulation will be reversed and the physical capital stock will, at some point, begin to decline as well.

This is an additional restraining factor to the process of cultural transmission. In fact, at some point the physical capital stock will fall below the corresponding thresholds necessary to induce Type-v parents (initially) and Type-x parents (subsequently) to devote any efforts in inculcating their offspring with the x trait. Eventually, what ensues is a vicious circle of mutually reinforcing declines in both k_t and η_t – a process that will lead the economy towards the low-income steady state $\left(\hat{k}_1, \hat{\eta}_1\right)$.

The dynamics are quite different though when we consider B as the starting point of the transition, despite the fact that the initial level η_0 is the same. The physical capital stock is high enough to induce relatively high levels of cultural instruction by both Type-x and Type-v parents. As a result, the gradual shift in the distribution of behavioural traits in favour of Type-x generates such an increase in human capital that, at some point, the stock of physical capital will gradually begin to increase due to the high level of saving. From that moment onward, there is a mutually-reinforcing, virtuous circle of rising k_t and η_t, as the economy converges to the high-income steady state $\left(\hat{k}_2, \hat{\eta}_2\right)$.

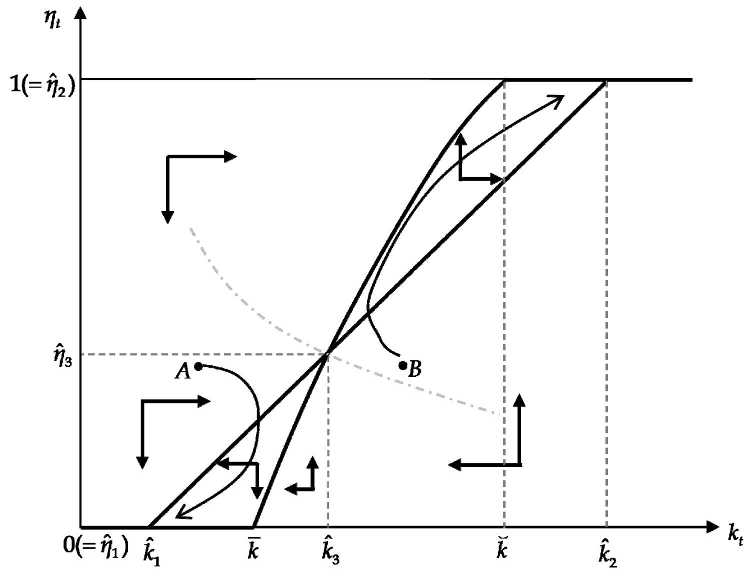

Figure 1. Dynamics under $\theta < \tilde{\theta}$

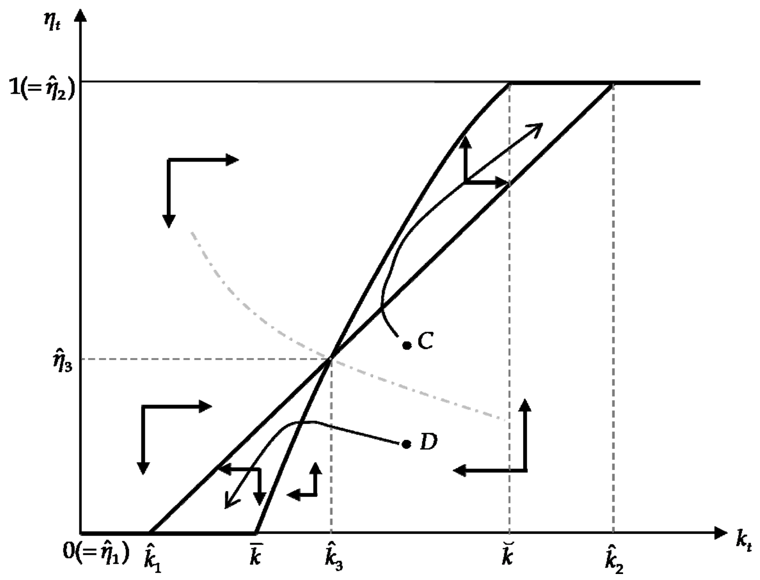

Figure 2. Dynamics under $\theta < \tilde{\theta}$

Now let us move to a scenario that entails the same initial value k_0 but two different initial conditions for the share of the population carrying the x trait. At point *C*, the stock of physical capital has the tendency to increase due to the high level of human capital that emanates from the relatively high proportion of people who dedicate more effort towards education activities when young. As the physical capital stock increases, it becomes more likely that, for a given η_t, the number of individuals who adopt the x trait will keep increasing over time. This process promotes the accumulation of physical capital even further which, in turn, supports a further increase in η_t due to the increased activities on cultural instruction by both Type-v and Type-x parents. This mutually-reinforcing process will eventually direct the economy towards the high-income steady state $(\hat{k}_2, \hat{\eta}_2)$. On the contrary, the low initial value for η_t at point *D* generates mutually-reinforcing forces that will gradually converge to the low-income steady state $(\hat{k}_1, \hat{\eta}_1)$, despite the fact that the initial stock of physical capital is the same. This is because the low level of aggregate human capital, associated with the low fraction of individuals who possess the x trait, will generate a gradual decline in the stock of physical capital. Consequently, it will become more likely that η_t will keep declining over time, mainly owing to the initially reduced, and subsequently absent, cultural instruction activities by parents of both types, but also reinforced through the oblique transmission.

A formal representation of the implications which I discussed above is provided in

Proposition 4. *Consider $\theta < \tilde{\theta}$. When the equilibrium is path-dependent, both the existing stock of physical capital and the existing distribution of cultural attitudes towards education, are critical in determining the economy's long-term prospects, i.e., whether it will converge to the low- or the high-income equilibrium.*

Proof. It follows from the preceding results and analysis. ■

Next, I will analyse the dynamics and the long-run outcomes that transpire when $\theta > \tilde{\theta}$. Note that this is a situation where $\overline{k} > \tilde{k}$ holds. Hence, we can combine (37) together with $k_t > \tilde{k} \Rightarrow \gamma_x(k_t) > (1-\theta)$ to infer that

$$\eta_{t+1} - \eta_t = \begin{cases} \leq 0 & \text{if} \quad k_t < \tilde{k} \\ \geq 0 & \text{if} \quad k_t > \tilde{k} \end{cases}. \tag{43}$$

In this case, the possible outcomes associated with path-dependent equilibria can be summarised by means of

Lemma 4. *Suppose that $\theta > \tilde{\theta}$ and $g^{\frac{1}{1-a}} \underline{e}^{\beta} < \left(\dfrac{\mu}{\theta} \right)^{1/\omega} < g^{\frac{1}{1-a}} \overline{e}^{\beta}$ hold. Then there exist two pairs of stable steady state equilibria $\left(\hat{k}_1, \hat{\eta}_1\right)$ and $\left(\hat{k}_2, \hat{\eta}_2\right)$ such that $\hat{k}_1 < \hat{k}_2$ and $\hat{\eta}_1 < \hat{\eta}_2$, separated by a threshold level of physical capital $\tilde{k} \in \left(\hat{k}_1, \hat{k}_2\right)$.*

Proof. See the Appendix. ■

Note that, similarly to the preceding analysis, the steady state solutions are $\hat{\eta}_1 = 0$, $\hat{k}_1 = g^{\frac{1}{1-a}} \underline{e}^{\beta}$, $\hat{\eta}_2 = 1$ and $\hat{k}_2 = g^{\frac{1}{1-a}} \overline{e}^{\beta}$. Given this, we can infer the characteristics that determine the transition towards the long-run equilibrium through

Proposition 5. *Consider $\theta > \tilde{\theta}$. When the equilibrium is path-dependent, only the existing stock of physical capital is critical in determining the economy's long-term prospects, i.e., whether it will converge to the low- or the high-income equilibrium.*

Proof. It follows from Lemma 4. ■

The dynamics under this scenario are illustrated on the phase diagram of Figure 3. What becomes evident here is that, given the result in (43), the only factor that determines whether the economy will converge to the low- or the high-income equilibrium is the initial stock of physical capital. At point *E*, the stock of physical capital is sufficiently high to induce an increase in η_t. As this happens, the resulting increase in aggregate human capital will promote the process of physical capital accumulation which, in turn, will motivate both Type-x and Type-v parents to engage more into the kind of activities that may instil the x trait in their children. At point *F*, however, the share of the population who adopt the x trait declines over time because, on the one hand, Type-v parents do not dedicate any effort to promote the adoption of the x trait by their children, whereas, on the other hand, the corresponding efforts by Type-x parents are too limited to ensure that a sufficiently large number of young individuals will adopt the behavioural patterns that are conducive to the formation of human capital. These effects are reinforced by the external factors of cultural transmission, hence generating a vicious circle where the gradual decline in η_t impedes the process of physical capital formation (due to the decrease in human capital) – an outcome that reinforces the net reduction of the population adopting education-promoting attitudes.[15]

[15] Irrespective of the different dynamic implications associated with the relative value of θ, the pair of stable long-run equilibria is either $(\hat{k}_1, 0)$ or $(\hat{k}_2, 1)$ where $\hat{k}_1$ and $\hat{k}_2$ are given in (38) and (39) respectively. Note that, in both solutions, the tax rate affects the long-run equilibrium through the composite term $g \equiv \frac{(1-a)A(1-\tau)^a}{2+\rho}\left(\frac{B\tau}{m}\right)^{1-a}$. Hence, the tax rate $\hat{\tau}$ that maximises the economy's income (whatever the long-run equilibrium) is the one that maximises g, i.e., $\hat{\tau} = 1 - a$, exactly as in Barro (1990).

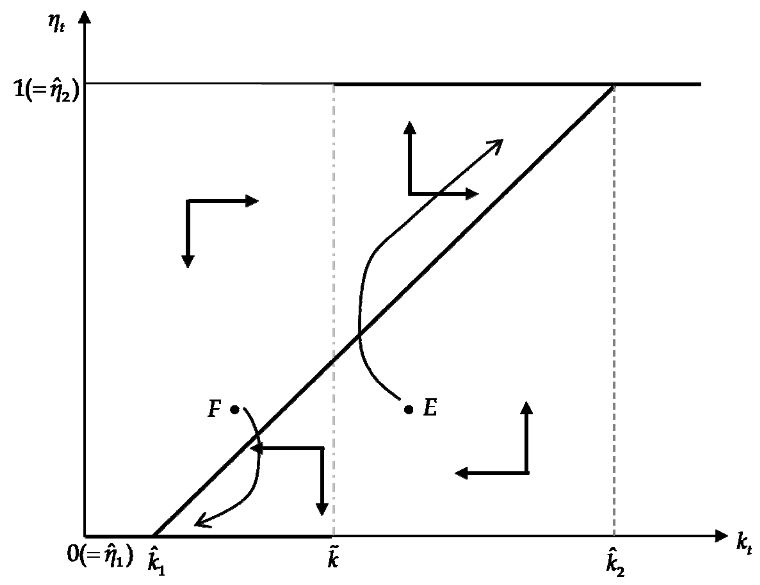

Figure 3. Dynamics under $\theta > \tilde{\theta}$

The outcomes presented in Propositions 4 and 5 reveal some important implications of the model, in relation to the forces that permeate the formation of physical capital and the process of cultural change. These can be summarised by means of

Corollary 1. *When multiple, divergent paths of economic development exist, the initial stock of physical capital is always crucial in determining the economy's long-term prospects. The initial distribution of different attitudes towards education can also be crucial, as long as there is a sufficiently high degree of social segregation.*

Why is the pre-existing share of traits critical for the model's outcomes only under a high degree of social segregation (i.e., low θ)? This is because – other things being equal – segregation is conducive to the prevalence of the Type-v trait. Under such circumstances, a relatively high initial value of η_t is central in counteracting the low value of θ, hence facilitating the dynamic process whereby the share of people who adopt the x trait increases over time. The reason why the pre-existing value of the capital stock is always important (irrespective of θ) relates mainly to the outcome in Lemma 1: Parents are willing to engage with the cultural instruction of their children, only if the capital stock is above a threshold.

At this point, it should be noted that previous studies have also highlighted the role of social segregation and stratification in the context of parental indoctrination and cultural transmission (e.g., Bisin and Verdier 2000; Patacchini and Zenou 2011; Bar-Gill and Fershtman 2016) as well as for issues pertaining to education, human capital and economic growth (e.g., Bénabou 1996; Gradstein and Justman 2002). As it will become clear in the next section, one of this study's novelties is that it highlights the role of physical capital formation in contributing to the amplification of existing differences in cultural attitudes towards education through the process of cultural transmission. [16]

6 Robustness of the Proposed Mechanisms

The purpose of this section is to establish the underlying mechanisms behind this study's main results. In this respect, the questions to be addressed here are the following: (i) Is the interplay between capital accumulation and cultural change critical for the emergence of multiple, divergent development paths? (ii) In the absence of a cultural complementarity, is the effect of physical capital formation on the return to education, and therefore on the process of cultural transmission, critical for a long-run equilibrium that is sensitive to the initial distribution of cultural attitudes?

To answer these questions, I shall examine two modifications of the original framework: The first one will remove the process of cultural change, assuming instead that the distribution of different attitudes towards human capital-promoting activities is fixed; the second one will examine a scenario where the distribution of these attitudes among the population is endogenous, but not affected by physical capital formation. Furthermore, the second modification will also consider an extension in which cultural complementarities permeate the intergenerational transmission of attitudes, as a means of examining whether the implications of the current framework are consistent with – and comparable to – the ones proposed by Bisin and Verdier (2001, 2008).

[16] It should be once more noted that some aspects of the cultural transmission process in my study (e.g., type of altruism and parental preferences) differ from the prototypical framework of Bisin and Verdier (2001). Despite these differences, however, in Section 6 I show that, in the absence of any effect of physical capital formation on cultural transmission, the long-run equilibrium is sensitive to the initial distribution of different attitudes among the population, only under the presence of a cultural complementarity – exactly as in Bisin and Verdier (2001). This establishes that, despite any differences, this study's underlying framework is consistent with – and comparable to - those of the existing literature. Therefore, its results and implications contribute to a further understanding of the mechanisms that pervade the dynamics of cultural transmission.

Let us begin with the former case and assume that $\overline{\eta} \in [0,1]$ is the fixed fraction of Type- x individuals in the economy. Given that this approach disables the process of cultural transmission, the stock of physical capital is the only state variable in the economy. It evolves according to

$$k_{t+1} = gk_t^a[\overline{\eta}(\overline{e}^\beta - \underline{e}^\beta) + \underline{e}^\beta]^{1-a}, \tag{44}$$

from which it is straightforward to establish that there is only one stable steady state equilibrium

$$\hat{k} = g^{\frac{1}{1-a}}[\overline{\eta}(\overline{e}^\beta - \underline{e}^\beta) + \underline{e}^\beta], \tag{45}$$

to which the capital stock will converge, irrespective of k_0. Thus, this analysis reveals that, in the context of this study's framework, the joint evolution of physical and human capital *per se* is not sufficient to generate multiple paths of economic development. The process of (endogenous) cultural transmission is a key element to the emergence of multiple development paths.

Now, let us examine the equilibrium outcomes that transpire when the physical capital stock and, therefore, economic dynamics do not affect the process of cultural change. A technical device that allows us to achieve this is to assume that the parent's utility from her child's human capital is adjusted for the negative externality of economic activity on labour productivity (see Eq. 12). In other words, the utility function in (10) is rewritten as follows:

$$-\Psi_i(e_{i,t}) + \frac{\ln(c_{i,t+1}) + \pi_{i,t+1}(\Omega_{t+2}h_{x,t+2})^\sigma + (1-\pi_{i,t+1})(\Omega_{t+2}h_{v,t+2})^\sigma - \Phi_i(\gamma_{i,t+1})}{1+\rho} + \frac{\ln(d_{i,t+2})}{(1+\rho)^2}. \tag{46}$$

Solving the parent's problem, and substituting (12) and (25) yields $\gamma_i^* = 1 - \mu_i \;\forall t$, where $\mu_i \equiv \sqrt{\dfrac{\varphi_i}{(B\tau/m)^\sigma(\overline{e}^{\beta\sigma} - \underline{e}^{\beta\sigma})}}$.[17] As we can see, augmenting the parent's altruistic component by labour productivity is just a useful device that only 'switches off' the effect of physical capital on optimal cultural instruction, without altering any of the other elements and results of the model. In other words, it works as if one sets the composite term $\omega = 0$ in Eq. (30). Once more, the share of the population who adopt the x trait evolves according to

$$\eta_{t+1} = \eta_t + (1-\eta_t)\{\eta_t[\gamma_x^* - (1-\theta)] + (1-\theta\eta_t)\gamma_v^*\}, \tag{47}$$

in which we can substitute $\gamma_i^* = 1 - \mu_i$ and manipulate algebraically to write as

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[17] The restriction $\mu_i \in [0,1]$ is adopted to guarantee that $\gamma_i^* \in [0,1]$.

$$\eta_{t+1} = \eta_t + (1-\eta_t)[\eta_t(\theta\overline{\mu} - \underline{\mu}) + 1 - \overline{\mu}] = \Gamma(\eta_t)\,. \tag{48}$$

As we can see, cultural change is not affected by the formation of physical capital, contrary to the case presented in (37). This is a straightforward result, emerging from the parent's realisation that the adverse externality of economic activity on labour productivity eradicates the positive effect of the physical capital stock on the return to her offspring's human capital investment. This outcome has important implications for the model's dynamics and long-run outcomes. A formal exploration of the economy's long-run equilibrium is presented in

Lemma 5. *If either $\theta > \tilde{\theta}$ or $\theta < \tilde{\theta}$ and $\overline{\mu}(1-\theta) < 1 - \underline{\mu}$, there is a unique pair of stable steady state equilibria $\hat{\eta} = 1$ and $\hat{k} = g^{\frac{1}{1-a}}\overline{e}^{\beta}$. If $\theta < \tilde{\theta}$ and $\overline{\mu}(1-\theta) > 1 - \underline{\mu}$, there exist two pairs of steady state equilibria $\left(\hat{k}_1, \hat{\eta}_1\right)$ and $\left(\hat{k}_2, \hat{\eta}_2\right)$, where $\hat{\eta}_1 = \dfrac{1-\overline{\mu}}{\underline{\mu} - \theta\overline{\mu}}$, $\hat{k}_1 = g^{\frac{1}{1-a}}[\hat{\eta}_1(\overline{e}^{\beta} - \underline{e}^{\beta}) + \underline{e}^{\beta}]$, $\hat{\eta}_2 = 1$ and $\hat{k}_2 = g^{\frac{1}{1-a}}\overline{e}^{\beta}$. The pair $\left(\hat{k}_1, \hat{\eta}_1\right)$ is stable whereas the pair $\left(\hat{k}_2, \hat{\eta}_2\right)$ is unstable.*

Proof. See the Appendix. ■

The main repercussion from Lemma 5 is that, as long as the formation of physical capital does not have an impact on the process of cultural transmission, there is only one pair of stable steady state equilibria. Consequently, the long-run equilibrium is unique and invariant to initial conditions, meaning that multiple paths of economic development will not emerge in this framework. In other words, the impact of physical capital formation on the process of (endogenous) cultural transmission is also a key element to the emergence of multiple development paths.

The general implication of the analysis so far can be summarised as follows:

Corollary 2. *Multiple paths of economic development emerge if and only if the dynamic processes of physical capital accumulation and cultural change are mutually-reinforcing.*

Now, I shall examine whether the presence of cultural complementarities could reinstate the sensitivity of the long-run equilibrium to the initial distribution of cultural attitudes among the population, within the context of the previous example in which the cultural transmission process is invariant to physical capital formation. If it does, it would mean that the implications of this study are indeed comparable to – and extent – those in Bisin and Verdier (2001, 2008).

Cultural complementarity is a situation in which the optimal solution for $\gamma^*_{i,t+1}$ is increasing in η_{t+1}. Such a scenario can emerge in my model as follows: Suppose that we replace Eq. (7) with

$$f_{i,t+1} = [1-\zeta_i(\eta_{t+1})]^{\delta}\varphi_i\,, \quad \delta > 1\,. \tag{49}$$

Solving the parents' problem in this case yields

$$\gamma^*_{x,t+1} = 1-\underline{\mu}(1-\eta_{t+1})^{\frac{\delta-1}{2}}\,,\ \gamma^*_{v,t+1} = 1-\overline{\mu}(1-\theta\eta_{t+1})^{\frac{\delta-1}{2}}\,, \tag{50}$$

from which it is straightforward to check that $\frac{\partial\gamma^*_{x,t+1}}{\partial\eta_{t+1}}, \frac{\partial\gamma^*_{v,t+1}}{\partial\eta_{t+1}} > 0$.[18] As the physical capital stock does not affect the formation of cultural attitudes, the dynamics of cultural change will be uniquely determined by $\eta_{t+1} = \eta_t + (1-\eta_t)\{\eta_t[\gamma^*_{x,t} - (1-\theta)] + (1-\theta\eta_t)\gamma^*_{v,t}\}$, after the substitution of the results in (50). Due to the complexity of the resulting expression, however, it is quite strenuous to characterise these dynamics analytically. For this reason, I will illustrate that multiple, path-dependent equilibria can emerge by means of a numerical example. Specifically, setting $\theta = 0.15$, $\delta = 3$, $\underline{\mu} = 0.9$ and $\overline{\mu} = 0.98$ results in two stable steady state equilibria, $\hat{\eta}_1 \simeq 0.189$ and $\hat{\eta}_2 = 1$, which are separated by an unstable steady state (i.e., a threshold) $\hat{\eta}_3 \simeq 0.551$ (see Figure 4).

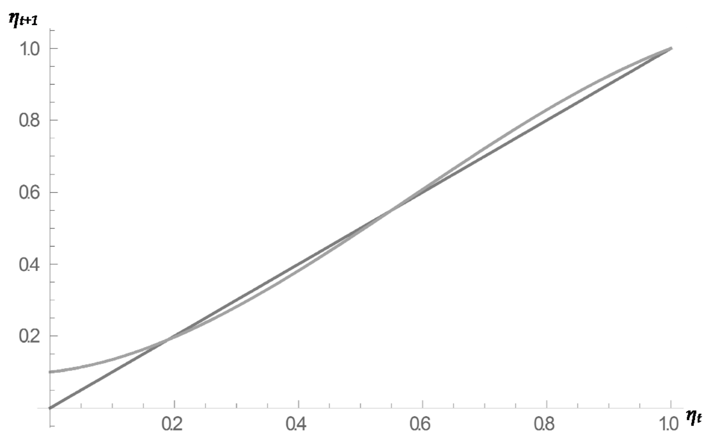

Figure 4. Multiple equilibria under cultural complementarity

[18] Note that when $\delta = 1$, we get the scenario whose equilibrium outcomes are summarised in Lemma 5.

Given these outcomes, we can recollect the results in Proposition 4 and Lemma 5 to summarise as follows: When physical capital formation does not affect the process of cultural transmission, the long-run equilibrium may be sensitive to the initial share of different cultural attitudes among the population, but only in the presence of a cultural complementarity – exactly as in Bisin and Verdier (2001, 2008). When physical capital formation does affect the process of cultural transmission, the long-run equilibrium may be sensitive to the initial share of different cultural attitudes among the population, even in the absence of a cultural complementarity. Formally, these implications can be presented in

Corollary 3. *The impact of physical capital accumulation on the process of cultural transmission may render the long-run outcomes sensitive to the existing distribution of different cultural attitudes among the population, even under circumstances where this distribution would be otherwise irrelevant.*

7 Alternative Approaches

7.1 An Alternative Role for Physical Capital

A key mechanism of the model is the effect of the physical capital stock on the process of cultural transmission. This effect emerges though the impact of physical capital on the human capital technology and, therefore, the return to education and the corresponding response by parents who wish to instil education-promoting values in their children. Surely, however, this is not the only scenario that can capture the role of physical capital on the type of cultural transmission that is addressed in this study. The role of this section is to show that the model's main results and implications remain unaffected in circumstances where, in addition to its contribution in the production of goods, physical capital reduces either the young's effort cost of education investment, or the parents' effort cost of instilling human capital-promoting values in their children. Note that, throughout this section, (3a) and (3b) are replaced (after setting $\beta = 1$) by

$$h_{i,t+1} = Be_{i,t}. \tag{51}$$

Let us consider the case where (1) is replaced by

$$\Psi_i(e_{i,t}, k_{h,t}) = \kappa(k_{h,t})\psi_i e_{i,t}, \tag{52}$$

where $\kappa'(k_{h,t}) < 0$. The idea here is that the capital stock devoted to education (e.g., IT systems, libraries etc.) reduces the marginal cost of achieving a given educational outcome. We can obtain the optimal effort in education as

$$e_{i,t}^{*} = \begin{cases} \dfrac{\overline{e}}{\kappa(k_{h,t})} & \text{if} \quad i = x \\ \dfrac{\underline{e}}{\kappa(k_{h,t})} & \text{if} \quad i = v \end{cases}, \tag{53}$$

where $\overline{e} \equiv p\beta\underline{\psi}^{-1}$ and $\underline{e} \equiv p\beta\overline{\psi}^{-1}$. For illustrative purposes, let us employ the functional form

$$\kappa(k_{h,t}) = k_{h,t}^{-1}, \tag{54}$$

and combine with (25), (51) and (53) to get

$$h_{x,t+1} - h_{v,t+1} = B\tau k_t(\overline{e} - \underline{e}) . \tag{55}$$

This analysis reveals that, apart from the normalisation $\beta = 1$, the results in (21) and, therefore, in (30), (36) and (37) remain identical. Consequently, all the outcomes and implications of the original model remain unaffected.

Next, instead of assuming that the capital stock reduces the marginal effort cost of education for the young, let us consider the case of a positive externality whereby part of the physical capital stock (e.g., information and communication technology) can facilitate the adoption of parenting techniques that reduce the parents' marginal effort cost of instilling the characteristics of Type-x in their children. Formally, we can modify Eq. (6) of the original model to

$$\Phi_i(\gamma_{i,t+1}, \overline{k}_{t+1}) = \frac{\kappa(\overline{k}_{t+1}) f_{i,t+1}\gamma_{i,t+1}}{1 - \gamma_{i,t+1}}, \tag{56}$$

where $\overline{k}_{t+1}$ is the average stock of capital and $\kappa'(\overline{k}_{t+1}) < 0$. Given that $\overline{k}_{t+1} = k_{t+1}$ in equilibrium, and after adopting the functional form

$$\kappa(k_{t+1}) = k_{t+1}^{-1}, \tag{57}$$

for illustrative purposes, it is straightforward to establish that the results in (29) and (30) remain identical, with only the composite parameter term μ_i changing to $\mu_i \equiv \sqrt{\dfrac{\varphi_i}{B^{\sigma}(\overline{e}^{\sigma} - \underline{e}^{\sigma})}}$.

Therefore, the dynamics in (37) remain qualitatively identical. In this case, note that because the human capital technology is not directly affected by the physical capital stock (compare Eq. 19 with 51), we can uncover the dynamics of the physical capital stock in (36) (for $\beta = 1$)

without the presence of the health externality captured by Ω_{t+1} in (11). Indeed, setting $\Omega = 1$ the dynamics of capital accumulation are described by $k_{t+1} = gk_t^a[\eta_t(\overline{e} - \underline{e}) + \underline{e}]^{1-a}$. Once more, the analysis reveals that all the outcomes and implications of the original model remain unaffected.

7.2 An Alternative Source of Differentiation among Parents of Different Types

One characteristic of this study is that parents are differentiated in their ability to inculcate their children with the human capital-promoting trait. The idea is that it is less challenging for Type-x parents to instil a trait that they already possess, contrary to Type-v parents – an idea formally captured by the parameters $\theta \in (0,1)$ and φ_i that affected the external aspects of cultural transmission as well as the effort cost of socialisation.

The purpose of this section is to examine the implications from an alternative source of differentiation among households of different types. Particularly, in this section I set $\theta = 1$ and $\varphi_i = \varphi \ \forall i = \{x, v\}$. Instead, I will assume that Type-x parents have a higher probability of inculcating their offspring with the x trait, for given amount of effort in socialisation. Formally, Eq. (27) of the original model is replaced by

$$z_i(\gamma_{i,t+1}) = \begin{cases} \gamma_{x,t+1} & \text{if} \quad i = x \\ \varepsilon\gamma_{v,t+1} & \text{if} \quad i = v \end{cases}, \tag{58}$$

where $0 < \varepsilon < 1$. Under this setting, it is straightforward to show that the parent's maximisation problem leads to results which are identical to (29) and (30). The only difference is on the composite parameter term μ_i which now takes the values $\overline{\mu} \equiv \sqrt{\dfrac{\varphi}{\varepsilon(B\tau)^\sigma(\overline{e}^{\beta\sigma} - \underline{e}^{\beta\sigma})}}$ (for $i = v$) and $\underline{\mu} \equiv \sqrt{\dfrac{\varphi}{(B\tau)^\sigma(\overline{e}^{\beta\sigma} - \underline{e}^{\beta\sigma})}}$ (for $i = x$). As in the original version of the model, the socialisation activities by Type-v parents fall short of the ones by Type-x parents. In the original version, this discrepancy was attributed to the fact that Type-x parents face lower effort costs, compared to Type-v ones, to achieve the same probability of successful socialisation; in this case, it is attributed to the fact that Type-x parents face a higher marginal increase in the probability of successful socialisation per unit of effort, compared to Type-v ones. Nevertheless, the results are equivalent irrespective of the scenario.

Now, let us move to the analysis of the dynamics. While Eq. (36) remains identical, the expression in (37) changes to

$$\eta_{t+1} = \Gamma(k_t, \eta_t) = \begin{cases} \eta_t & \text{if} \quad k_t \leq \underline{k} \\ \eta_t + (1-\eta_t)\eta_t \gamma_x(k_t) & \text{if} \quad \underline{k} < k_t \leq \overline{k} \\ \eta_t + (1-\eta_t)[\eta_t \gamma_x(k_t) + (1-\eta_t)\gamma_v(k_t)] & \text{if} \quad k_t > \overline{k} \end{cases}. \tag{59}$$

where $\underline{k} \equiv \underline{\mu}^{1/\omega}$ and $\overline{k} \equiv \overline{\mu}^{1/\omega}$ as in the original version of the model. Let us focus on parameter conditions that satisfy $g^{\frac{1}{1-a}} \underline{e}^{\beta} < \underline{\mu}^{1/\omega} < g^{\frac{1}{1-a}} \overline{e}^{\beta}$. From Eq. (59) it is evident that for $k_0 > \underline{k}$ it is $\eta_{t+1} - \eta_t > 0$, meaning that the economy will converge to a long-run equilibrium where $\hat{\eta}_2 = 1$ and $\hat{k}_2 = g^{\frac{1}{1-a}} \overline{e}^{\beta} > \underline{k}$, irrespective of the initial value η_0. However, for $k_0 \leq \underline{k}$ the long-run equilibrium can depend on η_0 as well. To see this, consider $\tilde{\eta}$ such that

$$\underline{k} = g^{\frac{1}{1-a}} [\tilde{\eta}(\overline{e}^{\beta} - \underline{e}^{\beta}) + \underline{e}^{\beta}], \tag{60}$$

and recall that, given (59), η_t remains stationary when $k_0 \leq \underline{k}$. If $\eta_o < \tilde{\eta}$ then the economy will converge to a long-run equilibrium where $\hat{\eta}_1 = \eta_0$ and $\hat{k}_1 = g^{\frac{1}{1-a}} [\eta_0(\overline{e}^{\beta} - \underline{e}^{\beta}) + \underline{e}^{\beta}] < \underline{k}$. If $\eta_o > \tilde{\eta}$, however, a long-run equilibrium where $\hat{\eta}_1 = \eta_0$ and $\hat{k}_1 = g^{\frac{1}{1-a}} [\eta_0(\overline{e}^{\beta} - \underline{e}^{\beta}) + \underline{e}^{\beta}]$ cannot exist because $\hat{k}_1 > \underline{k}$ by virtue of (60) and, given (50), whenever $k_t > \underline{k}$ we have $\eta_{t+1} - \eta_t > 0$. Put differently, when $\eta_o > \tilde{\eta}$ the economy will at some point exceed the threshold $\underline{k}$ and eventually converge to a long-run equilibrium where $\hat{\eta}_2 = 1$ and $\hat{k}_2 = g^{\frac{1}{1-a}} \overline{e}^{\beta} > \underline{k}$. In other words, the preceding analysis reveals that, once more, the initial values of both physical capital and of the distribution of traits across the population may matter for the long-run equilibrium of the economy.

8 Discussion and Conclusion

From a broad perspective, this study contributed to our current understanding of the mechanisms and implications that result from the two-way causal effects between economic growth and cultural change. More specifically, its aim was twofold. First, to develop a full-fledged growth model as a means of formalising the idea that the interplay between economic progress and cultural change in attitudes towards human capital-promoting activities, can provide a powerful propagation mechanism that directs economies into either a virtuous circle of sustained economic improvements or a vicious circle towards low levels of per capita income. Second, to enrich our understanding of the conditions under which differences in cultural characteristics (e.g., attitudes, values and norms) can be amplified in the long-run through the process of intergenerational transmission of cultural traits and preferences.

Applying some scepticism to the importance of the current research endeavour, one could argue that, in the end, what matters is that behavioural traits are embodied within the 'deep' preference parameters that determine the optimal accumulation of human capital in existing models of growth. Therefore, straightforward comparative statics on the steady state equilibrium suffice in order to infer how differences in these parameters affect education, human capital, and economic growth. In other words, the underlying process of cultural evolution, which led to the adoption of specific behavioural traits, adds little or nothing to our understanding of economic growth and development. Of course, this argument would be fundamentally flawed, mainly for two reasons. The first reason is that it ignores the plethora of empirical work that establishes a relation between education-oriented cultural change and economic performance – a sample of this work was cited in the first two sections of this study. The second reason is the essence of this study's contribution. Particularly, it demonstrated how and why a growth model that is enriched with the cultural transmission of a behavioural trait that embodies people's attitudes towards human capital-promoting activities, offers important – and empirically-relevant as well – insights, not only into the process of economic development but also into the process of cultural transmission itself.

Naturally, the analysis can be extended to derive implications on issues that – with the purpose of keeping the model tightly focused, and without blurring the mechanisms at work – were not examined in the current framework. One such extension could involve a dynamic externality whereby a young individual's human capital is positively affected by the human capital of her parent. Another possible way to achieve a similar outcome – and as long as income effects dominate – would be a scenario where the cost of the offspring's socialisation impinges on the parent's labour supply. An alternative set-up involves a scenario where, rather than transmitting attitudes towards education, parents transmit their human capital directly to their children. However, such a set-up would be more relevant to a framework of occupational choice and occupation-specific skills like in Chakraborty *et al.* (2016). In the context of this study, it would mean that less educated parents consciously transmit a relatively low level of human capital to their offspring – a scenario that differs from the ideas and mechanisms that this study seeks to analyse. In any case, all these approaches would be conducive to the study of income distribution dynamics and their interplay with the process of cultural transmission, thus they represent an interesting and rewarding avenue for future research.

Appendix

Proof of Lemma 3

Using the system in (36) and (37), let us write the Jacobian matrix of partial derivatives

$$\begin{pmatrix} F_{k_t}\left(\hat{k},\hat{\eta}\right) & F_{\eta_t}\left(\hat{k},\hat{\eta}\right) \\ \Gamma_{k_t}\left(\hat{k},\hat{\eta}\right) & \Gamma_{\eta_t}\left(\hat{k},\hat{\eta}\right) \end{pmatrix},$$

where

$$F_{k_t}\left(\hat{k},\hat{\eta}\right) = a, \tag{A1}$$

$$F_{\eta_t}\left(\hat{k},\hat{\eta}\right) = (1-a) g^{\frac{1}{1-a}} (\overline{e}^{\beta} - \underline{e}^{\beta}), \tag{A2}$$

$$\Gamma_{k_t}\left(\hat{k},\hat{\eta}\right) = \begin{cases} 0 & \text{if} \quad k_t \le \underline{k} \\ (1-\hat{\eta})\hat{\eta}\gamma'_x & \text{if} \quad \underline{k} < k_t \le \overline{k} \\ (1-\hat{\eta})[\hat{\eta}\gamma'_x + (1-\theta\hat{\eta})\gamma'_v] & \text{if} \quad k_t > \overline{k} \end{cases}, \tag{A3}$$

$$\Gamma_{\eta_t}\left(\hat{k},\hat{\eta}\right) = \begin{cases} 1-(1-\theta)(1-2\hat{\eta}) & \text{if} \quad k_t \le \underline{k} \\ 1+[\gamma_x(\hat{k})-(1-\theta)](1-2\hat{\eta}) & \text{if} \quad \underline{k} < k_t \le \overline{k} \\ 1+[\gamma_x(\hat{k})-(1-\theta)](1-2\hat{\eta}) - \gamma_v(\hat{k})[1-\theta\hat{\eta}+\theta(1-\hat{\eta})] & \text{if} \quad k_t > \overline{k} \end{cases}. \tag{A4}$$

For $k_t \le \overline{k}$, the steady state solutions are $\hat{\eta}_1 = 0$ and $\hat{k}_1 = g^{\frac{1}{1-a}} \underline{e}^{\beta}$, therefore $\Gamma_{k_t}\left(\hat{k}_1,\hat{\eta}_1\right) = 0$. Furthermore, note that $\Gamma_{\eta_t}\left(\hat{k}_1,\hat{\eta}_1\right) \in (0,1)\ \forall k_t \le \overline{k}$ because $\Gamma_{\eta_t}\left(\hat{k}_1,\hat{\eta}_1\right) = \theta$ if $k_t \le \underline{k}$, or $\Gamma_{\eta_t}\left(\hat{k}_1,\hat{\eta}_1\right) = \theta + \gamma_x(\hat{k}_1)$ if $\underline{k} < k_t \le \overline{k}$.[19] Given these, the trace and the determinant of the Jacobian matrix are $Tr = a + \Gamma_{\eta_t}(\bullet)$ and $Det = a\Gamma_{\eta_t}(\bullet)$ respectively. Since $Tr^2 - 4Det = [a - \Gamma_{\eta_t}(\bullet)]^2 > 0$ the eigenvalues are real and distinct numbers, given by

$$\lambda_{1,2} = \frac{Tr \pm \sqrt{Tr^2 - 4Det}}{2}. \tag{A5}$$

[19] Recall that $\gamma_x(\hat{k}) < 1-\theta$ when $k_t \le \overline{k} < \tilde{k}$.

Substituting the existing results in (A5) yields $\lambda_1 = a \in (0,1)$ and $\lambda_2 = \Gamma_{\eta_t}(\bullet) \in (0,1)$, meaning that the steady state pair $\left(\hat{k}_1, \hat{\eta}_1\right)$ is a stable equilibrium.

Next, consider the case $k_t > \tilde{k} > \overline{k}$ where the steady state solutions are $\hat{\eta}_2 = 1$ and $\hat{k}_2 = g^{\frac{1}{1-a}} \overline{e}^{\beta}$. Again we have $\Gamma_{k_t}\left(\hat{k}_2, \hat{\eta}_2\right) = 0$, $Tr = a + \Gamma_{\eta_t}(\bullet)$ and $Det = a\Gamma_{\eta_t}(\bullet)$, where $\Gamma_{\eta_t}(\bullet) = 1 - \gamma_x(\hat{k}_2) + (1-\theta)(1-\gamma_v(\hat{k}_2)) \in (0,1)$.[20] Once more, $Tr^2 - 4Det = [a - \Gamma_{\eta_t}(\bullet)]^2 > 0$ implies that the eigenvalues are real and distinct numbers, equal to $\lambda_1 = a \in (0,1)$ and $\lambda_2 = \Gamma_{\eta_t}(\bullet) \in (0,1)$. Thus, the steady state pair $\left(\hat{k}_2, \hat{\eta}_2\right)$ is a stable equilibrium.

Finally, we will focus on the steady state pair $\left(\hat{k}_3, \hat{\eta}_3\right)$ which exists on the interval $\overline{k} < k_t < \tilde{k}$. Combining (30), (40) and (A3), we get $\Gamma_{k_t}\left(\hat{k}_3, \hat{\eta}_3\right) = \dfrac{\omega(1-\hat{\eta}_3)}{\hat{k}_3}$ and $\Gamma_{\eta_t}\left(\hat{k}_3, \hat{\eta}_3\right) = 1 - \dfrac{(\underline{\mu} - \theta\overline{\mu})(1-\hat{\eta}_3)}{(\underline{\mu} - \theta\overline{\mu})\hat{\eta}_3 + \overline{\mu}} = 1 - \dfrac{(\underline{\mu} - \theta\overline{\mu})(1-\hat{\eta}_3)}{\hat{k}_3^{\omega}} \equiv 1 - \delta \in (0,1)$. Defining

$$F_{\eta_t}(\bullet)\Gamma_{k_t}(\bullet) = (1-a)g^{\frac{1}{1-a}}(\overline{e}^{\beta} - \underline{e}^{\beta})\frac{\omega(1-\hat{\eta}_3)}{\hat{k}_3} \equiv \xi > 0,$$

it follows that

$$Tr^2 - 4Det = [a - (1-\delta)]^2 + 4\xi > 0, \tag{A6}$$

meaning that the eigenvalues are real and distinct numbers. Given (A5) and (A6), let us focus on the following eigenvalue:

$$\lambda_2 = \frac{Tr + \sqrt{Tr^2 - 4Det}}{2} = \frac{a + 1 - \delta + \sqrt{[a-(1-\delta)]^2 + 4\xi}}{2}. \tag{A7}$$

The expression in (A7) is unambiguously positive, therefore it is sufficient to show that $\lambda_2 > 1$ as a means of proving that the steady state pair $\left(\hat{k}_3, \hat{\eta}_3\right)$ is unstable. Using (A7), the condition $\lambda_2 > 1$ requires

$$\xi > (1-a)\delta \Rightarrow$$

$$g^{\frac{1}{1-a}}(\overline{e}^{\beta} - \underline{e}^{\beta})\frac{\omega}{\hat{k}_3} > \frac{\underline{\mu} - \theta\overline{\mu}}{\hat{k}_3^{\omega}} \Rightarrow$$

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[20] Recall that $\gamma_x(\hat{k}) > 1-\theta$ when $k_t > \tilde{k}$.

$$\frac{\omega \hat{k}_3^{\omega-1}}{\underline{\mu}-\theta\overline{\mu}} > \frac{1}{g^{1/(1-a)}(\overline{e}^{\beta}-\underline{e}^{\beta})}. \tag{A8}$$

This is a condition that indeed holds, because the existence of a steady state on $\overline{k} < k_t < \tilde{k}$, requires that that the slope of Eq. (40) must be greater than the slope of Eq. (42), when evaluated at $\hat{k}_3$. ■

Proof of Lemma 4

Using $\overline{k} > \tilde{k}$, the proof of Lemma 3 can be used as a guide to examine the stability of the steady state pairs $\left(\hat{k}_1, \hat{\eta}_1\right)$ and $\left(\hat{k}_2, \hat{\eta}_2\right)$. ■

Proof of Lemma 5

Consider Eq. (48) and assume $\theta > \tilde{\theta}$. Then $\eta_{t+1} - \eta_t > 0\ \forall t$, therefore the only steady state solution is $\hat{\eta} = 1$. Now assume $\theta < \tilde{\theta}$, in which case there are two steady state solutions $\hat{\eta}_1 = \dfrac{1-\overline{\mu}}{\underline{\mu}-\theta\overline{\mu}}$ and $\hat{\eta}_2 = 1$. Note that for $\hat{\eta}_1$ to be interior, we need $\overline{\mu}(1-\theta) > 1-\underline{\mu}$ to hold; otherwise, $\hat{\eta}_1 > 1$ and the only accepted steady state solution will be $\hat{\eta}_2 = 1$. From (48) we have $\Gamma'(\eta_t) = \overline{\mu} - (\underline{\mu}-\theta\overline{\mu})(1-2\eta_t) > 0$. Evaluating at $\hat{\eta}_2 = 1$ yields

$$\Gamma'(1) = \overline{\mu}(1-\theta) + \underline{\mu} \begin{cases} >1 & \text{if} \quad \overline{\mu}(1-\theta) > 1-\underline{\mu} \\ <1 & \text{if} \quad \overline{\mu}(1-\theta) < 1-\underline{\mu} \end{cases}.$$

It follows that when $\hat{\eta}_1$ is ruled out, due to being greater than 1, $\hat{\eta}_2 = 1$ is a stable steady state solution whereas when $\hat{\eta}_1$ is an interior solution, $\hat{\eta}_2 = 1$ is unstable. For the latter case, we can evaluate

$$\Gamma'(\hat{\eta}_1) = 1 - [\overline{\mu}(1-\theta) - (1-\underline{\mu})],$$

and conclude that $\hat{\eta}_1$ is a stable steady state solution by virtue of $\Gamma'(\hat{\eta}_1) \in (0,1)$.

All in all, the stable steady state equilibrium emerging from (48) will be a unique one, no matter what the parameter configurations are. Consequently, there will be a corresponding stable steady state equilibrium for $\hat{k}$, emerging from Eq. (36). ■

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