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Culturally Risk Averse? – A Model of Economic Growth with Endogenous Culture [1]

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Abstract

This research studies the dynamic interplay between the evolution of cultural traits and the process of economic development. In particular, this paper shows how cultural attitudes, in this case differences in risk attitudes, influence economic decision making while at the same time illustrating how these attitudes endogenously change over time. In order to study this joint evolution of cultural and economic variables, an endogenous growth model is integrated with a cultural transmission mechanism along the lines of Bisin & Verdier. This provides us with a framework for the analysis of cultural attitudes that is both general and flexible so that it could be adapted for the study of culture in its full multidimensionality. The model predicts that higher economic success of more risk tolerant agents will over time lead to an increase in their representation in the society, which in turn will speed up economic growth. At the same time, though, the more risk averse type will not be completely eliminated. Using individual level data on risk attitudes across Chinese provinces, empirical evidence supporting this relationship between economic incentives and risk attitudes is provided

Keywords

Economic growth, cultural change, cultural transmission, risk aversion

JEL Classification

A14, J24, O11, O15, O33, O41, Z10

1 Introduction

Economic transformation goes hand in hand with sociocultural change. Economic historians, as for example Cipolla (1980) and Mokyr (1985), have long been pointing out the role of cultural factors such as openness to adoption and adaptation of new technologies or eagerness for undertaking risky entrepreneurial activities in order to explain why the Industrial Revolution happened first in England. Traditionally, however, economists have tended to neglect the role of culture, that is a society's set of values, beliefs, attitudes and preferences, when trying to explain economic phenomena[1].

Recently though, a growing empirical literature has emerged emphasizing the importance of cultural factors as determinants of economic decisions and outcomes. Barro and Mc Cleary (2003) for example argue that the strength of religious beliefs can explain differences in income across countries. Fernandez and Fogli (2006) and Fernandez (2007) provide evidence that fertility and female labor force participation rates have cultural roots. Guiso, Sapienza and Zingales (2006) show among other things that culture can explain differences in the probability to become an entrepreneur. Moreover, Algan and Cahuc (2007) analyze the correlation between attitudes of American immigrants and those in their countries of origin and find that preferences for redistribution have also a cultural component. Tabellini (2007) shows that cultural norms can account for differences in growth and income levels within Europe. Finally, Klasing (2008) provides evidence that cultural differences can explain a large degree of differences in political institutions.

On the other hand, it has also to be emphasized that cultural attitudes should not be seen and treated as exogenous. Carroll and Summers (1991) for example show that consumption-age profiles are steeper when economic growth is high; Inglehart and Baker (2000) show that economic growth is associated with less traditional values[2]. More generally, Jones (2006) notes that "every culture represents an equilibrium among current economic and social forces which are unlikely to be permanent."

However, despite this empirical evidence, the question of how cultural attitudes can affect comparative economic development has, to a large extent, not yet been touched by the modern theory of economic growth. Most importantly, is has hardly been discussed how the role of cultural attitudes could be formally modelled without imposing exogenously fixed attitudes, but taking into account the interaction between culture and economic conditions.

The paper proposes a model that displays a dynamic interplay between the evolution of cultural traits and the process of economic development. By 'cultural trait' we mean the parameter value

[1] The Merrian Webster Dictionary defines culture as "the integreated patterns of human knowledge, belief and behavior that depend upon the capacity for learning and transmitting knowledge to succeeding generations" and "the customary beliefs, social forms and material traits of a racial, religious, or social group."

[2] According to Inglehart and Baker typical traditional values are a low tolerance for abortion and divorce, tendency to emphasize male dominance in political and economic life, importance of family life and the importance of religion.

of a specific cultural attitude, which could in general be any kind of preference or belief. Hence, in principle we could think of many parameters that could be treated as cultural traits. Yet, in order to keep the analysis simple and tractable, in this model, we are going to focus solely on the concept of risk aversion as one particular component of culture. Given that, we are going to show how cultural differences in risk aversion influence economic decision making regarding investment in human capital and the extent of research activity, while at the same time we will be illustrating how these risk preferences endogenously change over time. The proposed theory indicates that distinct cultural entities are characterized by different paths of economic development and helps to explain why different countries or cultural regions experience quite different development paths.

The model presented in this paper is based on three building blocks. The first one is a model of cultural transmission, describing how cultural traits are transmitted from one generation to the other and generating the law of motion for the evolution of cultural traits over time. Following Bisin and Verdier (1998, 2000), who introduced the theory of cultural transmission based on the seminal work by Cavalli-Sforza and Feldman (1981) and Boyd and Richerson (1985), we assume that there are two possible distinct cultural traits, or more precisely, in the specific context of this paper, two different levels of risk aversion. Every adult in this model has one child and is able to transmit his own cultural trait to his child with some probability. If the parent fails to directly influence his child's trait, the child will randomly pick a cultural trait existing in this society. Parents care about the economic wellbeing of their children and the survival of their own cultural trait, and choose the level of direct transmission, that is, the probability of directly influencing the child's trait, optimally, such that they maximize their utility. However, parents are not perfectly altruistic. They are able to anticipate which economic choice a child of a certain cultural type will optimally make, but they will evaluate the children's choice with their own preferences, that is they only imperfectly empathize with their children. We show that a parent will spend the more resources on directly influencing his child's trait and consequently transmit his own trait with a higher probability, the smaller is the current fraction of his type in the population (minority effect) and the economically more successful he perceives his own cultural type to be compared to other types in the population.

The above mechanism is then merged with the second building block of the model, a Romer (1990)-type model of endogenous economic growth with three sectors: a final goods-sector that produces a homogenous output good; an intermediate sector that produces intermediate goods which are then used as inputs in the production of the final good; and a research sector that produces the designs for intermediate goods. In contrast to Romer, though, we assume that research activity is risky, meaning that each researcher produces a positive number of innovations or new designs with a probability smaller than one[3].

The third building block of our model embodies the notion that cultural attitudes influence

[3] For more details on the stochastic nature of the innovation process the reader is referred to Aghion and Howitt (1992, 2005).

human capital decision making and the extent of research activity. Decisions are made by overlapping generations of agents whose preferences are of the Epstein-Zin-type[4]. Agents live for three periods. They consume leisure and build up human capital in the first period, and work and raise a child in their second period of life. Finally, in their third period of life they consume their wages from the previous period[5] along with interest and derive utility from having a child. Agents, however, differ in their level of risk aversion, which is an important factor in their career choices. As research activity is risky, at each point in time only agents who are sufficiently risk tolerant will choose to work in the research sector[6]. Thus, the aggregate composition of the population in terms of risk aversion determines the extent of research activity and the rate of technological progress in the economy.

We show that as capital is being accumulated, the level or risk tolerance necessary to induce agents to switch to the research sector falls and gives rise to a higher number of researchers and thus a higher rate of technological progress. The model hence exhibits the existence of a poverty trap: Countries with very risk-averse individuals might become stuck in an equilibrium without entrepreneurial activity and with a low level of productivity[7]. Everything else being equal, the sooner a country starts to allocate resources to research, the richer it will be in the long-run, even though the long-run growth rate is unaffected by the time in which the transition to a regime with an active research sector occurs.

The laws of motion for the accumulation of capital, the evolution of cultural types, and the evolution of the price for innovations form a three-dimensional discrete dynamical system, determining the evolution of the economy and its steady-state, where the steady-state is defined as the state where the capital stock is growing at a constant rate and the distribution of cultural types and the price level are stable. Unlike most evolutionary selection models, however, our model exhibits convergence to a non-degenerate polymorphic distribution of cultural traits, meaning that cultural diversity within the society is preserved and there is no complete assimilation. We are thus able to explain the adaptability of cultural traits to the economic environment as well as its inertia over time. We show that less risk averse societies will start allocating resources to the research sector and consequently start growing earlier and will grow at a higher rate. We also show that the higher are the economic benefits of working in the risky sector, the higher will be the fraction of more risk tolerant types in the steady state. This is because over time agents will understand the economic benefits of risk tolerance and transmit more risk tolerant attitudes to subsequent generations.

[4] For further details on this type of preferences see Epstein and Zin (1998, 1999).

[5] The assumption of consumption taking place only in the third period of life is just made for convenience and does not affect the qualitative results of the model.

[6] In this paper the expressions "more risk tolerant" and "less risk averse", and "less risk tolerant" and "more risk averse" will be used interchangeably. It should be noted, however, that in fact there are no risk loving or risk neutral agents in this model, but all are risk averse, some less and some more.

[7] In this paper, the terms "entrepreneurs" and "researchers" will be used interchangeably.

We test the latter relationship between employment in a sector that carries risk and risk attitudes empirically, using individual level information on risk attitudes from China. While before 1979 a private sector was inexistent in China and everybody worked in secured state-owned or community-owned sector jobs, the economic reforms introduced after 1979 lead to a major increase in private enterprise jobs that impose at least some risks on the employees. Our analysis exploits the fact that these reforms and hence the establishment of private sector jobs began in different provinces at different points in time. Our results show that people from provinces that introduced risky private sector jobs earlier are nowadays less risk averse than people from provinces where employment opportunities have longer been dominated by secured state-owned sector jobs. This is because learning about the benefits of private sector jobs and cultural change take time, such that provinces that started making experience with private sector jobs earlier had more time to develop and transmit more risk tolerant attitudes, and hence are nowadays in overall less risk averse.

The paper is organized as follows; Section 2 presents existing empirical evidence on the cultural aspects of risk attitudes and its role for economic decisions. It also relates to the existing literature. Section 3-6 present the formal model. Section 7 provides empirical evidence from Chinese provinces. Section 8 concludes.

2 Empirical Evidence and Related Literature

2.1 Evidence

Risk aversion is one of the key parameters in the theory of decision under uncertainty. It has been well established theoretically that differences in risk aversion should matter for occupational choices and that agents are being sort into more and less risky occupations according to their level of risk aversion (Kihlstrom & Laffont, 1979; Kanbur, 1979). At the same time, according to the viewpoint of the Schumpetarian growth theory as developed by Aghion and Howitt (1992, 1998, 2005), based on the insights of Schumpeter (1934, 1942) , the role of entrepreneurs who take risks is crucial in the process of innovation, which, as most economist would agree, is probably the only source of sustained economic growth. With new information on risk attitudes available from household surveys, recently also many empirical studies have confirmed a significant relationship between risk attitudes and occupational choice.

Using a survey of 1'800 people from a Dutch province, born in 1939/1940 and surveyed during childhood and adulthood, Van Praag and Cramer (2001) and Cramer, Hartog, Jonker, and Van Praag (2002) show that risk aversion negatively affects the probability to become an entrepreneur, i.e. to become self-employed. As a measure of risk aversion the authors used the amount of money the subjects answered to be willing to invest in a hypothetical lottery with certain stake and probability. Using a similar hypothetical lottery question, Guiso and Paiella (2005) provide similar evidence with survey data of 3'500 people in Italy. They find that being risk averse rather than risk prone reduces the probability to become self-employed by 6 percentage points, which corresponds to 36 percent of the sample share of self-employed people. Caliendo, Fossen and Kritikos (2006) look at how the risk attitude of a respondent reported in 2004 is related to whether the respondent became self employed between 2004 and 2005, and confirm again that a higher willingness to take risks is associated with a higher probability of becoming self-employed. Looking at a cross-section of countries, Shane (1992, 1995) also provides evidence that less risk averse countries are more innovative.

Having evidence that the level of risk aversion is significantly related to the willingness to perform risk taking entrepreneurial activities, the natural questions that arise are whether risk attitudes differ across cultural groups and where attitudes toward risk come from. In an experiment Henrich and McElreath (2002) find that the only variable that can explain difference in risk behavior across a sample of undergraduate students at University of California, Los Angeles is the cultural origin of he students. These results are also confirmed for a sample of Chilean farmers, presented in the same paper.

Dohmen, Falk, Huffman and Sunde's (2006) empirical study with German data, even further supports this observation and gives indication about the origins of risk aversion. With data from 3,595 children and both their parents, the authors show that risk attitudes of parents and children are highly correlated with each other even after controlling for a variety of background characteristics. The results hold for both general risk attitudes as well as attitudes concerning specific risk, as for example financial risks or occupational risks. Generally, this correlation could be explained with two channels, genetic transmission and cultural transmission, where in case of the latter children's attitudes are shaped by social learning from the parents. However, there are two crucial finding that indicate that genetic transmission can at least not be the sole story. First of all, the correlation is stronger between children and mothers, who are usually more involved in a child's upbringing, than the one between fathers and children. Second, first born children and those with fewer siblings turned out to have been more influenced by their parents' risk attitudes; this is line with the idea of the cultural transmission model that parents actively "invest" in their children's cultural traits, and hence will have less influence if they have to split their resources between more children, and that they will have less influence on later born children because they tend to give more attention to the first born while becoming more "cool" in the upbringing of later born children. These results indicate that risk attitudes are determined by intergenerational transmission through socialization and can hence be seen as a cultural trait.

To briefly summarize the empirical findings: The findings indicate that 1) risk tolerant people are more prone to choose risk-taking entrepreneurial activities, 2) the level of risk aversion varies greatly between individuals of different cultural origin and cannot be explained by observable individual characteristics, and that 3) risk aversion seems to be culturally transmitted form parents to children. The idea of this paper is to provide a model that takes care of these empirical observations and combines them into a single model that features individual occupational choice according to the degree of risk aversion and an endogenous evolution of risk aversion driven by cultural transmission of risk attitudes between generations. Before we describe the model, we will in the following briefly relate our work to the two most closely related fields of research that attempted to endogenize cultural preferences, namely evolutionary growth theory and the cultural transmission literature.

2.2 Related Literature

Our research proposes a dynamic relationship between cultural norms and economic conditions. In the model, the evolution of cultural traits is driven by two forces, concerns for existing traditions and economic incentives to imitate successful behavioral patterns, with the latter idea having its origins in evolutionary biology. This framework allows us to study the change in values driven by economic incentives and at the same time to take into account their persistence. Up until now, very few attempts have been made by other authors to examine this reciprocal relationship between cultural norms and economic development; in most cases culture is treated as a fixed exogenous factor. The existing literature on the dynamics of culture norms can be distinguished along two streams, one that analyses evolutionary models in the framework of Unified Growth Theory (Galor and Weil, 1999; Galor, 2005) and one that looks at cultural transmission.

In the former group,Galor and Moav (2002) and Galor and Michalopoulos (2006) study the endogenous change in preferences over time in response to changes in the economic environment. Specifically, Galor and Moav (2002) explore the dynamic interaction between the process of economic development and preference for quality of children. They argue that during early stages of economic development preference for offspring quality was evolutionary advantageous, leading to an increase in the average level of human capital and triggering technological progress that ultimately lead to a take-off from the Malthusian trap.

Galor and Michalopoulos (2006) study the evolution of risk aversion and argue that entrepreneurial spirit evolved non-monotonically on the course of human history. In early stages of development, the risk-tolerant types have an evolutionary advantage, leading to an increase in their representation. In matured stages however, the risk-averse type gained evolutionary advantage, implying a reversal of the representation of risk-tolerant types in the economy. Both papers study an evolutionary model where the representation of specific cultural traits is solely determined by the relative evolutionary advantages of these traits[8] in the sense of a "survival of the fittest". This purely evolutionary selection mechanism, however, implies that in the long-run the population will be homogenous in term of cultural traits, or in other words, that there is no room for cultural diversity, for the most successful trait will always be selected[9]. Galor and Michalopou-

[8] The evolutionary advantegeous trait could be the one that displyas higher than average fertility or the one with higher income or payoffs

[9] I use the term "purely evolutionary argument" or "evolutionary argument" to refer to the assumption that

los note that, to the extent that risk-tolerant individuals undertake higher payoff projects, their evolutionary advantage in early stages would be accentuated and the evolutionary advantage of risk-averse agents in higher stages of economic development would be mitigated. However, they conclude, that in the context of Unified Growth Theory, in higher stages of economic development a higher income capacity has no longer a positive effect on fertility (Galor and Weil (2000); Lagerlöf, 2006), hence the selection of the risk averse type would still be unambiguous.

This conclusion, though, no longer holds if we take into account that individuals have some influence on the development of their cultural type beyond genetic heredity, but through education of children and imitation of successful role models. Examples like the persisting cultural differences between Flemings and Walloons in Belgium even 250 years after the country was founded, or the persistent traditions of cultural minorities like the Amish in the United States clearly show that there is a high degree of cultural diversity between countries as well as within countries and that even economically not very conducive traits can persist. This is contrary to the predictions of the Galor-Moav and Galor-Michalopoulos model. We therefore argue that a non-degenerate steady-state solution as derived in our model is much more reasonable and better matches empirical evidence of cultural diversity.

To counter this drawback of Unified Growth Theory, we draw from the literature on cultural transmission based on Bisin and Verdier (1998, 2000, 2006) which studies the evolution of cultural traits from a purely cultural perspective, where "purely cultural" means that the cultural trait whose dynamics is being investigated, is an attribute that does not give rise to any differences in material payoffs or reproductive success. Bisin and Verdier study the evolution of cultural traits over time, building upon a model of the evolutions of genes originally developed in evolutionary biology and later adapted by Boyd and Richerson (1985) and Cavalli-Sforza and Feldman (1981) for the study of cultural traits. Bisin and Verdier assume that parents are able to influence the cultural trait of their offspring. They do so by actively socializing their child, for example by teaching it certain behavioral norms or by choosing a specific neighborhood or school, which imposes a cost on the parent that is reflecting the intensity of the parental socialization. The higher the socialization effort, the higher is the probability that it will be successful, that is the higher the probability that the child will in fact adopt the cultural trait of the parent. Parents choose this level of socialization optimally. The probability of success of the socialization effort of the parent affects the transition probabilities between two successive generations which determine the evolution of these cultural traits and the steady-state. Due to the fact that parents in this model care for the conservation of their own cultural trait, the extinction of minority traits is prevented and a polymorphic distribution or cultural diversity is preserved even in equilibrium[10].

changes in certain (cultural) traits are solely driven by selection or imitation of the most succesful type. The initiating force behind this evolution can be exogenous, for example an economic shock. This expression should not be confused with the analog expression used in evolutionary biology, namely that of a continuous spontaneous mutation in genes that is not caused by a specific exogenous event.

[10] Hauk and Saez-Marti (2002) for example use the framework of Bisin and Verdier to study the cultural trans-

The existing literature on cultural transmission, however, mostly does not consider that cultural attitudes of people also affect the economic conditions these people face, which contradicts the empirical findings that culture is an important determinant of economic outcomes. Also, the model of Bisin and Verdier is not a general equilibrium macroeconomic model, but mainly a mechanism describing the evolution of cultural traits.

To deal with both types of unsupported empirical implications apparent in the current literature, the model proposed in this paper integrates both, evolutionary forces, which can explain changes in values, and cultural transmission, which explains the persistence of values, into one model of cultural change, generating a dynamic but inertial relationship between cultural traits and the economic environment. We argue that cultural traits will be stable as long as there are no perceived income differences associated with different traits. While the economy slowly evolves, eventually new economic opportunities arise which are taken over only by some types of agents. These endogenously generated differential economic payoffs give rise to cultural change and a simultaneous evolution of cultural values and economic variables until a new equilibrium is reached. Due to the forces of cultural transmission, driven by parents caring for the survival of their traditions and only imperfectly empathizing with the children, this new equilibrium will be non-degenerate, thus explaining the persistence of cultural values. We think that this interaction of evolutionary and cultural transmission forces is much more reasonable and more suitable for explaining cultural variation over time and place.

To our knowledge, only Doepke and Zilibotti (2008) have followed a similar strategy of integrating cultural transmission into a dynamic economic model. Doepke and Zilibotti look at the endogenous choice of the rate of time preference. Similar to our model, parents in their model can invest into shaping the time preferences of their children. Their investment responds to economic incentives: parents, who anticipate that their children will have a steep income profile will instill patients in their children, because this will increase the children's future happiness. Consequently, these more patient children would in the next period in fact prefer to choose an occupation with a steep income profile. When at some point the opportunity to invest into physical capital arises, only the patient agents will take advantage of this opportunity, start accumulating capital and become wealthier. With the focus being on patience, this model explains economic and cultural divergence within a society through the channel of capital accumulation. Our model looks at the role of another preference, risk aversion, and its crucial role for technological progress.

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mission of corruption, assuming that the fraction of corrupt agents is affected by their economic payoffs. They show that, depending on the initial state of the society, the society will either converge to a steady-state with a low level of corruption or to one with a high level.

3 The structure of the model

Suppose an economy with infinite discrete time and three sectors of production as in Romer (1990). In the beginning of each period, the economy's research sector produces new designs for intermediate goods, also called innovations, and sells them to the intermediate-goods-sector that produces intermediate goods based on the existing and new designs. Each distinct intermediate good is produced by exactly one intermediate-good-producer; all intermediate good producers compete on the market for capital and ideas. The economy is hence characterized by monopolistic competition. The intermediate goods become available to the final goods sector in the same period where they are used together with labor and human capital to produce a single homogenous output good.

Decisions regarding consumption, human capital investment and socialization of offsprings are made by overlapping generations of risk-averse agents. For simplicity, population is assumed to be constant. Agents are heterogenous in the level of risk aversion; the composition of the population in terms of risk aversion, that is the distribution of risk aversion within the population, is endogenized. As explained above, risk aversion is treated as a cultural trait that is transmitted between generations. We model a dynamic relationship between the frequency with which a certain cultural trait shows up in the population, or more specifically, the frequency of a certain level of risk aversion, and economic conditions. On the one hand, we show that agents' degree of risk aversion, which is influenced by the socialization effort of cultural parents and exposition to peers during childhood, determines the allocation of labor to the research- and the final-goods-sector. On the other hand, we argue that cultural parents take into account the potential economic well-being of their offsprings when socializing them to a certain cultural trait. The evolution of risk aversion and the economic variables is studied in a three dimensional dynamical system. We show that the society's distribution of cultural traits converges to a non-degenerate polymorphic distribution.

We will begin this section by describing production in the economy and the transition probabilities of cultural traits. In section 3.4 to 3.7 we discuss preferences, the allocation of labor, and the socialization decision of parents that determines the intergenerational transmission of risk aversion and hence the endogenous evolution of risk aversion over time.

3.1 Final goods, intermediate goods and research output

Production in the final-goods-sector occurs according to an increasing-returns-to-scale technology that is subject to endogenous technological progress. Technological change is due to innovations that broaden the set of intermediate goods. The amount of final goods produced at time t is,

$$Y_t = {H_Y}^{\alpha} L_{Yt}^{\beta} \int_{j=1}^{A_t} x_t(j)^{1-\alpha-\beta} dj, \tag{1}$$

where L_{Yt} is the number of workers employed at time t, H_Y their level of human capital and $x_t(j)$ the quantity of intermediate goods of type j used in the production.

Each type of intermediate goods is based on a different design produced in the research sector. Intermediate-good-firms transform one unit of capital into one unit of the intermediate good; therefore, if A_t is the amount of innovations and hence the total number of varieties of intermediate goods available at time t, the aggregate stock of capital is given by $K_t = \int_{j=1}^{A_t} x_t(j)dj = x_t A_t$. The production-function for final goods can hence be written as:

$$Y_t = (A_t H_Y)^{\alpha}(A_t L_{Yt})^{\beta} K_t^{1-\alpha-\beta}. \tag{2}$$

For the production of innovations in the research sector we assume that,

$$\Delta A_t \equiv A_t - A_{t-1} = H_A A_{t-1} \int_{a=1}^{L_{At}} \eta(a)da, \tag{3}$$

where L_{At} is the total number of researchers at time t and H_A their corresponding level of human capital. $\eta(a)$ is the random level of productivity of a researcher with index a with

$$\eta(a) = \begin{cases} \overline{\eta} > 0 & \text{, with probability } z \\ 0 & \text{, with probability } (1-z). \end{cases}$$

This random variable is assumed to be identically and independently distributed across individuals. By the law of large numbers, ΔA_t is then given by

$$\Delta A_t = z\overline{\eta}(H_A L_{At})A_t.$$

Human capital of an individual working in sector ν, with $\nu \in (Y, A)$, is produced according to the standard production function (Mincer, 1958)

$$H_\nu = e^{\psi \tau_\nu T},$$

where τ_ν is the fraction of time spent on schooling during childhood, T is the total amount of time (in years) that could be potentially allocated to schooling and corresponds to the length of one period of life; ψ is the return to each year of schooling. Due to competition on the labor market, wages in every period equal the marginal product of labor, hence, an individual i will be facing the wage (in efficiency units of current technology A_t),

$$w_t^i = \begin{cases} w_{t,Y} \equiv \beta {H_Y}^{\alpha} L_Y^{\beta-1} k_t^{1-\alpha-\beta} & \text{, if } i \text{ is a worker} \\ w_{t,A} \equiv \eta(i) H_A P_{At} & \text{, if } i \text{ is a researcher} \end{cases},$$

where P_{At} is the market price for innovations or new designs, which will be determined in the next section, and $k_t \equiv \frac{K_t}{A_t}$.

3.2 Prices for intermediate goods and new designs

Aggregate demand in the final-goods-sector for intermediate goods of each distinct intermediate-good firm is derived by solving the maximization problem

$$\max_{x_t(j)} \int_{j=1}^{A} \left[{H_Y}^{\alpha} L_{Yt}^{\beta} x_t(j)^{1-\alpha-\beta} - p_t(j) x_t(j) \right] dj, \tag{4}$$

that is by maximizing profits in the final goods sector with $p_t(j)$ being the price for one unit of intermediate goods of type j at time t.

The first-order-condition implies,

$$p_t(j) = (1-\alpha-\beta) {H_Y}^{\alpha} {L_{Yt}}^{\beta} x_t(j)^{-\alpha-\beta} \equiv p(x_t(j)). \tag{5}$$

Facing the inverse demand-function of the final-goods-producers, each intermediate-good-firm chooses $x_t(j)$ such that it maximizes its profits:

$$x_t(j) = \arg\max p(x_t(j)) x_t(j) - r_t x_t(j) = (1-\alpha-\beta) {H_Y}^{\alpha} {L_{Yt}}^{\beta} x_t(j)^{1-\alpha-\beta} - r_t x_t(j), \tag{6}$$

where r_t is the rental-rate of capital[11].

Solving for the first-order-condition gives,

$$p_t(j) = p_t = \frac{r_t}{1-\alpha-\beta} \tag{7}$$

Since the price p_t is the same for all producers j, the solution is symmetric with every intermediate good producer producing the same amount x_t. The profit of each producer is therefore given by

$$\Pi_t = p_t x_t - p_t(1-\alpha-\beta) x_t = p_t k_t (\alpha+\beta). \tag{8}$$

Innovations, i.e. new designs for intermediate goods, are produced in the beginning of each period according to (3). Once an innovation is discovered, the inventor receives a patent and sells it to an intermediate-good firm. Due to competition between the intermediate-good-firms on the market for innovations, the price for each innovation, P_{At}, will be determined by the no-arbitrage condition:

$$\frac{P_{At+1} - P_{At} + \Pi_t}{P_{At}} = r_t. \tag{9}$$

[11] Remeber here that the intermediate goods sector uses capital as the only input.

Together with (7) and (8) P_{At+1} can be written as:

$$P_{At+1} = P_{At}(1 + r_t) - p_t k_t(\alpha + \beta) \tag{10}$$

where,

$$r_t = (1 - \alpha - \beta)^2 (A_t H_Y)^{\alpha} (A_t L_{Yt})^{\beta} K_t^{-\alpha-\beta}, \tag{11}$$

follows from the optimal condition (7).

3.3 Transmission of cultural traits I: Transition probabilities

The evolution of the distribution of cultural types is described by a model of cultural transmission as presented in Bisin and Verdier (2000, 2001). We assume that there are two possible types of cultural traits in this economy, type h and type l, who differ from each other in their attitudes toward risk; h is the less risk averse type and l the more risk averse type. The fraction of individuals with trait h at time t is denoted q_t.

Each agent has exactly one child. As discussed on Bisin and Verdier (1998), children are assumed to be born without defined risk attitudes. They are first exposed to their parents' influence who can directly transmit their cultural type with probability d_t^i with $i = \{h, l\}$. If a child is not directly socialized by his parent of type i, which occurs with probability $(1 - d_t^i)$, he will pick a role model at random, i.e., he will pick trait h with probability q_t and trait l with probability $(1-q_t)$[12]. The speed of cultural change is hence determined by the following transition probabilities where P^{im} indicates the probability that a type i parent has a child of type m :

$$\begin{aligned} P_t^{hh} &= d_t^h + (1 - d_t^h)q_t \\ P_t^{hl} &= (1 - d_t^h)(1 - q_t) \\ P_t^{lh} &= (1 - d_t^l)q_t \\ P_t^{ll} &= d_t^l + (1 - d_t^l)(1 - q_t). \end{aligned} \tag{12}$$

[12] Our model thus exhibits unbiased oblique transmission, as discussed in Boyd and Richerson (1985) and Saez-Marti and Sjögren (2008). In the literature on cultural transmission the term 'oblique transmission' is used to describe socialization of an agent by exposure to the society at a large. On the other hand, the process of direct cultural transmission from parent to offspring is called 'vertical transmission'. Current literature on cultural transmission usually assumes unbiased oblique transmission, that is, it assumes that cultural traits are picked at random, although, positive or negative biases can in general also be studied as shown in Boyd and Richardson (1985). A positive bias implies that the probability that a naive offspring is picking a certain trait in the population is greater than if he had selected the model at random, thus the probability is higher than the current representation of this trait in the population. In analogy, oblique transmission is negatively biased if the probability of selecting the trait is smaller than if it had been selected randomly.

The dynamics of the fraction of the cultural type h is then given by:

$$\begin{aligned} q_{t+1} &= P_t^{hh} q_t + P_t^{lh}(1-q_t) \\ &= q_t(1-q_t)(d_t^h - d_t^l) \end{aligned} \tag{13}$$

In the following section we will discuss how parents choose the level of direct socialization d_t^i.

3.4 Preferences and constraints

Agents in this economy care about their own lifetime consumption as well as about the future economic wellbeing of their offsprings[13]. Agents live for three periods. In the first period of life an individual consumes leisure l and builds up human capital by spending the fraction τ_ν with $v \in (Y, A)$ of his time on schooling. In the second period of life the agents is employed either as workers (Y) or a researchers (A) and raises one child. In the third period he consumes his entire income along with accrued interest and derives utility from having a child. In both, period 1 and 2, an individual is endowed with one unit of time that is supplied inelastically.

Consumption in period one and three of an individual i is given by

$$l_{1t-1,\nu} = \begin{cases} 1-\tau_Y & \text{, if worker} \\ 1-\tau_A & \text{, if entrepreneur} \end{cases} \tag{14}$$

$$c^i_{3t+1,\nu} = \begin{cases} w_{t,Y}(1+r_{t+1}) & \text{, if worker} \\ \eta(i) H_A P_{At}(1+r_{t+1}) & \text{, if entrepreneur} \end{cases} \tag{15}$$

where the wage in the final-goods sector is given by $w_{t,Y} \equiv \beta {H_Y}^\alpha L_Y^{\beta-1} k_t^{1-\alpha-\beta}$ (see section 3.1).

Decisions about human capital and socialization of the child are made at two different points in time. When the agent is young, he chooses the fraction of time he goes to school, facing his (uncertain) consumption when old. When the agent enters the second period of life, he gives birth to a child and decides how to socialize him or her, facing the (uncertain) wage of his child in the future. By chronologically separating these two decisions and assuming that when choosing their own human capital agents take the future wages of their children as given, the maximization problem is reduced to two separate two-period problems which greatly simplifies the analysis. We will first describe decision over human capital and job choice of the agent when he is young and afterwards his socialization choice as a parent.

[13] Caring for children's economic wellbeing can be motivated by parents desire for old age security in the form of financial support from their children (for further discussions of this hypothesis see for example Neher (1971) and Srinivasan (1988)). Alternative formulations according to which individuals generate utility from the whole lifetime utility of their offsprings would require parents to predict their childrens' socialization choices and would greatly complicate the model. We presume that this would not qualitatively change the predictions of the model.

3.5 Human capital choice

An agent i working in sector ν chooses the amount of time devoted to schooling, τ_ν such that he maximizes utility $U^{t,i}$ from his lifetime consumption.

Consumption in period three is uncertain for those agents working as entrepreneurs, coming from the assumption that research activity involves the risk of failure. Utility from lifetime consumption of an agent with cultural trait i working in sector ν can be represented by an aggregator function $G(\cdot)$ as discussed in Epstein and Zin (1989, 1991) who build upon the non-expected-utility axioms of Kreps and Porteus (1978):

$$U_\nu^{t-1,i}(l_{t-1,\nu}, c^i_{3t+1,\nu}) = G(l^i_{t-1,\nu}, \mu^i[\widetilde{U}_{t+1,\nu}]). \tag{16}$$

where $\widetilde{U}_{t+1}$ is the random utility accruing in period three of an agent born at time $t-1$ and $\mu^i[\cdot]$ is its certainty equivalent.

This form of utility implies intertemporal consistency and the stationarity of preferences. Moreover, it allows for a separation of risk aversion from intertemporal substitution that is not possible in the expected utility framework. As explained in Epstein and Zin (1989), intertemporal substitution is expressed in G, while the certainty equivalent function $\mu^i[\cdot]$ reflects the degree of risk aversion of an individual with trait i. As common in OLG-models with capital, we assume an elasticity of substitution of 1 which leads to a log-utility-representation of G:

$$G(l_{t-1,\nu}, \mu^i[\widetilde{U}_{t+1}]) = \gamma \ln l_{t-1,\nu} + (1-\gamma) \ln \mu^i[\widetilde{U}_{t+1,\nu}]) \tag{17}$$

with γ being the discount factor. As proposed in Epstein and Zin (1991), we consider a constant relative risk-aversion expected utility specification for the certainty equivalent $\mu[\cdot]$, with $\delta^i \in (0,1]$ being interpreted as the risk aversion parameter and the degree of risk aversion increasing as δ^i falls:

$$\mu^i[\widetilde{U}_{t+1,\nu}] = \left[E\widetilde{U}^{\delta^i}_{t+1,\nu}\right]^{1/\delta^i}. \tag{18}$$

E is the expectations operator. Assuming that $U(c^i_{3t+1,\nu}) = c^i_{3t+1,\nu}$, utility from own lifetime consumption is given by:

$$U_\nu^{t-1,i} = \begin{cases} \gamma \ln l_{t-1,Y} + (1-\gamma)\ln[w_{t,Y}(1+r_{t+1})] & \text{, if worker} \\ \gamma \ln l_{t-1,A} + (1-\gamma)\ln[z^{1/\delta^i}\overline{\eta} H_A P_{At}(1+r_{t+1})] & \text{, if entrepreneur} \end{cases} \tag{19}$$

Maximizing this utility function with respect to τ_ν leads to:

$$\begin{aligned} \tau_Y &= 1 - \frac{\gamma}{(1-\gamma)\alpha\psi T} \\ \tau_A &= 1 - \frac{\gamma}{(1-\gamma)\psi T}. \end{aligned} \tag{20}$$

Since $\alpha < 1$, we see that entrepreneurs acquire more human capital.

3.6 Allocation of labor between final-goods production and research

The allocation of labor between the research- and the final-goods sector is endogenously determined, such that agents are indifferent between working in the research-sector or in the final-goods-sector. In Romer's original model the allocation of labor is determined such that wages are equalized across the two sectors. Since in this framework agents are risk-averse and differ in their level of risk-aversion, an agent i is willing to become an entrepreneur if his utility from lifetime consumption as a researcher is higher than or equal to that as a worker, given his degree of risk-aversion δ^i, $i \in (h.l)$, that is if:

$$U_A^{t,i} \geq U_Y^{t,i}. \tag{21}$$

We assume that agents of type l are sufficiently risk averse such that they would never become researchers. It can easily be seen from (19) that for $\delta^l \to 0$ the condition in (21) would never be met. Hence, given that we just assume two risk aversion types, only individuals of type h would potentially become researchers[14][15].

Since we are interested in the role of risk aversion as a cultural trait and want the same cultural trait to be associated with the same payoff, we only consider the case where either all individuals of type h become researchers at time t or none[16]. Given the current fraction of h-types, the condition from the point of view of an individual then is to become a researcher if and only if

$$\begin{aligned} & \gamma \ln(1-\tau_A) + (1-\gamma)\ln[z^{1/\delta^h}\overline{\eta} H_A P_{At}(1+r_{t+1})] \\ \geq\ & \gamma \ln(1-\tau_Y) + (1-\gamma)\ln[\beta H_Y{}^{\alpha}((1-q_t)L)^{\beta-1} k_t^{1-\alpha-\beta}(1+r_{t+1})]. \end{aligned} \tag{22}$$

[14] The essential idea of research activity is that people put effort into some projects not knowing yet whether this project is going or be succesful or not. This means that they will observe the random schock after they have already worked in their job and hence cannot condition their job choice on the nature of the schock. For example, an economist is working on an empirical project involving the collection and assembling of huge amounts of data. By the time he finally gets to run his regressions in STATA and can figure out whether his project was succeful or not (meaning whether he gets nice and significant results or not), he has already spent a lot of time and effort on the data compilation. Having this example in mind, we can easily imagine that only sufficiently risk tolerant people would like to become economists.

[15] In this model, people cannot insure themselves against the potential failure of their research activity. This is because they work for just one period and when young they have no wealth and hence cannot access capital markets. Also, individual research output is not always perfectly veryfiable and hence not perfectly insurable. We will therefore abstract from the possibility of insurance in this model. We conjecture, though, that the existence of insurance schemes would mitigate the importance of risk aversion and would make individuals with different risk attitudes behave more similarily.

[16] This could be motivated by agents not being able to coordinate about who should switch sectors and who should not, implying that each agent of type h would switch to the research sector if it is individually rational to do so.

Lemma 1 *There exists a cut-off-value $\widehat{\delta}(q_t, k_t)$ with,*

$$\widehat{\delta}(q_t, k_t) = \frac{-\ln z}{\frac{\gamma}{1-\gamma}\ln(\frac{1-\tau_A}{1-\tau_Y}) + \ln(\frac{\overline{\eta} H_A P_{At}}{\beta {H_Y}^{\alpha}((1-q_t)L)^{\beta-1}k_t^{1-\alpha-\beta}})}, \tag{23}$$

such that an agent with trait h will only become a researcher if and only if $\delta^h \geq \widehat{\delta}(q_t, k_t)$, with $\widehat{\delta}(q_t, k_t)$ non-negative, $\frac{\partial \widehat{\delta}(q_t,k_t)}{\partial q_t} > 0$, $\frac{\partial \widehat{\delta}(q_t,k_t)}{\partial k_t} < 0$ and $\frac{\partial^2 \widehat{\delta}(q_t,k_t)}{\partial k_t^2} > 0$ (see Appendix C).

Proof. The left-hand side of (21) is strictly increasing in δ^{ih} for $z < 1$ while the right-hand-side is independent of δ^h. Thus there exists a $\widehat{\delta}(q_t, k_t)$ such that (21) is satisfied with equality. ■

Lemma 2 *Depending on the values of the parameters determining the steady-state, there is a threshold time $\widehat{t}$ such that agents of type h become entrepreneurs for all $t \geq \widehat{t}$.*

Proof. As long as no agent works as a researcher we have $\Delta A_t = 0$ and hence $A_t = A_0 = 1$. Because of $\frac{\partial \widehat{\delta}}{\partial k_t} < 0$, as k_t is growing over time due to capital accumulation, there will be a $\widehat{t}$ such that $\delta^h = \widehat{\delta}(q_t, k_{\widehat{t}})$ at $t = \widehat{t}$ and $\delta^h > \widehat{\delta}(q_t, k_{\widehat{t}})$ for all $t > \widehat{t}$. ■

The intuition behind this result is that a higher stock of capital increases the relative wage of researchers, making, as capital accumulates, even less risk tolerant agents willing to choose the risky occupation. Lemma (2) implies the existence of a poverty trap: If capital reaches its steady-state level given by $K^* = \left[s(A_0 h^Y)^{1-\alpha} L\right]^{1/(1-\alpha)}$ before the capital stock is large enough to induce a change in the allocation of labor, the economy will forever remain in an equilibrium without entrepreneurial activity and without technological progress. The level of $K_{\widehat{t}}$ necessary to induce an endogenous shift of labor to the R&D sectors can hence be interpreted as a poverty threshold. Capital transfers from abroad can assist an economy to pass the poverty threshold and escape from the poverty trap.

Corollary 3 *Up to time $\widehat{t}$ there is no active research sector and we have $A_t = A_0$. For $t \geq \widehat{t}$ all agents of type h become researchers while l-types work in the final-goods-sector. We thus have that the fraction of individuals of generation t working as researchers is equal to the fraction of type-h agents in generation t.*

Corollary 4 *The higher is the starting value K_0, the lower is the value of $\overline{\eta}$ necessary for given parameters such that $\delta^h \geq \widehat{\delta}(k_t, q_t)$. This implies that countries starting with higher values of capital need to have a less productive research sector in order to be willing to allocate resources to the research sector.*

Proof. This result follows from the fact that $\widehat{\delta}(k_t, q_t)$ is strictly decreasing in k_t. ■

Remembering that the fraction of agents of type h in period t is denoted as q_t and the fraction of l-type agents as $(1 - q_t)$, equation (3) for $t \geq \widehat{t}$ then implies:

$$A_t = z\overline{\eta}(H_A q_t L_t)A_{t-1} + A_{t-1}.$$

The model presented in this section thus shows that the path of economic development and the transition to a modern economy with an active R&D sector depends on cultural traits in the form of variations in the degree of risk aversion. The less risk averse the least risk averse type in the population is, the earlier this society will start allocating resources to R&D. And at the same time, the more people decide to be researchers, the higher is the rate of technological progress. The following section will discuss the endogenous evolution of risk aversion. Section 4 analyzes the joint evolution of risk aversion and the economic variables.

3.7 Transmission of cultural traits II: Optimal choice of direct socialization

When entering the second period of life, individuals become parents and have to socialize their children, i.e. shape their risk preferences. Parents are assumed to care about their children's future economic wellbeing as well as are concerned about preserving their own cultural trait. However, because they are boundedly rational and cannot forecast future wages of their children, they expect their children to have the same income as their own generation, taking children's human capital as given[17]:

$$Ew_{t+1,\nu}^{child} = \begin{cases} w_{t,Y} & \text{, if the child is a worker} \\ w_{t,A}^{m} & \text{, if the child is an entrepreneur,} \end{cases}$$

with $w_{t,A}^m \equiv \eta(m) H_A P_{At}$ being the wage of an individual m in the research sector. Utility of a parent with risk attitudes of type i over period two and three, $V^{t,i}$, is represented by the analog of the Epstein-Zin aggregator function discussed in section 3.4:

$$V^{t,i} = \begin{cases} -\phi \ln C(d_t^i) + (1-\phi)\left[E\widetilde{V}_{t+1,Y}^{\delta^i}\right]^{1/\delta^i} & \text{, if child is worker} \\ -\phi \ln C(d_t^i) + (1-\phi)\left[E\widetilde{V}_{t+1,A}^{\delta^i}\right]^{1/\delta^i} & \text{, if child is researcher} \end{cases} \tag{24}$$

[17] Assuming that parents form rational expectations when choosing their level of socialization d_t^i and can correctly forecast next period's wages would not qualitatively change the results: the steady state would be unaffected, only the speed of convergence would rise. However, because we do not have any prior on the speed of convergence, we prefer to make the simplifying assumption of adaptive expectations to keep the model tractable. Additionally, forecasting wages correctly in this model is such a complicated process, that we do not consider it reasonable to assume that parents can actually perform this task. Apart from forecasting next period's capital stock, it requires parents to forecast next period' fraction of h-types, q_{t+1}. In addition to the fact that q_{t+1} depends on parents' own socialization choice (d_t^i) that on the other hand is a function of q_{t+1}, those parental generations who have not yet opened the research sector have to determine whether in fact the next generation would enter the research sector or not. This means that they would have to determine their socialization effort and forecast q_{t+1} first assuming that their children would be working in both sectors. Then, knowing q_{t+1}, they would have to determine whether in fact h-type children would we willing to work in the research sector at the given level of q_{t+1}. If this is not the case, parents have to revise their choice and choose d_t^i and forecast q_{t+1}, assuming that the entire next generation will still be working just in the final goods sector.

where $C(d_t^i)$ is the cost of socializing the child, and $\widetilde{V}_{t+1,\nu}$ is the random utility an agent derives from having a child working in sector ν. We assume:

$$V_{t+1,\nu} = \begin{cases} w_{t,Y}\overline{V} & \text{, if child is worker and same type as parent} \\ w_{t,Y} & \text{, if child is worker and different type than parent} \\ w_{t,A}^m & \text{, if child is researcher and different type than parent} \\ w_{t,A}^m\overline{V} & \text{, if child is researcher and same type as parent} \end{cases} \tag{25}$$

where $\overline{V} > 1$ is the extra utility a parent derives from having a child of the same cultural type, and can be interpreted as the parent caring for the survival or preservation of his type[18]. Parents know that a child of type h would become researcher, while a type l would be a worker, given that time $\widehat{t}$ has been reached, and can hence predict wages of the children given their type.

Plugging in the definition for $V_{t+1,\nu}$ and rewriting leads to:

$$V^{t,i} = \begin{cases} -\phi \ln C(d_t^h) + (1-\phi)\ln z^{1/\delta^h}\overline{\eta}H_A P_{At} + (1-\phi)V \equiv V^{t,hh} & \text{, if parent and child are type } h \\ -\phi \ln C(d_t^h) + (1-\phi)\ln w_{t,Y} \equiv V^{t,hl} & \text{, if parent} = h\text{, child} = l \\ -\phi \ln C(d_t^l) + (1-\phi)\ln z^{1/\delta^l}\overline{\eta}H_A P_{At} \equiv V^{t,lh} & \text{, if parent} = l\text{, child} = h \\ -\phi \ln C(d_t^l) + (1-\phi)\ln w_{t,Y} + (1-\phi)V \equiv V^{t,ll} & \text{, if parent} = \text{child} = l \end{cases} \tag{26}$$

with $V \equiv \ln \overline{V}$. Because a parent does not know in advance which cultural trait his child is going to have but only the transition probabilities P^{hh}, P^{hl}, P^{hl} and P^{ll} discussed in section (3.3), an h-type (l-type) parent will choose d_t^h (d_t^l) such that she maximizes expected utility given by:

$$\begin{matrix} P^{hh}V^{t,hh} + P^{hl}V^{t,hl} & \text{, if parent} = h \\ P^{lh}V^{t,lh} + P^{ll}V^{t,ll} & \text{, if parent} = l \end{matrix} \tag{27}$$

Assume that the costs of direct socialization $C(d_t^i)$ are given by $C(d_t^i) = e^{0.5(d_t^i)^2}$. For simplicity we set $\phi = 0.5$. Applying the first-order-conditions and solving for d_t^h and d_t^l respectively gives:

$$\begin{aligned} d_t^{h*} &= (1-q_t)(V + z^{1/\delta^h}\overline{\eta}H_A P_{At} - \beta {H_Y}^{\alpha}((1-q_t)L)^{\beta-1}k_t^{1-\alpha-\beta}) \\ d_t^{l*} &= q_t(\beta {H_Y}^{\alpha}(V + (1-q_t)L)^{\beta-1}k_t^{1-\alpha-\beta} - z^{1/\delta^l}\overline{\eta}H_A P_{At}). \end{aligned} \tag{28}$$

As we see from these equations, parents will spend the more resources on directly influencing their children's trait, the smaller is the current fraction of their type (minority effect) and the economically more successful they perceive their own cultural type compared to the other type.

Substituting the optimal values d_t^{h*} and d_t^{l*} for d_t^h and d_t^l in equation (13) leads to the following

[18] The assumption of $\overline{V} > 1$ in case that parent and child have the same cultural trait ensures dynamics of q_t even in the absence of wage differentials between types or in the case where capital is zero. It also ensures that the qq-locus, the geometric plane such that q_t is in a steadt-state, which we will be describing in the next section, is defined for $k_t = 0$ and can hence be anaylzed graphically.

representation of the law of motion for cultural types:

$$\begin{aligned} q_{t+1} &\equiv q_t(1-q_t)\{V - 2q_tV + \overline{\eta}H_AP_{At}[(1-q_t)z^{1/\delta^h} + q_tz^{1/\delta^l}] - \beta {H_Y}^{\alpha}((1-q_t)L)^{\beta-1}k_t^{1-\alpha-\beta}\} + q_t \\ &\equiv \omega(q_t, k_t, P_{At}) \end{aligned} \tag{29}$$

4 The process of economic development

4.1 Evolution of capital

In the beginning of each period, the total initial capital stock K_t is owned by the old generation. Because the old generation leaves no bequests and wants to die with no assets, all their capital stock plus any increases in capital must be purchased by the young generation with their savings, implying that savings of the young, i.e. those agents that are currently in their second period of life, equal the next periods capital stock. Hence for $t < \widehat{t}$, when both types of agents work in the final goods sector and choose a level of human capital equal to H_Y, the evolution of the capital stock is given by

$$K_{t+1} = \beta(A_tH_Y)^{\alpha}(A_tL)^{\beta}K_t^{1-\alpha-\beta}. \tag{30}$$

Since for $t < \widehat{t}$ technology is constant, the state variable will be $k_{t+1} \equiv \frac{K_{t+1}}{A_{t+1}} = \frac{K_{t+1}}{A_0}$. (30) thus implies,

$$k_{t+1} = \beta(H_Y)^{\alpha}L^{\beta}k_t^{1-\alpha-\beta}.$$

For $t \geq \widehat{t}$ the capital stock at time $t+1$ will be:

$$K_{t+1} = q_tLz\overline{\eta}H_AA_tP_{At} + \beta(A_tH_Y)^{\alpha}A_t^{\beta}((1-q_t)L)^{\beta}K_t^{1-\alpha-\beta},$$

leading to the state variable,

$$\begin{aligned} k_{t+1} &\equiv \frac{K_{t+1}}{A_{t+1}} \\ &= \frac{q_tLz\overline{\eta}H_AP_{At} + \beta {H_Y}^{\alpha}((1-q_t)L)^{\beta}k_t^{1-\alpha-\beta}}{1 + z\overline{\eta}H_Aq_{t+1}L} \\ &\equiv \xi(q_t, k_t, P_{At}). \end{aligned} \tag{31}$$

4.2 The evolution of cultural types

The evolution of the composition of cultural types was described in sections 3.3 and 3.7. As we remember from these sections, the change in the fraction of type h agents within the population is given by

$$q_{t+1} = \omega(q_t, k_t, P_{At}).$$

4.3 Evolution of the price for innovations

The evolution of the price for the designs produced in the research sector, or we can call it the patent price, is according to the non-arbitrage equation (9) governed by

$$\begin{aligned} P_{At+1} &= P_{At}(1+r_t) - p_t k_t(\alpha+\beta) \\ &= P_{At} + (1-\alpha-\beta) H_Y{}^{\alpha}\left((1-q_t)L\right)^{\beta} k_t^{-\alpha-\beta}[P_{At}(1-\alpha-\beta) - k_t(\alpha+\beta)] \\ &\equiv \theta(q_t, k_t, P_{At}) \end{aligned} \tag{32}$$

5 The dynamical system

The development of the economy is characterized by the evolution of capital per unit of technology, k_t, the fraction of agents of type h, q_t, and the patent price P_{At}.

As we discussed in section 4.1, in case that the capital stock k_t reaches an equilibrium before agents of type h are willing to move to the research sector, no separation of types into different occupations will occur and both types will work in the final-goods-sector, facing the same wages. In this case the dynamical system is just given by:

$$\begin{aligned} q_{t+1} &\equiv q_t(1-q_t)\{V - 2q_t V\} + q_t \\ k_{t+1} &\equiv \beta(H_Y)^{\alpha} L^{\beta} k_t^{1-\alpha-\beta} \end{aligned} \tag{33}$$

with three equilibria

$$\{q_t, k_t\} = \left\{ \begin{array}{c} (0.5, \beta(H_Y)^{\alpha} L^{\beta} k_t^{-\alpha-\beta}) \\ (0, \beta(H_Y)^{\alpha} L^{\beta} k_t^{-\alpha-\beta}) \\ (1, \beta(H_Y)^{\alpha} L^{\beta} k_t^{-\alpha-\beta}) \end{array} \right\}$$

If the economy starts with no capital, its equilibrium will be given by $\{q_t, k_t\} = \{(0.5, 0), (0, 0), (1, 0)\}$.

As long as at some point in time a separation of the two types into both occupations occurs, the evolution of the economy is fully determined by the evolution of a three-dimensional non-linear discrete dynamical system that is governed by the sequence $\{q_t, k_t, P_{At}\}_0^{\infty}$ such that,

$$\begin{aligned} q_{t+1} &= \omega(q_t, k_t, P_{At}) \\ k_{t+1} &= \xi(q_t, k_t, P_{At}) \\ P_{At+1} &= \theta(q_t, k_t, P_{At}). \end{aligned} \tag{34}$$

5.1 The steady-state

Once a separation of labor into both sectors has occurred, steady-state equilibria are triplets $\{\overline{q}, \overline{k}, \overline{P}\}$ such that,

$$\begin{aligned} \overline{q} &= \omega(\overline{q}, \overline{k}, \overline{P}_A) \\ \overline{k} &= \xi(\overline{q}, \overline{k}, \overline{P}_A) \\ \overline{P}_A &= \theta(\overline{q}, \overline{k}, \overline{P}_A) \end{aligned} \tag{35}$$

Because the underlying law of motions of this system are rather complex, we prefer to not analyze the system graphically, as this would only confuse the reader and not have any value added. Hence we will just derive the properties of the system from simulations. As we show in the simulation in Appendix (C), the system has one unique equilibrium given by

$$\{\overline{q}, \overline{k}, \overline{P}_A\} = \left\{\overline{q}, \overline{k}, \overline{P}_A = \frac{\alpha+\beta}{1-\alpha-\beta}\overline{k}\right\}.$$

This equilibrium is a saddle with convergence occurring for any q_0 and k_0 and P_{At} only converging if it moves along the stable arm.

This feature of P_{At} can also be immediately seen from the law of motion of P_{At}, $P_{At+1} = \theta(q_t, k_t, P_{At})$. Setting $(P_{At+1} - P_{At}) = 0$ we derive the equilibrium condition for P_{At} given by

$$P^*_{At} = \frac{k_t(\alpha+\beta)}{(1-\alpha-\beta)}. \tag{36}$$

Taking derivatives of the difference equation $P_{At+1} - P_{At}$ with respect to k_t, we find

$$\frac{\partial}{\partial k_t}(P_{At+1} - P_{At}) < 0, \tag{37}$$

implying that the patent price P_{At} will either grow to infinity or fall to zero for any

$$P_{At} \neq \frac{k_t(\alpha+\beta)}{(1-\alpha-\beta)}.$$

5.2 Comparative Statics

The following lemmas state how the equilibrium changes if key parameters change.

Lemma 5 *An increase in the wage of researchers (h-types), for example on the form of increases in their human capital H_A, increases the equilibrium value of q_t and raises the equilibrium growth rate of income, consumption, and capital, given by $\overline{g} \equiv z\overline{\eta}H_A\overline{q}L$. An increase in worker's relative wage has the opposite effect. It reduces the equilibrium share of researchers and the growth rate.*

Proof. See Appendix 1.3.1. ■

The intuition behind this result is the following: An increase in the relative wage of researchers, for example in the form of an increase in their human capital, gives people incentives to install more risk tolerant values on their children. The rise in q_t leads to a higher growth rate since more innovations are produced in equilibrium. A relative rise in wages of l-types who are workers makes the option of being an entrepreneur and taking risks less attractive. Hence incentives to transmit trait h are reduced and the growth rate falls. This result holds also for any parameter change that would change the relative wages of researchers or workers.

Lemma 6 *A rise in the risk aversion parameters δ^h or δ^l increases the equilibrium level $\overline{q}$ and hence raises the growth rate.*

Proof. See Appendix A.3.2. ■

As we can see from the law of motion of q_t (equation (29)), the growth in q_t is a positive function of the degree of risk tolerance, δ, of both types. This is because with lower risk aversion, individuals perceive the risky but potentially high payoffs in the research sector as more attractive and hence have incentives to install more risk tolerant values in their offsprings. This result implies a positive relationship between risk tolerance and growth. This result is roughly consistent with empirical findings by Shaw (1996) who finds a negative relationship between individual risk aversion and personal income growth.

Lemma 7 *The higher the initial capital stock k_0, the earlier the economy will start allocating resources to the research sector and hence the earlier it will take of to the modern sustained growth regime.*

Proof. This result follows from the fact that the threshold function $\widehat{\delta}(q_t, k_t)$ is decreasing in k_t. ■

Lemma 8 *The more risk tolerant the least risk averse type (type h) is, the earlier the economy will start allocating resources to the research sector.*

Proof. This result follows again from the fact that the $\partial\widehat{\delta}(q_t, k_t)/\partial k_t < 0$. ■

Corollary 9 *Lemmata (5) and (6) imply, holding everything else constant, that a country that has more capital and/or is less risk averse will be richer than a country that has less capital and/or is more risk averse even in the very long run and even if eventually both countries converge to the same growth rate. This is because an earlier take-off to sustained growth is associated with persistent per capita income advantages.*

6 Case Study: Risk Aversion and Private Sector Activity in China

The model proposed suggests that if economic incentives of choosing a risky occupation rise, we should observe an increase in the fraction of people choosing this occupation, followed by an increase in the representation of risk tolerant agents that occurs after learning about the benefits of being more risk tolerant has taken place. The economic reform process in China that affected different provinces at different points in time is an interesting set up to test this prediction of the model. We will be looking at whether and how the economic liberalization of certain regions changed the employment structure within these regions relative to other regions and whether there is a connection between employment structure and risk attitudes of the population.

In the past 40 years, China has been going through a major economic reform process, including rural reforms, industrial reforms, reforms of state-owned enterprises, liberalization of prices and foreign trade, and the gradual establishment of Special Economic Zones that were opened to foreign investors[19]. The especially interesting point in this reform process is that the Chinese government "experimented" with market economy by first only liberalizing and opening up some few regions; after the first success became visible, the new policies were gradually extended to other regions. The first four Special Economic Zones, opened in 1979, are located in Guangdong and Fujian province and were chosen because they were economically and politically relatively unimportant, such that in case the experiment failed, negative impacts on the rest of the economy could be minimized (Zhang, 2000); Fujian province was in fact one of the least developed areas of the country before the reform. After 1984 the government gradually opened all coastal provinces[20], while the gradual opening of inland cities started after 1992.

Before the reforms, all enterprises were either state-owned or collective-owned. Since privatization of large state enterprises by selling out to private investors was practically still ruled out in the early 1990s and transformation of state-owned enterprises to a shareholding system turned out to be very difficult due to undefined property rights and existing social welfare liabilities of the companies (Perkins, 1994), the opening to foreign investors and the setting up of foreign funded enterprises brought with it a major increase in private sector employment opportunities. While employment in the state-sector implies a secure job with lifelong tenure and access to extensive social welfare services such as housing, pensions and health services (Perkins, 1994; Zhang, 2000), private sector employment can be considered as much more risky, with the possibility of dismissal, wages frequently depending on the firm's profits and the additional burden of loosing other welfare services in case of a dismissal.

The fact that the increase in risky private sector employment opportunities was driven by

[19] See Perkins (1994) for a nice overview of the Chines economic reforms.

[20] For example, the Pudong area of Shanghai, which had already been a politically important and prosperous city in the 1920s, only opened in 1990.

a sudden event, the Special Economic Zone policy of the Chinese government, reached different regions at different points in time and, most importantly, economically unimportant and poor regions earlier, gives us the unique opportunity to compare the employment structure of those regions that became special economic zones early with those that opened up very late or are not yet open, and compare their attitudes toward risk, or more precisely, their attitudes toward occupational risks. These occupational risk attitudes are proxied by survey questions from the World Values Survey (Inglehart, Basanez and Moreno, 2001). We expect people from Guangdong and Fujian to be less risk averse nowadays than people from other Chinese provinces. This is because people from Guangdong and Fujian started making experiences with risky but high paying private sector jobs[21] much earlier than other provinces and hence had more time to learn that being more risk tolerant might actually pay off and to transmit more risk tolerant attitudes to subsequent generations.

In order to be able to interpret potential differences in risk aversion across provinces as coming from an endogenous change in risk aversion via social learning, we need to rule out two possible alternative explanations: First of all, that this result in not just coming from the fact that people in Guangdong and Fujian have always been different from those in other provinces; and second, that this result is not driven by self-selection, with more risk-tolerant people from various regions of China migrating to Guangdong and Fujian to get a job in the private sector.

Concerning the first point, is has long been emphasized by many historians (e.g. Elvin, 1973) that the Chinese society has been remarkably stable and has remained culturally homogenous for many thousand years; controlling ideology through ideological campaigns and propaganda during the Mao era - even it was meant to destroy traditional Chinese cultural values - further homogenized cultural attitudes across the country. In addition, we will be mainly comparing provinces that are all located at the coast with similar geographical conditions and had similar economic conditions in the early 1980s.

Coastal people in China are generally seen as culturally similar and probably slightly different from inland people. From Table 1a we can see that gross output value of industry and agriculture (which we take as a proxy for income) per employed person in 1982 as well as GDP per worker in 2000 - ignoring Shanghai and Beijing that are truly exceptional cases - are very similar across the coastal provinces of China, and that their standard deviations across the coastal provinces are lower than those across all provinces. Also, in terms of the fraction of the population employed in the primary and tertiary sector (Table 1b), Guangdong and Fujian do not seem to be different from other provinces. We think that given the geographical and economic commonalities and the general idea on cultural homogeneity we can assume that people in the coastal provinces have

[21] Average earnings between 1995 and 2006 have been in average 53% higher in foreign-funded enterprises than in state-owned companies (China Statistical Yearbook, 2007). We do not claim that this wage difference can be entirely explained by a risk premium. However, the very fact that people in China work in the private sector even though it is risky compared to employment in the traditional state-owned enterprises, indicates that there must be some benefits of working in the private or foreign funded sector.

been culturally very similar before the economic reform and similarity risk averse[22].

[Tables 1a and 1b around here]

Concerning the second point, it has to be noted that migration in China is highly restricted through the Hukou (household registration) system, established in 1958. Residence in China is defined as a birth right and entitles the resident to local access to permanent jobs, housing, public schooling, health services, and in rural areas also to a plot of land. Getting a permission for permanent migration is very difficult, especially in the case of rural-urban migration, and costly since it implies abandoning local ownership claims to land and local enterprises without compensation. Temporary migration requires to go through a bureaucratic process of getting an official permit from both the home location and the city of in-migration; additionally, migrants have to pay a high licence fee equivalent to several monthly wages, very often still have to pay taxes in the home location, and will be not have access to housing, health services and schooling in the city of in-migration (Au & Henderson, 2006; Tunon, 2006). Major reforms of the Hukou system that will facilitate migration in the future only started after 2001, that is after the year the World Values Survey data, which provide us information about risk attitudes, were collected. Interviews for the World Values Survey were also solely conducted with people who are formally residing and registered in the area the interview took place[23] and who hence have most likely been born in that area.

Given these facts, namely that migration itself is highly restricted and information about risk attitudes comes from official residents, we think we can safely argue that any potential differences in risk aversion between Guangdong/Fujian and the inland provinces are not coming from self-selection through migration, but should be interpreted as at least partially having arisen in an endogenous process - initiated by the differential economic reform process - within each province, as proposed in our theory.

That vast changes in values occurred in China with the economic liberalization is also documented in Zhang (2000), who cites a survey of 2000 people conducted in 1994 in Shanghai[24], that showed, among others, that in answering the question "what kind of job is ideal to you", the first choice for the 19-32 year olds is to work for foreign companies as manager,s while the first option for those 50 years and above is to be part of the government cadres. The 19-34 year olds also prefer to "live a life according to one's own wish" (66%) in contrast to "work for the interests of the society" (5%), while among the elderly to work for the society is preferred (36%) over to live according to one's own wish (20%).

[22] If different economic conditions are the reasons for differences in risk attitudes, we should expect Shanghai to be especially risk tolerant, given that it is exceptionally rich, has very few people employed in agriculture, but 44 percent of its working population employed in the tertiary sector and more than 60 percent in private and foreign funded enterprises.

[23] See the detailed World Values Survey sampling report downloadable at http://www.jdsurvey.net/bdasepjds/wvsevs/home.jsp?OWNER=WVS.

[24] Sun Jiaming (1997), cited in Zhang (2000).

We will begin our investigation of the relationship between private sector employment and risk attitudes by looking at employment structure and average risk aversion across provinces, together with simple correlations. Afterwards we will be presenting results from regressions.

6.1 Data

Employment and production data are from the China Statistical Yearbooks (State Statistical Bureau of China) 1983-2006. While data on the number of people employed in the whole country are available for all years, provincial level data are only available from 1993 onward. However, because employment in each individual province as a fraction of total Chinese employment has been constant between 1993 and 1995 and only started slightly moving after 1996, we predict the 1982 to 1992 provincial level employment by assuming that the share of employment of each province in total Chinese employment has been constant and equal to the average share employed between 1993 and 1995.

Data on risk aversion (and other individual characteristics we use as controls in the regressions) are from the World Values Survey (Inglehart, Basanez and Moreno, 2001). We use the 2001 wave because previous waves do not provide sufficient coverage of provinces; the 1990 wave samples only 11 provinces with Fujian not even included, while the 1995 wave does not even provide information on the provinces where the interviews were conducted. The 2001 wave covers 1000 individuals in 24 out of the 31 Chinese provinces. All individuals are official residents of the neighborhoods where the interviews were conducted. Sampling was based on multi-stage (county - township - village - household) probability proportional to size equidistance sampling, such that the final household sample is considered to be an equi-probability sample. As a measure of attitudes towards risk, or more precisely, attitudes towards occupational risk, we take the answers from two questions asked in the survey. The first question asked "Which aspects of a job are important to you". The answer to this question is recorded as one if a person mentions "good job security" and zero otherwise. To cross check that the results are not driven by measurement error of the risk attitude question, we additionally also look at the answer to the question "If you were looking for a job, which aspect of a job would you personally rank first?". The answer to this question was recorded as one if the person considered "a safe job with no risk" as most important. The correlation between the answers to these two questions is 0.65.

6.2 Results

6.2.1 Aggregate results across provinces

Figure 1a shows the fraction of the employed population working in the state-owned sector for seven provinces, Guangdong and Fujian, open to foreign investors since 1979, and the other five costal provinces, Heibei, Zheijiang, Jiangsu, Shandong, and Liaoning, which started opening between

1985 and the early 1990s[25]. Even though provincial level data between 1985 and 1993 are missing, we can clearly see that the percentage of people employed in the state-owned sector in Guangdong and Fujian province already fell significantly before 1993, while the fractions in the other provinces, ignoring the exceptional high numbers in Liaoning, have remained roughly constant, or have even been increasing, until 1997. Nowadays, Guangdong and Fujian province have among the lowest level of state sector employment, even though Guangdong started with a level that was the highest among all coastal provinces except for Liaoning. The opposite picture can be seen in Figure 1b that displays the fraction of people working in private and foreign-funded enterprises. We can see for the whole country that private sector employment has not been existing in China before 1988. The fact, though, that this fraction had already reached a level of 2.5 percent in Guangdong and Fujian province by 1993, while it was still close to zero in the other coastal provinces, clearly indicates that private sector employment has started to rise there much earlier than in the other provinces, and with the gap still growing in 2006.

[Figure 1a and 1b around here]

Our theory proposes that the increased experience with risky private sector/foreign-funded sector employment, together with the higher earnings in these sectors (see Footnote 22) will lead to an increase in the representation of more risk tolerant people and hence to an in average lower level of risk aversion. Figure 2 shows risk attitudes toward occupational risks in the seven coastal provinces, measured by the fraction of people saying that "good job security is an important aspect in a job".

As we can see, this fraction is only 56% in Guangdong and Fujian, while it is between 64% and 92% in the other coastal provinces, with the average level in China being in between at 68%. What is the most striking observation, though, is the fact that the order of provinces (other than Guangdong and Fujian) in terms of risk aversion, with Liaoning having the highest percentage of people saying that job security is important, followed by Heibei, Jiangsu, Shandong, and Zheijiang, reflects exactly the order of provinces in terms of state-sector employment we have seen in Figure 2a: Liaoning has the highest fraction of state-employed population, followed again in this order by Heibei, Jiangsu, Shandong, and Zheijiang.

[Figure 2 around here]

Table 2 shows simple correlations between the answer to the risk attitude question and the fraction of people employed in the state-owned sector and the private/foreign funded sector in 1993, the earliest year we have provincial level data. We see that while the correlations are close to zero and even negative for the state-sector when we look at all provinces, the sub-sample of

[25] We do not display results for Shanghai here, because Shanghai is very different from the other provinces, more than twice as rich and with more than 60% of its working population being employed in the private and foreign funded sector. The regressions presented in section 7.2.2 though include Shanghai.

coastal provinces (without Shangai) shows a clear and strong negative correlation between risk aversion and private/foreign funded sector employment and a clear and strong positive correlation with state-owned sector employment. When we on the other hand compute the same correlations with employment data from 2000, this clear picture vanishes. This is in line with our story, as we argue that it is the early differences in employment opportunities that matter, because changes in attitudes take time. Given the fact that nowadays all coastal provinces are open and offer the same opportunities for workers, we should not see such a pattern for employment data from more recent years.

6.2.2 Regression results

Table 3a provides evidence on the relationship between risky private sector employment and risk attitudes from regression analysis, making use of the individual level data from the World Values Survey. The dependent variable is the individual answer to the question on attitudes concerning risks in job. The variable "Job security important" is equal to one if the individual mentions "good job security" to be an important aspect in a job. The variable "First choice: safe job" is recorded as equal to one if the individual says that "a safe job with no risk" would be his first choice if he was looking for a job.

We estimate probit regressions, regressing the dependent variable on exogenous individual characteristics (sex, age) and two important dummy variables. The dummy "Guangdong/Fujian" takes a value of one if the individual interviewed is from either Guangdong or Fujian province and zero otherwise. The dummy variable "Coast" is equal to one if the individual is from any of the eight coastal provinces (including Shanghai) and zero otherwise. Hence, in the omitted group are the people from the inland provinces. All regressions exclude individuals from Xizang province (Tibet Autonomous Region) because its people are ethnically and culturally very different from other Chinese. However, all results would also hold qualitatively and quantitatively if we included Xizang.

[Table 3a and 3b around here]

In column (1) we regress the variable "Job security important" on sex (female=1 if person is female; 0 if male), age and the squared level of age.

The results show that people from Guangdong or Fujian province are significantly less risk averse than people from the other coastal provinces of China and, because the coefficient on the Guangdong/Fujian dummy are absolutely larger than the one on the coastal dummy, also less risk averse than people from any other province. Being from Guangong or Fujian reduces the likeliness to consider job security to be important by 65 percentage points.

Interestingly, coastal people seem to be in general more risk averse than inland people. We interpret this as coming from the experience with state-owned enterprises that have historically played a much bigger role in the economically and politically important coastal regions than in the remote inland provinces. If state-owned enterprises have not played such a major role in inland provinces and hence people could not experience secure jobs to the same extent as at the coast, job security has no meaning to these people and hence preferences over job security would not have been formed to the same extent as in coastal areas. Table 4 shows that overall, with few exceptions, the fraction of people employed in state-owned sectors in the inland provinces has indeed been lower in 1982 than in the coastal areas, supporting our interpretation.

[Table 4 around here]

As commonly found and intuitively reasonable[26], even though here not significant, middle aged people are less risk averse than the young and old. There are no unemployed people in our sample, so that the results are not driven by people who do not care about job security because they just do not have a job. However, including unemployed people in the sample would not affect the results as Table 3b shows, which displays all regressions results using the full sample including unemployed people.

In column (2) we replace the dependent variable by our alternative measure of risk aversion, "First choice: safe job", to test whether the results are not just driven by measurement error in the dependent variable. The results for this variable are very similar to the previous case, again showing that Guangdong and Fujian people are significantly less risk averse than individuals from other provinces of China.

To check for the robustness of our results we include other control variables. The most important economic variables are education and income. Of course, these variables are endogenous, since, as also our model predicts, high income and education could change risk attitudes but more risk tolerance could also lead to higher income and make people invest more in human capital; however, income and human capital are sufficiently important economic variables so that it would still be interesting to see their effects on risk attitudes. Hence, in columns (3) we add, income and its squared term and in column (4) education and the squared level of education of the respondent to the regression. Household income is recorded in the following way: "1", if the monthly household income is less than 4'000 Yuan (about US$ 480 in 2000), "2", if household income is between 4'001 and 10'000 Yuan, and "3", if it exceeds 10'000 Yuan (about US$ 1200). Education is recorded in a similar fashion with "1" implying that a person has completed primary school or never attended school, "2" if a person completed junior or senior high school, and "3" if he or she has at least some college education. Columns (5) and (6) repeat this exercise using our alternative left hand side variable. As we can see, the estimated effects of the Guangdong/Fujian dummy and coastal dummy are very robust to the inclusion of these variables. The point estimates for Guangdong/Fujian and the coastal change only slightly and remain equally significant.

[26] See for comparison for example Guiso et al. (2006).

In columns (7) and (8) we add further, though again potentially endogenous, variables, namely the number of children a person has, whether or not she or he is married or lives together with someone in a marriage-like relationship, and whether or not she or he works in the agricultural sector (farmer with own farm or agricultural laborer). The latter dummy variable is used as a proxy for a rural/urban dummy to pick up differences between people from rural and urban areas. The additional control variables again do not change the effects of our variables of interest.

Finally, in columns (9) and (10) we show that even though Shanghai has an exceptionally high fraction of people employed in the private and foreign funded sector but introduced economic reforms late, it is not different from other coastal provinces in terms of risk attitudes. Additionally including a dummy for Shanghai that takes a value of one if a person is from Shanghai province and zero otherwise does not affect the Guangdong/Fujian dummy. This result indicates that value change takes time and that exposure to risky job does not immediately change risk attitudes.

7 Concluding remarks

This paper presented a new model of economic growth with endogenous cultural traits by integrating a cultural transmission mechanism into an overlapping generations endogenous growth model. The theory suggests that distinct cultural entities are characterized by different paths of economic development and helps to explain why different countries or cultural regions experience quite different economic traits, reflected in persistent income gaps.

In this model, we focused on the role of risk aversion, defined as one component of culture, for technological progress and showed how the composition of cultural traits itself changes over time driven by changes in the economic conditions. The evolution of cultural traits in our model is driven by two forces: A cultural transmission force based on parents' imperfect empathy with their children and concerns for the survival of existing cultural traits - explaining the persistence of cultural values - and a Darwinian evolutionary force generating an increase in the representation of the economically more successful type. These forces together generate a polymorphic distribution of cultural traits in the steady-state. The result is therefore different from evolutionary models as in Galor & Moav (2002) and Galor & Michalopoulos (2006) in which the distribution of traits converges to the degenerate case. The model implies that, everything else being equal, less risk averse societies will start allocating resources to R&D and start growing earlier, and grow at a higher rate.

The model highlights the role of capital and human capital for the process of development as a means of triggering technological progress. Societies need to be endowed or need to have accumulated a certain minimum amount of human capital and physical capital in order to be willing to invest resources in research activity. More specifically, in our model, an increase in the capital stock of the economy leads to a fall in the cut-off level of risk tolerance that has to be exceeded to make agents willing to allocate resources to the research sector.

This result is similar to theoretical results in the endogenous growth literature and in accordance with empirical evidence on the investment behavior of countries over different stages of economic development (e.g. Robinson, 1971): Howitt and Mayer-Foulkes (2005) develop a model of R&D-implementation based on Schumpeterian growth theory. They show that countries need to surpass a threshold skill level to be able to perform research activity. A country that has parameter values more favorable to innovation will make the transition to a modern R&D economy earlier while countries lagging behind will find it increasingly difficult to catch up, since the increasing technological backwardness leads to an erosion of skills.

In the model presented in this paper a similar force is generated, but its origin is cultural. Countries need to surpass a threshold level of capital in order to make the least risk-averse type willing to invest resources in research activity. Once the most risk-tolerant group of agents has moved to the research sector, it becomes increasingly difficult and unattractive for other types of agents to switch, since the increasing rate of technological progress reduces incentives to move to the research sector for it reduces wage differentials between workers and researchers.

The model predicts that higher incentives to install more risk tolerant attitudes, for example in the form of higher payoffs of risky jobs or the very establishment of risky but high paying jobs, will lead to an overall decrease in risk aversion. We tested this prediction empirically, arguing that differential timing of the economic reform policies across provinces in China created risky private and foreign-funded enterprise jobs in some provinces, but not or only late in other provinces. We showed that people from Guangdong and Fujian province, which were the first provinces introducing market reforms, opening their markets to foreign investors, and establishing risky private sector employment opportunities, are significantly less risk averse with respect to occupational risks than people from other provinces, and especially other coastal provinces who are culturally and economically otherwise very similar. We argue that this is because people from Guangdong and Fujian had more time to experience and learn about the benefits of more risk tolerant attitudes and hence more time to transmit such attitudes to subsequent generations.

Risk attitudes are not the only component of cultural preferences. Future research should look into the role of other cultural norms. We think that the framework proposed in this paper is in general flexible and could be adapted to study the role of various other components of culture. The empirical evidence we provided in this paper is currently based on just one cross section. It would be interesting to see whether in the future, when more waves of the World Values Survey will become available, differences in risk attitudes between Guangdong, Fujian and the other coastal provinces will become smaller and attitudes across the Chinese provinces will start converging again.

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A Proofs for the comparative statics

In the following we will, if necessary, base our arguments on the assumption of concrete parameter values. Specifically, we will be assuming the following:

Parameter	Interpretation	Assigned value
τ_A	Fraction of time spent on schooling for researchers	0.75
τ_Y	Fraction of time spent on schooling for workers	0.25
z	Probability of success in the research sector	0.8
ψ	Returns to schooling	20%
$\overline{\eta}$	Productivity of researchers/entrepreneurs	0.02
α	Elasticity of output w/r to human capital	1/4
β	Elasticity of output w/r to labor	1/6
δ^l	risk tolerance of l-types	0.1
δ^h	risk tolerance of h-types	0.8
L	Population size	10
A_0	Starting level of technology	1
γ	Weight of period 1 utility	0.3

A.1 The $qq-$locus

Noting that P_{At} has to move along the stable arm given by $P_{At} = \dfrac{k_t(\alpha+\beta)}{(1-\alpha-\beta)}$, the qq-locus conditional on that this is the case is the geometric locus of all pairs $\{q_t, k_t\}$ such that q_t is in a steady-state:

$$qq \equiv \{q_t, k_t\} : q_{t+1} - q_t = 0.$$

Along the qq-locus we have,

$$\begin{aligned}
& \omega'(q_t, k_t) - q_t \qquad (38) \\
= \; & q_t(1-q_t)\{V - 2q_tV + \overline{\eta}H_A \frac{k_t(\alpha+\beta)}{(1-\alpha-\beta)}[(1-q_t)z^{1/\delta^h} + q_t z^{1/\delta^l}] - \beta {H_Y}^{\alpha}((1-q_t)L)^{\beta-1}k_t^{1-\alpha-\beta}\} \\
= \; & 0.
\end{aligned}$$

Equation (37) implies three equilibria for q_t :

1. $q^*_{1t} = 0$

2. $q^*_{2t} = 1$

3. the implicit function given by

$$F = V - 2q_t V + \overline{\eta} H_A \frac{k_t(\alpha+\beta)}{(1-\alpha-\beta)}[(1-q_t)z^{1/\delta^h} + q_t z^{1/\delta^l}] - \beta H_Y{}^{\alpha}((1-q_t)L)^{\beta-1} k_t^{1-\alpha-\beta} = 0 \quad (39)$$

Total differentiation of the implicit function F determining the qq-locus gives:

$$\frac{dq_t}{dk_t} = -\frac{\frac{\partial F}{\partial k_t}}{\frac{\partial F}{\partial q_t}} = \frac{\overline{\eta} H_A \frac{(\alpha+\beta)}{1-\alpha-\beta}[(1-q_t)z^{1/\delta^h} + q_t z^{1/\delta^l}] - (1-\alpha-\beta) D E^{\beta-1} k_t^{-\alpha-\beta}}{2V - \overline{\eta} H_A P_{At}[-z^{1/\delta^h} + z^{1/\delta^l}] + (1-\beta) D E^{\beta-2} k_t^{1-\alpha-\beta}}.$$

with $\beta H_Y{}^{\alpha} \equiv D,^{\alpha}((1-q_t)L) \equiv E$.

$\frac{\partial F}{\partial k_t} \geq 0$ for

$$k_t \geq \left[\frac{(1-\alpha-\beta)^2 D E^{\beta-1}}{\overline{\eta} H_A(\alpha+\beta)[(1-q_t)z^{1/\delta^h} + q_t z^{1/\delta^l}]}\right]^{1/(\alpha+\beta)} \equiv \widehat{k}(q_t)$$

and ≤ 0 otherwise.

$$\begin{aligned}
\frac{\partial \widehat{k}(q_t)}{\partial q_t} &= \frac{1}{\alpha+\beta}\widehat{k}(q_t)^{-1} \\
&\cdot \{\frac{(1-\beta)L(1-\alpha-\beta)\beta D E^{\beta-2}[\overline{\eta} H_A \frac{(\alpha+\beta)}{1-\alpha-\beta}[(1-q_t)z^{1/\delta^h} + q_t z^{1/\delta^l}]]}{[\overline{\eta} H_A \frac{(\alpha+\beta)}{1-\alpha-\beta}[(1-q_t)z^{1/\delta^h} + q_t z^{1/\delta^l}]} \\
&- \frac{(1-\alpha-\beta) D E^{\beta-1}[\overline{\eta} H_A \frac{(\alpha+\beta)}{1-\alpha-\beta}[-z^{1/\delta^h} + z^{1/\delta^l}]]}{[\overline{\eta} H_A \frac{(\alpha+\beta)}{1-\alpha-\beta}[(1-q_t)z^{1/\delta^h} + q_t z^{1/\delta^l}]}\} \\
&> 0
\end{aligned}$$

since $z^{1/\delta^h} > z^{1/\delta^l}$.

A.2 The kk-locus

The kk-locus, conditional on that P_{At} evolves along the stable arm and on q_t being in a steady state, i.e. with $q_{t+1} = q_t$, is the geometric locus of all pairs $\{q_t, k_t\}$ such that k_t is in a steady-state.

$$kk \equiv \{q_t, k_t\} : k_{t+1} - k_t = 0$$

That is along the kk-locus we have

$$k_t = \frac{q_t L z \overline{\eta} H_A P_{At} + \beta D E^{\beta} k_t^{1-\alpha-\beta}}{1 + z\overline{\eta} H_A q_t L}, q_t \neq 1^{27} \quad (40)$$

Solving for k_t we derive

$$k_t^* = [\frac{\beta {h_Y}^{\alpha}((1-q_t)L)^{\beta}}{1 + z\overline{\eta} H_A q_t L - q_t L z \overline{\eta} H_A \frac{(\alpha+\beta)}{(1-\alpha-\beta)}}]^{1/(\alpha+\beta)}, q_t \neq 1 \tag{41}$$

with

$$\frac{dk_t^*}{dq_t} = \frac{1}{\alpha+\beta} k_t^{*-1} \frac{(1-\alpha-\beta)DE^{\beta-1}L\{-\beta + z\overline{\eta}H_A L \frac{(1-2\alpha-2\beta)}{(1-\alpha-\beta)}[q_t(1-\beta)-1]\}}{[1+z\overline{\eta}H_A q_t L(1-\alpha-\beta)]^2} < 0.$$

Figure A.1 graphically displays the qq- and the kk-locus.

A.3 Proof of Lemmas 5 & 6

A.3.1 Proof of Lemma 5: Change in H_A and H_Y

We study the effect of a change in wages of researchers (type h) and workers (type l) using the example of a change in human capital H_A and H_Y.

Change in H_Y:

The kk-locus becomes steeper when human capital of l-types (workers) increases:

$$\frac{\partial k_t^*}{\partial H_Y} = \frac{1}{\alpha+\beta} k_t^{*-1} \frac{\alpha\beta {H_Y}^{\alpha-1} E^{\beta}}{1 + z\overline{\eta} H_A q_t L - q_t L z \overline{\eta} H_A \frac{(\alpha+\beta)}{(1-\alpha-\beta)}} > 0$$

The slope of the qq-locus falls since

$$\begin{aligned} \frac{\partial}{\partial H_Y}\frac{dq_t}{dk_t} &= \frac{\overline{\eta} H_A \frac{(\alpha+\beta)}{1-\alpha-\beta} \alpha(1-\alpha-\beta)\beta {H_Y}^{\alpha-1} E^{\beta-2} k_t^{1-\alpha-\beta} L\{z^{1/\delta^l}(1-2q_t+\beta q_t)\}}{[-\overline{\eta} H_A \frac{(\alpha+\beta)k_t}{1-\alpha-\beta}[-z^{1/\delta^h} + z^{1/\delta^l}] + (1-\beta)LDE^{\beta-2}k_t^{1-\alpha-\beta}]^2} \\ &- \frac{\overline{\eta} H_A \frac{(\alpha+\beta)}{1-\alpha-\beta} \alpha(1-\alpha-\beta)\beta {H_Y}^{\alpha-1} E^{\beta-2} k_t^{1-\alpha-\beta} L\{z^{1/\delta^h}(1-2q_t+\beta q_t) + z^{1/\delta^h}(1-\beta)\}}{[-\overline{\eta} H_A \frac{(\alpha+\beta)k_t}{1-\alpha-\beta}[-z^{1/\delta^h} + z^{1/\delta^l}] + (1-\beta)LDE^{\beta-2}k_t^{1-\alpha-\beta}]^2} \\ &< 0 \end{aligned}$$

because of $z^{1/\delta^h} > z^{1/\delta^l}$ and $(1 - 2q_t + \beta q_t) > 0$. The fact that the kk-locus intersects the qq-locus in its downward sloping part and both loci become steeper as H_Y rises, implies that the equilibrium value of q_t, $\overline{q}$, and hence the growth rate will be reduced.

Change in H_A:

The kk-locus becomes flatter when human capital of h-types (researchers) increases:

$$\frac{dk_t^*}{dH_A} = \frac{1}{\alpha+\beta} k_t^{*-1} \frac{-[\beta {H_Y}^{\alpha}((1-q_t)L)^{\beta}][z\overline{\eta} q_t L \frac{(1-2\alpha-2\beta)}{(1-\alpha-\beta)}]}{[1 + z\overline{\eta} H_A q_t L - q_t L z \overline{\eta} H_A \frac{(\alpha+\beta)}{(1-\alpha-\beta)}]^2} < 0$$

The slope of the qq-locus falls as H_A rises since

$$\begin{aligned}\frac{\partial}{\partial H_A}\frac{dq_t}{dk_t} &= \frac{DEk_t^{1-\alpha-\beta}\overline{\eta}\frac{(\alpha+\beta)}{1-\alpha-\beta}L\{(1-\beta)[z^{1/\delta^h}(1-q_t)+q_t z^{1/\delta^l}]\}}{[-\overline{\eta}H_A\frac{(\alpha+\beta)k_t}{1-\alpha-\beta}[-z^{1/\delta^h}+z^{1/\delta^l}]+(1-\beta)LDE^{\beta-2}k_t^{1-\alpha-\beta}]^2} \\ &+\frac{DEk_t^{1-\alpha-\beta}\overline{\eta}\frac{(\alpha+\beta)}{1-\alpha-\beta}L\{(1-\alpha-\beta)[z^{1/\delta^h}(1-q_t)-z^{1/\delta^l}(1-q_t)]\}}{[-\overline{\eta}H_A\frac{(\alpha+\beta)k_t}{1-\alpha-\beta}[-z^{1/\delta^h}+z^{1/\delta^l}]+(1-\beta)LDE^{\beta-2}k_t^{1-\alpha-\beta}]^2} \\ &> 0.\end{aligned}$$

Following the analog to the argument above, $\overline{q}$ and the growth rate will rise.

A.3.2 Proof of Lemma 6: Change in δ^h and δ^l

Noting, that an increase in δ is equivalent to an increase in $z^{1/\delta}$, we can derive the following results for the qq-locus. The kk-locus is unaffected by a change in δ^h or δ^l.

$$\frac{\partial}{\partial z^{1/\delta^h}}\frac{dq_t}{dk_t}=\frac{\overline{\eta}H_A\frac{(\alpha+\beta)k_t}{(1-\alpha-\beta)}\{-z^{1/\delta^l}\overline{\eta}H_A\frac{(\alpha+\beta)}{(1-\alpha-\beta)}+DEk_t^{-\alpha-\beta}[2(1-\beta)-\alpha]}{[-\overline{\eta}H_A\frac{(\alpha+\beta)k_t}{1-\alpha-\beta}[-z^{1/\delta^h}+z^{1/\delta^l}]+(1-\beta)LDE^{\beta-2}k_t^{1-\alpha-\beta}]^2}$$

This expression is positive for

$$k_t<\widetilde{k}(q_t)\equiv\left[\frac{(1-\alpha-\beta)\beta {h_Y}^{\alpha}((1-q_t)L)^{\beta-1}[2(1-\beta)-\alpha]}{z^{1/\delta^l}\overline{\eta}H_A(\alpha+\beta)}\right]^{1/(\alpha+\beta)}$$

with $\frac{\partial\widetilde{k}(q_t)}{\partial q_t}>0$.

Because for the intersection of the kk-locus with the k_t-axis, $k_t^*(0)$, we have that $k_t^*(0)<\widetilde{k}(0)$, and $\frac{\partial\widetilde{k}(q_t)}{\partial q_t}>0$, the equilibrium $(\overline{q},\overline{k})$ must be to the left of $\widetilde{k}(q_t)$ where the qq-locus would become flatter as δ^h rises. Hence $\overline{q}$ and the corresponding growth rate would increase.

$$\frac{\partial}{\partial z^{1/\delta^l}}\frac{dq_t}{dk_t}=\frac{\overline{\eta}H_A\frac{(\alpha+\beta)}{1-\alpha-\beta}k_t\{\overline{\eta}H_A\frac{(\alpha+\beta)}{1-\alpha-\beta}z^{1/\delta^h}+DEk_t^{-\alpha-\beta}L[2q_t(1-\beta)-(1-\alpha-\beta)+\alpha q_t]\}}{[-\overline{\eta}H_A\frac{(\alpha+\beta)k_t}{1-\alpha-\beta}[-z^{1/\delta^h}+z^{1/\delta^l}]+(1-\beta)LDE^{\beta-2}k_t^{1-\alpha-\beta}]}$$

This expression is positive for

$$k_t>\underline{k}(q_t)\equiv[\frac{(1-\alpha-\beta)DE^{\beta-2}L[-q_t(2-2\beta+\alpha)+(1-\alpha-\beta)]}{\overline{\eta}H_A(\alpha+\beta)z^{1/\delta^h}}]^{1/(\alpha+\beta)})$$

which is positive for $q_t>\frac{(1-\alpha-\beta)}{(2-2\beta+\alpha)}$. Hence $\underline{k}(q_t)$ is a negatively sloped line in the k_t-q_t-plane, starting from $q_t=\frac{(1-\alpha-\beta)}{(2-2\beta+\alpha)}<0.5$ (the starting value of the qq-locus) with $\underline{k}(0)=\widehat{k}(0)$, and very close to the q_t-axis (assuming the parameters values listed above). Noting that $\widehat{k}(q_t)$ is positively sloped and very flat, this implies that the entire qq-locus will be above $\underline{k}(q_t)$ and hence will become flatter as δ^l is increased, making $\overline{q}$ and the equilibrium growth rate $\overline{g} \equiv z\overline{\eta} H_A \overline{q} L$ rise.

B Features of $\widehat{\delta}(q_t, k_t)$

Because the model can only be analyzed if the patent price P_{At} neither explodes nor falls forever, we have to assume that P_{At} evolves along the stable path, given by $P_{At} = \frac{(\alpha+\beta)}{1-a-\beta} k_t$, when analyzing the relationship between the threshold level of risk aversion, $\widehat{\delta}(q_t, k_t)$, and its arguments. Substituting $P_{At} = \frac{(\alpha+\beta)}{1-a-\beta} k_t$ for P_{At} in equation (23) and differentiating with respect to q_t and k_t gives (noting that $\ln z < 0$) :

$$
\begin{aligned}
\frac{\partial \widehat{\delta}(k_t, q_t)}{\partial k_t} &= \frac{\ln z}{[\frac{\gamma}{1-\gamma} \ln(\frac{1-\tau^A}{1-\tau^Y}) + \ln(\frac{\overline{\eta} H_A (\alpha+b) k_t^{\alpha+\beta}}{(1-\alpha-\beta) D E^{\beta-1}})]^2} \frac{\alpha+\beta}{k_t} < 0 \\
\frac{\partial^2 \widehat{\delta}(k_t, q_t)}{\partial k_t^2} &= \frac{\ln z}{[\frac{\gamma}{1-\gamma} \ln(\frac{1-\tau^A}{1-\tau^Y}) + \ln(\frac{\overline{\eta} H_A (\alpha+b) k_t^{\alpha+\beta}}{(1-\alpha-\beta) D E^{\beta-1}})]^2} \left(\frac{-(\alpha+\beta) - (\alpha+\beta)^2}{k_t^2} \right) > 0 \\
\frac{\partial \widehat{\delta}(k_t, q_t)}{\partial q_t} &= -\frac{\ln z}{[\frac{\gamma}{1-\gamma} \ln(\frac{1-\tau^A}{1-\tau^Y}) + \ln(\frac{\overline{\eta} H_A (\alpha+b) k_t^{\alpha+\beta}}{(1-\alpha-\beta) D E})]^2} \frac{1-\beta}{(1-q_t)} > 0 \\
\frac{\partial^2 \widehat{\delta}(k_t, q_t)}{\partial q_t^2} &= -\frac{\ln z}{[\frac{\gamma}{1-\gamma} \ln(\frac{1-\tau^A}{1-\tau^Y}) + \ln(\frac{\overline{\eta} H_A (\alpha+b) k_t^{\alpha+\beta}}{(1-\alpha-\beta) D E})]^2} \left(\frac{(1-\beta) + (1-\beta)^2}{(1-q_t)^2} \right) < 0
\end{aligned}
$$

C Simulation of the model

In the following we will simulate the model in order to determine its steady-state and the stability of the steady-state. We will be assuming the parameter values listed in the beginning of the appendix. Additionally we scale up the production by a factor 10, i.e. the production function is

$$Y_t = 10(A_t H_Y)^\alpha (A_t L_{Yt})^\beta K_t^{1-\alpha-\beta}$$

.

The steady-state is given by the solution of the three-dimensional non-linear system:
$q_{t+1} = \omega(q_t, k_t, P_{At})$
$k_{t+1} = \xi(q_t, k_t, P_{At})$
$P_{At+1} = \theta(q_t, k_t, P_{At})$.

Suppose the solution is $(\overline{q}, \overline{k}, \overline{P}_A)$. Following Galor (2006), to determine the properties of this steady-state, we have to linearize the system around the steady-state and compute the eigenvalues of the Jordan matrix. The first-order Taylor approximation is given by

$$
\begin{aligned}
q_{t+1} &= \frac{\partial\omega(\overline{q},\overline{k},\overline{P}_A)}{\partial q_t}(q_t-\overline{q})+\frac{\partial\omega(\overline{q},\overline{k},\overline{P}_A)}{\partial k_t}(k_t-\overline{k})+\frac{\partial\omega(\overline{q},\overline{k},\overline{P}_A)}{\partial P_{At}}(P_{At}-\overline{P}_A)+\omega(\overline{q},\overline{k},\overline{P}_A)\\
k_{t+1} &= \frac{\partial\xi(\overline{q},\overline{k},\overline{P}_A)}{\partial q_t}(q_t-\overline{q})+\frac{\partial\xi(\overline{q},\overline{k},\overline{P}_A)}{\partial k_t}(k_t-\overline{k})+\frac{\partial\xi(\overline{q},\overline{k},\overline{P}_A)}{\partial P_{At}}(P_{At}-\overline{P}_A)+\xi(\overline{q},\overline{k},\overline{P}_A)\\
P_{At+1} &= \frac{\partial\theta(\overline{q},\overline{k},\overline{P}_A)}{\partial q_t}(q_t-\overline{q})+\frac{\partial\theta(\overline{q},\overline{k},\overline{P}_A)}{\partial k_t}(k_t-\overline{k})+\frac{\partial\theta(\overline{q},\overline{k},\overline{P}_A)}{\partial P_{At}}(P_{At}-\overline{P}_A)+\theta(\overline{q},\overline{k},\overline{P}_A),
\end{aligned}
$$

the linearized system is therefore

$$
\begin{aligned}
\begin{matrix} q_{t+1}\\ k_{t+1}\\ P_{At+1}\end{matrix} &= \begin{pmatrix}
\frac{\partial\omega(\overline{q},\overline{k},\overline{P}_A)}{\partial q_t} & \frac{\partial\omega(\overline{q},\overline{k},\overline{P}_A)}{\partial k_t} & \frac{\partial\omega(\overline{q},\overline{k},\overline{P}_A)}{\partial P_{At}}\\
\frac{\partial\xi(\overline{q},\overline{k},\overline{P}_A)}{\partial q_t} & \frac{\partial\xi(\overline{q},\overline{k},\overline{P}_A)}{\partial k_t} & \frac{\partial\xi(\overline{q},\overline{k},\overline{P}_A)}{\partial P_{At}}\\
\frac{\partial\theta(\overline{q},\overline{k},\overline{P}_A)}{\partial q_t} & \frac{\partial\theta(\overline{q},\overline{k},\overline{P}_A)}{\partial k_t} & \frac{\partial\theta(\overline{q},\overline{k},\overline{P}_A)}{\partial P_{At}}
\end{pmatrix}\begin{pmatrix} q_t\\ k_t\\ P_{At}\end{pmatrix}\\
&+\begin{pmatrix}
\omega(\overline{q},\overline{k},\overline{P}_A)-\frac{\partial\omega(\overline{q},\overline{k},\overline{P}_A)}{\partial q_t}\overline{q}-\frac{\partial\omega(\overline{q},\overline{k},\overline{P}_A)}{\partial k_t}\overline{k}-\frac{\partial\omega(\overline{q},\overline{k},\overline{P}_A)}{\partial P_{At}}\overline{P}_A\\
\xi(\overline{q},\overline{k},\overline{P}_A)-\frac{\partial\xi(\overline{q},\overline{k},\overline{P}_A)}{\partial q_t}\overline{q}-\frac{\partial\xi(\overline{q},\overline{k},\overline{P}_A)}{\partial k_t}\overline{k}-\frac{\partial\xi(\overline{q},\overline{k},\overline{P}_A)}{\partial P_{At}}\overline{P}_A\\
\theta(\overline{q},\overline{k},\overline{P}_A)-\frac{\partial\theta(\overline{q},\overline{k},\overline{P}_A)}{\partial q_t}\overline{q}-\frac{\partial\theta(\overline{q},\overline{k},\overline{P}_A)}{\partial k_t}\overline{k}-\frac{\partial\theta(\overline{q},\overline{k},\overline{P}_A)}{\partial P_{At}}\overline{P}_A
\end{pmatrix}\\
&= J\begin{pmatrix} q_t\\ k_t\\ P_{At}\end{pmatrix}+B
\end{aligned}
$$

where where J is the Jordan matrix of $\begin{pmatrix}\omega(q_t,k_t,P_{At})\\ \xi(q_t,k_t,P_{At})\\ \theta(q_t,k_t,P_{At})\end{pmatrix}$ evaluated at $(\overline{q},\overline{k},\overline{P}_A)$. The behavior of the nonlinear system in the proximity of the steady-state equilibrium $(\overline{q},\overline{k},\overline{P}_A)$ can be assessed on the basis of the behavior of the linearized system. Hence the eigenvalues of the Jacobian matrix J determine the local behavior of the nonlinear system. The evolution of the nonlinear system around the stead- state equilibrium can be examined based on the linearized system as long as the steady-state equilibrium is not non-hyperbolic, i.e. as long as the modulus of one of the eigenvalues is not equal to 1. The system is a stable node and it converges monotonically to its steady-state if all eigenvalues of the Jordan matrix are real, positive and of modulus smaller than one. The system is a saddle if at least one of the eigenvalues is of modulus larger than one.

The steady-state equilibrium of this system is given by $(\overline{q},\overline{k},\overline{P}_A)=(0.4878,1.1469,0.8192)$.The corresponding Jordan matrix J is

$$
J=\begin{pmatrix}
-0.0126 & -0.0856 & 0.1979\\
1.3563 & 0.3947 & 0.4681\\
-0.0000 & -4.3855 & 7.1397
\end{pmatrix}
$$

and its eigenvalues

$$
\begin{aligned}
\lambda_1 &= -0.0750 \\
\lambda_2 &= 0.8041 \\
\lambda_1 &= 6.7927.
\end{aligned}
$$

From the size and sign of the eigenvalues we can see that the steady-state is a saddle with both q_t and k_t converging to the steady-state values regardless of their initial levels, while P_{At} only converges for P_{A0} on the saddle path. Because the eigenvalues associated with k_t and P_{At} are positive, both converge monotonically, while q_t converges oscillatory.

Figure A.2 to A.4 display the simlated values of K_t, q_t and $\widehat{\delta}(q_t, k_t)$.

		GAP p.w. in 100 Yuan 1982	GDP p.w. in 100 Yuan 2000
Coast	Heibei	14.98	147.88
	Fujian	13.14	236.15
	Shandong	17.68	183.24
	Guangdong	15.75	250.25
	Liaoning	38.42	257.59
	Jiangsu	26.59	241.17
	Zheijiang	18.58	223.53
	Standard deviation in % of mean	**0.43**	**0.18**
	Mean	**18.20**	**192.50**
Inland	Henan	11.40	92.21
	Hubei	20.85	170.52
	Guizhou	7.65	48.56
	Shanxi	18.53	115.83
	Neimenggu	15.58	137.81
	Jilin	22.11	168.80
	Heilongjiang	32.44	198.96
	Anhui	11.78	90.08
	Jiangxi	12.57	103.50
	Hunan	13.38	106.64
	Guangxi	10.10	81.02
	Sichuan	11.55	90.41
	Yunnan	9.15	85.17
	Shaanxi	13.67	91.62
	Standard deviation in % of mean	**0.44**	**0.37**
	Mean	**14.08**	**105.43**
	Shanghai	121.36	676.15
	Beijing	50.35	398.45
	Standard deviation in % of mean	**0.45**	**0.44**
	Mean	**16.95**	**148.62**

GAP=Gross output value of agriculture and industry
All means and standard deviations exclude Shanghai and Beijing

Table 1a: Production across provinces

		% primary 1993	% tertiary 1993	% primary 2000	% tertiary 2000
Coast	Heibei	57.30	18.10	48.80	25.80
	Fujian	53.90	20.70	46.90	28.60
	Shandong	58.40	17.30	53.10	23.30
	Guangdong	43.00	26.30	41.10	32.70
	Liaoning	32.30	24.10	37.70	36.00
	Jiangsu	44.30	21.40	42.20	28.10
	Zheijiang	46.90	21.70	37.80	31.30
	Standard deviation in % of mean	**0.19**	**0.15**	**0.13**	**0.15**
	Mean	**42.04**	**18.72**	**38.47**	**25.74**
Inland	Henan	65.00	16.20	64.10	18.40
	Hubei	56.70	20.90	48.00	33.60
	Guizhou	77.60	11.80	67.30	23.40
	Shanxi	45.40	23.40	46.70	28.40
	Neimenggu	53.50	22.00	54.50	29.10
	Jilin	46.90	21.40	50.20	30.70
	Heilongjiang	38.10	22.60	49.50	29.30
	Anhui	64.30	17.60	59.80	24.40
	Jiangxi	57.50	22.20	51.90	33.70
	Hunan	65.60	17.30	60.80	24.60
	Guangxi	70.00	17.30	62.20	27.60
	Sichuan	66.70	16.90	59.60	25.90
	Yunnan	77.40	12.10	73.90	17.00
	Shaanxi	61.80	17.70	55.70	27.80
	Standard deviation in % of mean	**0.19**	**0.20**	**0.14**	**0.18**
	Mean	**56.45**	**17.31**	**53.62**	**24.94**
	Shanghai	9.20	34.00	13.10	44.10
	Beijing	11.80	43.40	11.70	55.90
	Standard deviation in % of mean	**0.22**	**0.19**	**0.18**	**0.17**
	Mean	**56.31**	**19.48**	**52.94**	**27.60**

Table shows fractions of the total employed population employed in the primary and tertiary sector
All means and standard deviations exclude Shanghai and Beijing

Table 1b: Employment structure across provinces

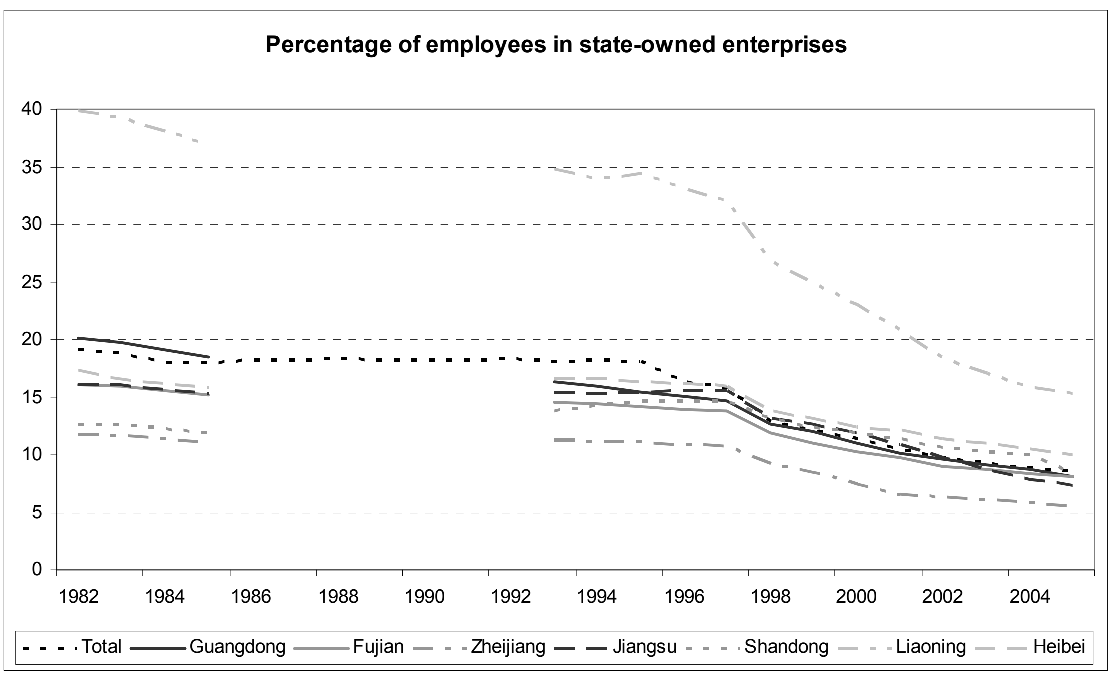

Figure 1a: Employment in state-owned enterprises across coastal provinces

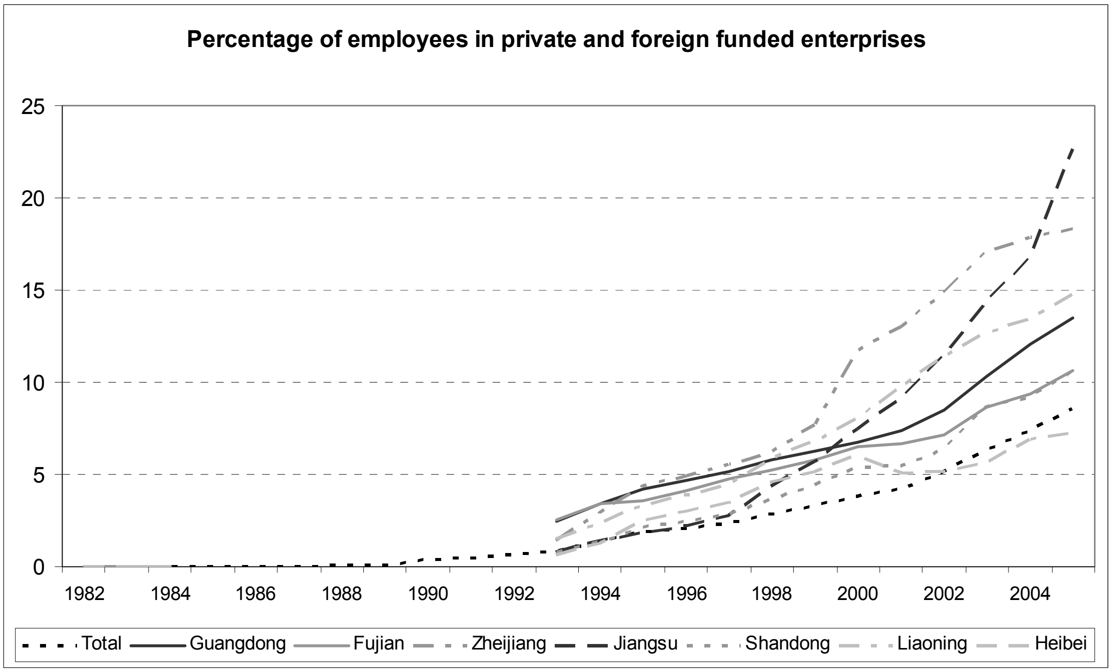

Figure 1b: Employment in private and foreign-funded enterprises across coastal provinces

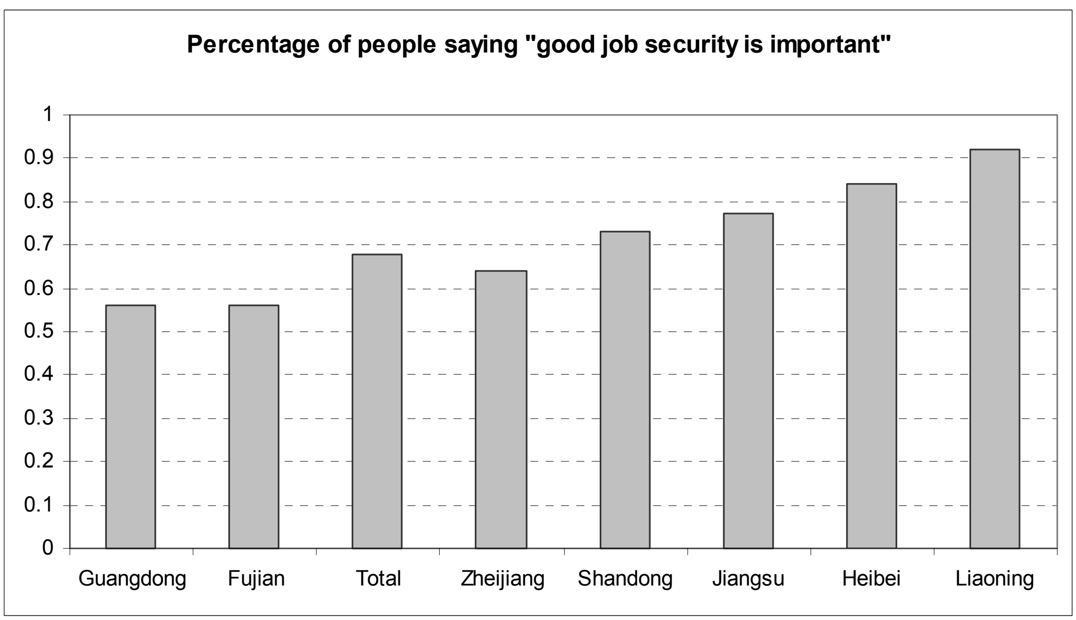

Figure 2: Risk Attitudes across coastal provinces

	% private	% private + foreign	% state-owned	% private	% private + foreign	% state-owned
	1993	1993	1993	2000	2000	2000
Coast: "Job security important"	-0.613	-0.710	0.656	0.072	-0.084	0.429
Total China: "Job security important"	-0.074	-0.085	-0.033	0.206	0.199	-0.197

% private=fraction of the total employed population working in private enterprises

% private + foreign=fraction of the total employed population working in private and foreign funded enterprises

% state-owned=fraction of the total employed population working in state-owned enterprises

Correlations exclude Shanghai

Table 2: Correlation between risk attitudes and employment across coastal provinces and the whole country

Table 3a: Regressions results without unemployed respondents

Dep. variable	(1) JS important	(2) FC: safe job	(3) JS important	(4) JS important	(5) FC: safe job	(6) FC: safe job	(7) JS important	(8) JS important	(9) FC: safe job	(10) FC: safe job
Guangdong/Fujian	-0.653***	-0.387**	-0.550***	-0.564***	-0.388**	-0.366*	-0.629***	-0.428**	-0.646***	-0.363*
	[0.190]	[0.193]	[0.195]	[0.197]	[0.196]	[0.197]	[0.192]	[0.196]	[0.191]	[0.194]
Coast	0.386***	0.319***	0.422***	0.392***	0.315***	0.291***	0.410***	0.222**	0.379***	0.295***
	[0.114]	[0.103]	[0.115]	[0.116]	[0.104]	[0.104]	[0.119]	[0.108]	[0.117]	[0.105]
Female	-0.0878	0.145	-0.0766	-0.121	0.154	0.171*	-0.107	0.153	-0.0878	0.144
	[0.101]	[0.0971]	[0.102]	[0.103]	[0.0975]	[0.0982]	[0.103]	[0.0987]	[0.101]	[0.0971]
Age	0.0183	0.0431	0.0177	0.0129	0.0433	0.0399	-0.00273	0.0480	0.0181	0.0419
	[0.0322]	[0.0318]	[0.0324]	[0.0326]	[0.0319]	[0.0319]	[0.0361]	[0.0350]	[0.0322]	[0.0318]
Age squared	-6.91e-05	-0.000363	-6.38e-05	-2.08e-05	-0.000372	-0.000299	0.000188	-0.000440	-6.84e-05	-0.000352
	[0.000394]	[0.000379]	[0.000396]	[0.000399]	[0.000380]	[0.000381]	[0.000440]	[0.000418]	[0.000394]	[0.000379]
Income			0.820*		0.889**					
			[0.430]		[0.397]					
Income squared			-0.247**		-0.217**					
			[0.107]		[0.0993]					
Education				0.756		0.643				
				[0.481]		[0.463]				
Education squared				-0.298**		-0.143				
				[0.135]		[0.133]				
Shanghai									0.0869	0.309
									[0.356]	[0.289]
							Control for marital status, # children, agricultural activity			
Observations	746	746	746	746	746	746	746	746	746	746

Probit regressions; dependent variables are whether or not job security is important ("JS important") or whether or not a safe job with no risk is the first choice when looking for a job ("FC: safe job")

Table 3b: Regressions results including unemployed respondents

Dep. variable	(1) JS important	(2) FC: safe job	(3) JS important	(4) JS important	(5) FC: safe job	(6) FC: safe job	(7) JS important	(8) JS important	(9) FC: safe job	(10) FC: safe job
Guangdong/Fujian	-0.656***	-0.409**	-0.570***	-0.556***	-0.418**	-0.382*	-0.637***	-0.449**	-0.648***	-0.382**
	[0.188]	[0.192]	[0.194]	[0.195]	[0.195]	[0.196]	[0.191]	[0.194]	[0.190]	[0.193]
Coast	0.412***	0.314***	0.444***	0.410***	0.312***	0.282***	0.426***	0.220**	0.403***	0.286***
	[0.111]	[0.0995]	[0.112]	[0.113]	[0.100]	[0.101]	[0.115]	[0.104]	[0.113]	[0.102]
Female	-0.0889	0.141	-0.0786	-0.111	0.147	0.170*	-0.102	0.142	-0.0893	0.138
	[0.0984]	[0.0941]	[0.0989]	[0.100]	[0.0944]	[0.0953]	[0.0998]	[0.0955]	[0.0985]	[0.0941]
Age	0.0207	0.0338	0.0207	0.0151	0.0339	0.0305	0.00176	0.0394	0.0206	0.0324
	[0.0313]	[0.0307]	[0.0314]	[0.0316]	[0.0308]	[0.0308]	[0.0348]	[0.0337]	[0.0313]	[0.0307]
Age squared	-0.000101	-0.000269	-0.000102	-4.17e-05	-0.000278	-0.000203	0.000131	-0.000349	-0.000100	-0.000257
	[0.000383]	[0.000367]	[0.000385]	[0.000388]	[0.000368]	[0.000369]	[0.000424]	[0.000403]	[0.000383]	[0.000367]
Income			0.776*		0.913**					
			[0.415]		[0.384]					
Income squared			-0.229**		-0.220**					
			[0.104]		[0.0964]					
Education				0.932**		0.643				
				[0.472]		[0.463]				
Education squared				-0.336**		-0.143				
				[0.134]		[0.133]				
Shanghai									0.114	0.356
									[0.351]	[0.283]
	Control for marital status, #									
Observations	789	789	789	789	789	789	789	789	789	789

Probit regressions; dependent variables are whether or not job security is important ("JS important") or whether or not a safe job with no risk is the first choice when looking for a job ("FC: safe job")

		% state-owned 1982
Coast	Shanghai	66.71
	Heibei	17.30
	Fujian	16.03
	Shandong	12.72
	Guangdong	20.15
	Liaoning	40.20
	Jiangsu	16.01
	Zheijiang	11.72
Inland	Beijing	59.09
	Henan	11.98
	Hubei	22.15
	Guizhou	11.88
	Shanxi	24.78
	Neimenggu	29.37
	Jilin	31.59
	Heilongjiang	44.62
	Anhui	11.69
	Jiangxi	17.00
	Hunan	13.58
	Guangxi	12.98
	Sichuan	12.89
	Yunnan	13.37
	Shaanxi	20.06

Table 4: Fraction of employed population in state-owned enterprises in 1982

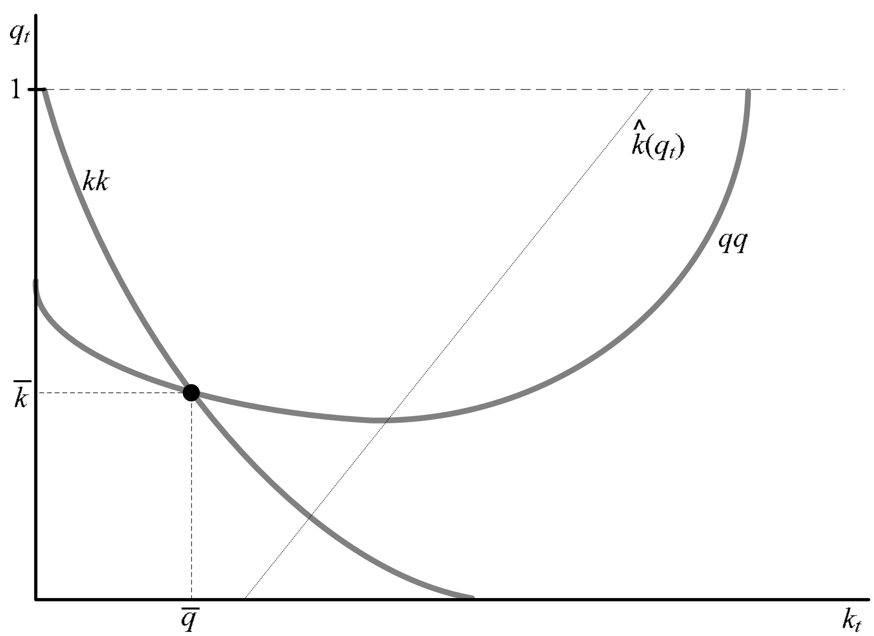

Figure A.1: The *qq*- and the *kk*-locus

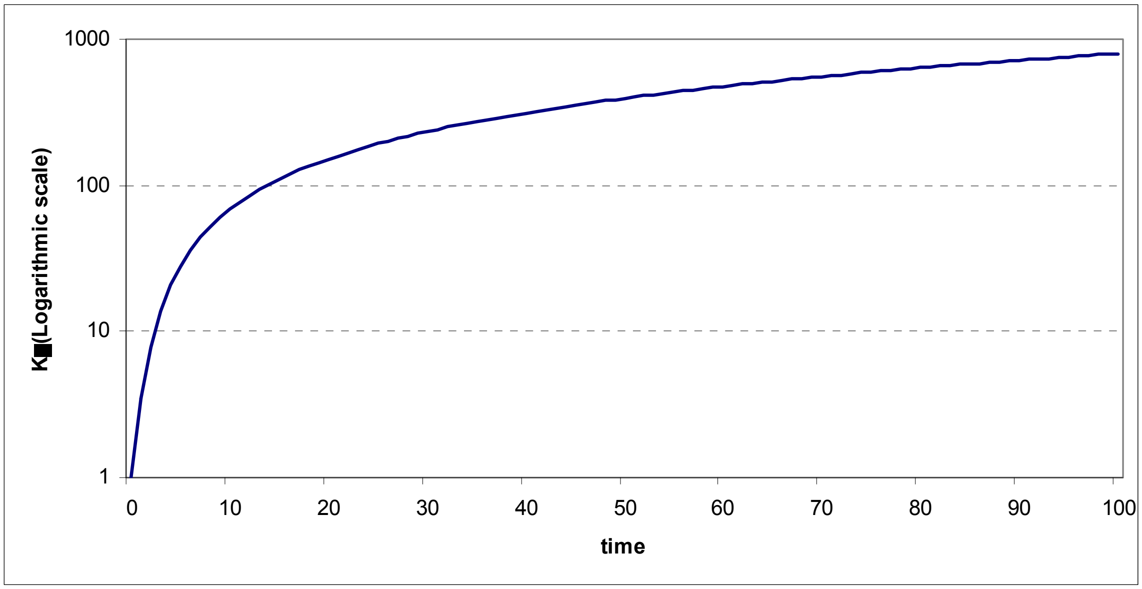

Figure A.2: Simulation of K_t

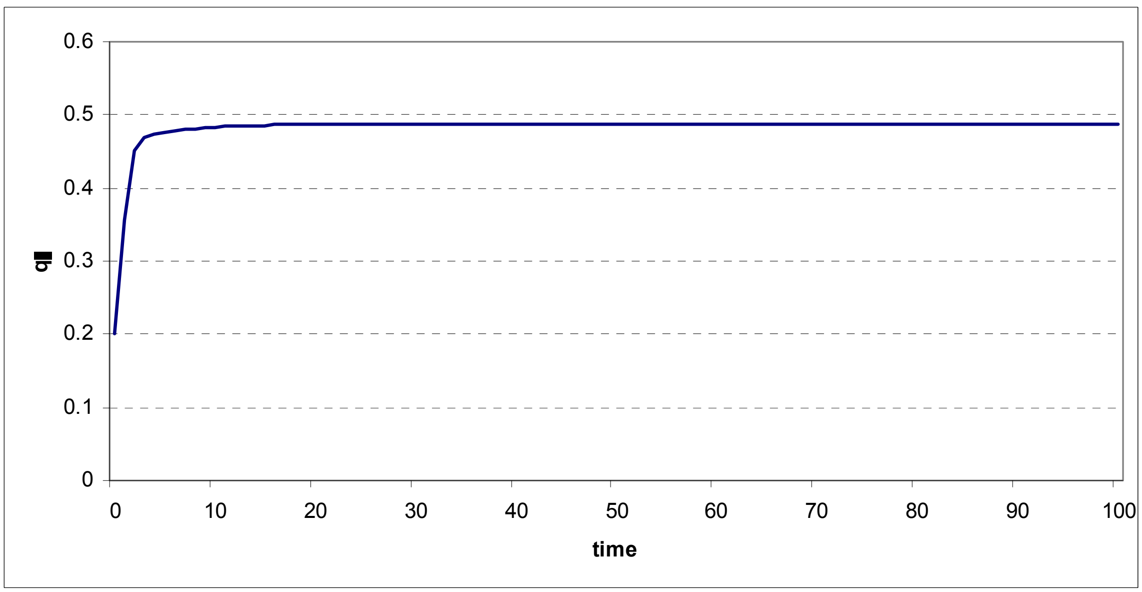

Figure A.2: Simulation of q_t

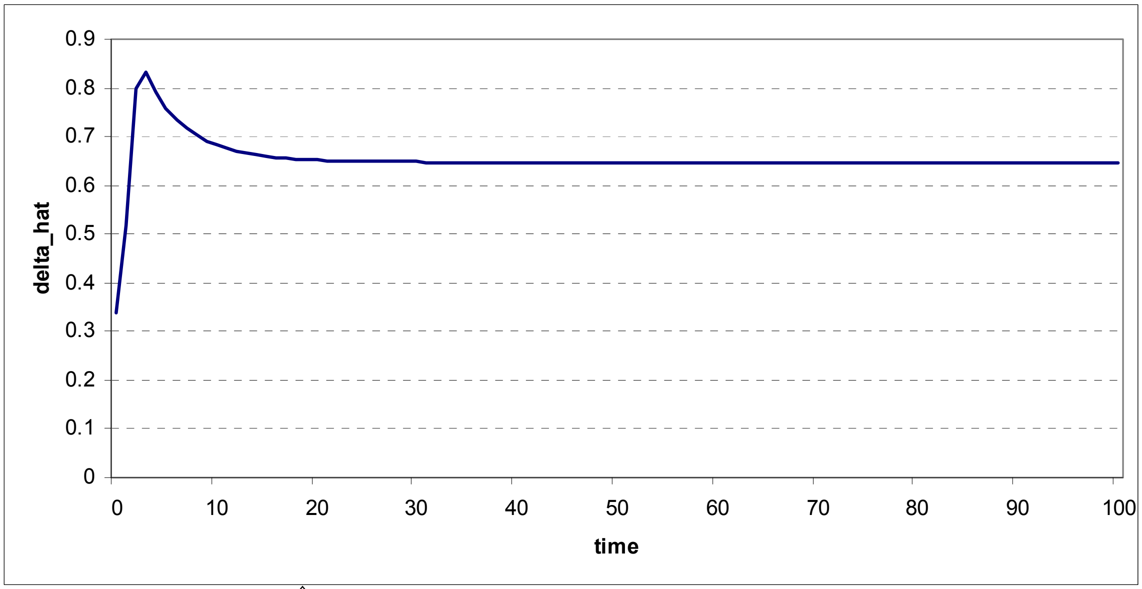

Figure A.3: Simulation of $\hat{\delta}(q_t, K_t)$