Essays on Productivity Change, Growth, and Development

by

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Dissertation

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To my parents.

Abstract

Essay 1: To replicate an industrial revolution: from exogenous to endogenous growth
In the last quarter of the second millennium many countries experienced, simultaneously, an industrial revolution (an exponential increase in the income per capita) *and* a demographic transition (an increase first and a decrease later of the population growth rate). How do we account for these facts? Following Lucas (2002b), I construct an overlapping generations model "from stagnation to growth", calibrate it, simulate the transition, and compare it with data for England between 1640 and 2000. The model can account fairly well for the joint movement of income per capita and population growth rates, as well as other dimensions of the data. The results emphasize the relevance of the costs of investment in human capital (costs of education), and suggest that the process of development can be understood as the passage from exogenous to endogenous growth. In this setting, the main anomaly is that the model generates higher income per capita growth rate during the 18$^{\text{th}}$ century than the one observed in the data.

Essay 2: Social ties and economic development (with Fernando Anjos)
This paper develops a general equilibrium model where the set of goods includes ties between economic agents (e.g., friendships or acquaintances). We refer broadly to these as social ties. A tie between any two agents is produced according to a technology that uses time from both parties. The model also assumes that social ties contribute toward social capital, which economizes on transaction costs between members of the same community. Our theoretical approach yields the existence of multiple equilibria, which can be interpreted as rational outcomes in societies with different cultural beliefs, in the sense of Greif (1994). We calibrate this model to data on social ties and income per capita for a cross section of 27 countries. Our main quantitative findings are the following: (i) heterogeneity in the average number of social ties can account for a significant portion of the heterogeneity in income per capita across countries; (ii) the model can account for between 1/5 and 1/2 of the changes in use of time in the United States between 1900 and 2000; (iii) according to one measure, the calibrated model implies that without social capital countries would be between 1/2 and 3/4 their actual size in terms of income per capita. Theoretically we have the following additional results: (i) a preference for social ties may significantly mitigate an other-

wise large underprovision of social capital; (ii) social capital is in some instances an important source of economic efficiency, very much complementary to labor and/or human capital; (iii) the elasticity of substitution between standard goods and social ties is an important determinant of the observed relationship between social capital and economic development; (iv) in some instances, an increase in productivity causes a decrease in welfare, via amplification of coordination failure in the production of social ties. Finally, in light of this model and our calibration, we conclude that social capital is mainly an externality of the consumption of social ties, and does not result from the agents' motivation to economize transaction costs.

Essay 3: Capital Accumulation, Sectoral Productivity, and the Relative Price of Non-Tradables: The Case of Argentina in the 90s
Kydland and Zarazaga (2002b) documented that in the 90s in Argentina large increases in total factor productivity (TFP) were accompanied by low investment. I try to solve this anomaly by disaggregating into two sectors, tradable and non-tradable sector, an otherwise standard dynamic general equilibrium model. This innovation is suggested by the highly different observed paths of TFP in each sector, which I document. I find that the model still can not account for the behavior of aggregate capital. This is mainly due to underinvestment in the tradable sector. Moreover, I find a second and quite robust anomaly: the simulated relative price of the non-tradable good (in terms of the tradable good) moves strongly opposite to the data. I found that this anomaly can not be solved by non-homothetic preferences, and contend that it would still hold in an open economy model. I end by suggesting a model in which the government sets the relative price of non-tradables by intervening in the markets for goods.

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Contents

Introduction

The three essays in this dissertation address the relationship between productivity change, growth and development. The first term refers to changes in the efficiency with which the factors of production (labor, physical capital, land) are used. The second term refers to the systematic increase in income per capita. The third term involves a host of processes, including structural, demographic, educational, and social change. Productivity change and income per capita growth present a tight relationship, in the sense that it is rare to observe one increasing without the other one increasing too. The association of both with development, though still strong, is less tight: Guatemala has a higher income per capita than Sri Lanka but a much lower literacy rate (Ray (1998)).

Even if some association is found between those terms, it is difficult to determine the direction of causality. Most of macroeconomics has focused on the causality from productivity change to income per capita growth, and from this to development (see, e.g., Greenwood and Seshadri (2005)). This is certainly the case in chapter 3, an exploration of the Argentinean performance in the 90s, in which sectoral productivity changes are taken as exogenous, and I compute the effects on capital per capita, income per capita, and prices. Exogenous is here just another word for unexplained. In this respect, I see the other chapters as both, an attempt in explaining productivity change, and as relaxations of the assumption about the direction of causality. Chapter 1, a theoretical quantitative exploration of the industrial revolution in England, starts by assuming some exogenous productivity change, which I associate to technical change. But soon enough individuals invest in human capital and, in this way, they increase their labor productivity endogenously. At that point, the increase in productivity is as much a consequence as a cause of income per capita growth. These changes are accompanied by structural (the passage from a primitive, land intensive, rural technology, to a modern, capital intensive, urban technology), demographic (the passage from high mortality-high fertility rates to low mortality-low fertility rates), and educational change (the passage from a negligible to a significant amount of time being used in investment in human capital). Again, without these developmental changes, both productivity and income per capita increases would be much milder.

In chapter 2 we provide evidence that, in a country cross-section, high income per capita is associated with a large *number* of social ties, and a low average *strength* of social ties. We enhance the discussion about causality between productivity and development by building a model in which social ties are both desired in themselves and technologically useful. Using this model we obtain that countries with different cultural beliefs with respect to the number of ties will present different rates of productivity change, by affecting the way individuals allocate their time. Causality goes, in this case, from social characteristics to productivity differences. Of course, nothing impedes to consider models in which causality runs in both directions. In fact, that is what this model implies, as productivity change determines social change, by affecting the strength of social ties. A concomitant structural change in this model is the increasing share of the transaction services sector vis à vis the transformational sector.

Models can be postulated in which causality runs in one, another, or in both directions. How do we test which model is true? We use the testable implications of the model. If the model can account simultaneously for many of the observables that can be related to the model, then it can be considered verified. In some occasions, the model may be rejected in some dimensions but still the causality postulated be right; some particularities of the model may need modification. In some other occasions, the anomalies may be robust to changes in the particularities of the model, and therefore the postulated causality should be questioned. In particular, this seems to be the case for the model in chapter 3. No matter how we specify the details of the model, the observed change in the relative price of non-tradables seems inconsistent with the observed changes in sectoral productivity, which suggests that these should not be postulated as the main drivers of the economy.

Something similar happens with the results of the model in chapter 1. Exogenous productivity change in the 18^{th} century can account for an increasing population growth rate but can not account for a stagnant income per capita, which leads us to conclude that that productivity change in the modern sector was probably not the main (or the only) engine of the economy.

The results of the model in chapter 2 also present anomalies. In particular, one version predicts that income per capita growth rates diminish in time (due to the decrease in effort), while the opposite is observed for early developed countries. However, this prediction can be modified by separating effort into labor and schooling, with the first diminishing and the second increasing in time, and with income per capita growth rates depending mainly on schooling. In this case, it would not be necessary to put into doubt the postulated direction of causality.

Chapter 1

To Replicate an Industrial Revolution: From Exogenous to Endogenous Growth

"When Paul Romer stresses "knowledge capital" as "blueprints", he is thinking of human capital at the most abstract and ethereal end of the spectrum: important additions to a society's human capital that are, for almost all of us, events that happen to us without our doing anything to bring them about. When another economist stresses improvements in literacy, he is thinking of human capital at the other end of the spectrum, far from Science with a capital S, capital that is accumulated only if many people devote their time and energy to doing so. *In any actual society, the accumulation of knowledge takes both of these extreme forms, as well as the range of possibilities in between, but it is only the second kind that can simultaneously also help us to explain the reduction in fertility that is essential to defeat the logic of Malthusian theory.*"

Robert Lucas (2002): "The Industrial Revolution: Past and Future", in *Lectures on Economic Growth*, pp. 159-160, my emphasis.

1.1 Introduction

England went in the last 200 years through an industrial revolution: from relatively constant living standards, income per capita increased dramatically, with growth rates systematically higher than in any previous period in world history. Concurrently, the country went in the last 300 years through a demographic transition: from slow growth, population increased strongly first and later it stabilized, with growth rates increasing first and later diminishing.

Can we account for these changing growth rates of population and income per capita? Can we account for the synchronization between the industrial revolution and the demographic transition? More specifically, can we construct a model that replicates quantitatively these facts?

In this paper I propose such a model, calibrate it, and simulate time series to compare with data. It is essentially an overlapping generations version of Lucas (2002b) model. This model presents two steady states, a stagnant Malthusian steady state and a positive constant growth steady state. I will associate the industrial revolution and the demographic transition to the transition in the model, from the stagnant steady state to the growth steady state.

Lucas (2002b) model has two main components: altruistic preferences that lead to a quantity-quality children trade-off (à la Becker, Murphy, and Tamura (1990)), and two technologies for good production (à la Hansen and Prescott (2002)): a primitive technology that only uses land as capital input, and has decreasing returns on it; and a modern technology that only uses human capital as capital input, and has constant returns on it.

The two components that I incorporate into the model are: (i) some secular exogenous growth of the modern technology; and (ii) costs of education. Some exogenous modern technological growth is sometimes necessary to change the basin of attraction of steady states. Costs of education are necessary to postpone the quality-quantity children substitution, and therefore obtain not only a decrease in population growth rate in the last 150 years, but also an increase in it in the previous 150 years.

The model simulation induces the following overall description of England's development. First, for a long time (pre-1640), land was important in production, and therefore population growth was constrained by its relative fix quantity. During this time the primitive technology improved by spurts and this can account for the increases in population, which were small when compared to the increases in the period 1750-1900. During this period, the modern technology was being improved though still not used. Second, around 1640, the modern technology became profitable and some people allocated labor to it. However, during this time, the costs of education in goods and time were high enough for people to invest minimally in human capital. Therefore the continuous (though rather small by modern standards) exogenous increase in modern technology productivity level translated mainly in an increase in population growth rate. Third, around 1800 it became profitable to invest endogenously in human capital, and, in the next 200 years, we will see the substitution of quantity for quality of children, associated with an increase in the growth rate of human capital (and income per capita) and a decrease in the growth rate of population.

In the model the "engine" of the economy is exogenous technical change first, and a mix of endogenous human capital and exogenous technical change later. I associate each of these engines with the two types of human capital distinguished by Lucas in the quote above. The first type (that I call technical change) does not imply a cost for the individual that benefits from it, while the second (which I call human capital) does.

I contend that my paper is a contribution in the following lines. First, it puts data and simulation next to each other, something rarely done for unified models of growth. Second, by using a model that endogeneizes population growth rate and a large part of the modern productivity growth rates, it increases the dimensions on which the model can be evaluated, by contrast to models that assume exogeneity of either population growth or productivity growth, or both (e.g., Hansen and Prescott (2002)). Third, it proposes a specific mechanism, exogenous productivity change, that drives the economy from stagnation to growth, and assesses the strengths and weaknesses of this explanation. We consider that the effects of this mechanism should be then compared to the consequences of alternatives (e.g., exogenous mortality changes, endogenous preferences [Doepke and Zilibotti (2008)], or endogenous technical change [Galor and Weil (2000) and Lagerlöf (2006)]), and decide which accords better with available evidence.

The paper is built as follows. Section 1.2 shows the big picture for England between 1640 and 2000. Section 1.3 presents the model and its solution. In Section 1.4 I calibrate the model, and in section 1.5 I present the results. I discuss some more general issues and conclude in section 1.6.

1.2 The big picture

Figures 1.1 and 1.2 present the big picture for England between 1640 and 2000. The former shows the population growth rate (every 20 years), and the latter shows the income per capita growth rate (every 20 years).[1]

Four stages can be distinguished. (i) Between 1640 and 1740 the population growth rate is low (an average of less than 3% every 20 years), while the income per capita presents growth spurts in the periods 1640-1680 and 1700-1720, but no systematic growth of the type we observe later. (ii) Between 1740 and 1820 the population growth rate increases dramatically and steadily from around 4% to near 40% every 20 years, while the income per capita presents a growth spurt in the period 1740-1760, but its growth is otherwise insignificant. (iii) Between 1820 and 1900 the population growth rate starts to decline slowly but it is still high by historical standards (between 25% and 35% every 20 years), while the income per capita growth rate increases and remains steady at a new level around 20% every 20 years. (iv) Between 1900 and 2000 the population growth rate diminishes from 25% to 5%, while the income per capita growth rate reaches a new higher platform at around 60% every 20 years.[2]

[1] Appendix 3.A.1 describes the sources and construction of the data.

[2] I ignored in this description the post-I World War depression, arguably the hardest for England in its modern history, as I am interested in longer term trends.

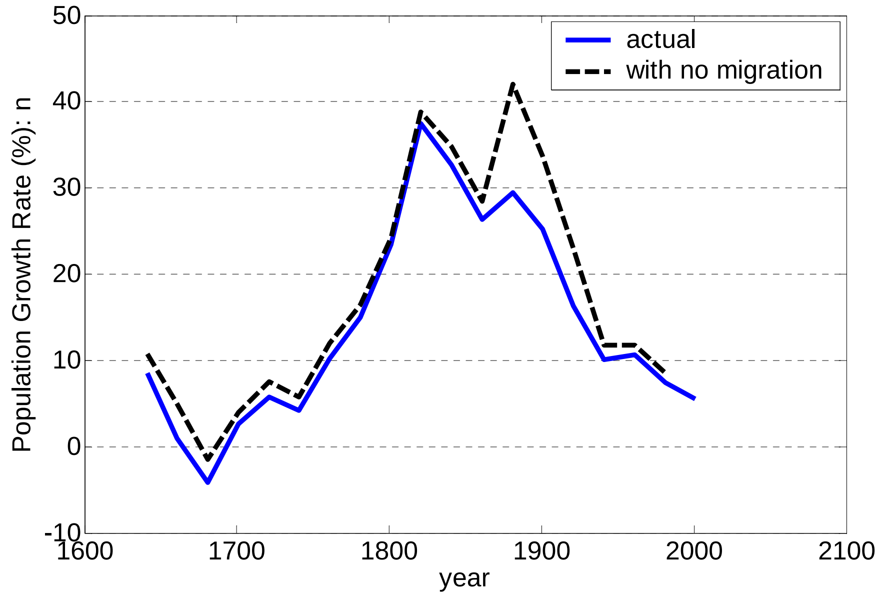


Figure 1.1: England, 1640-2000. Population growth rate (every 20 years, %).

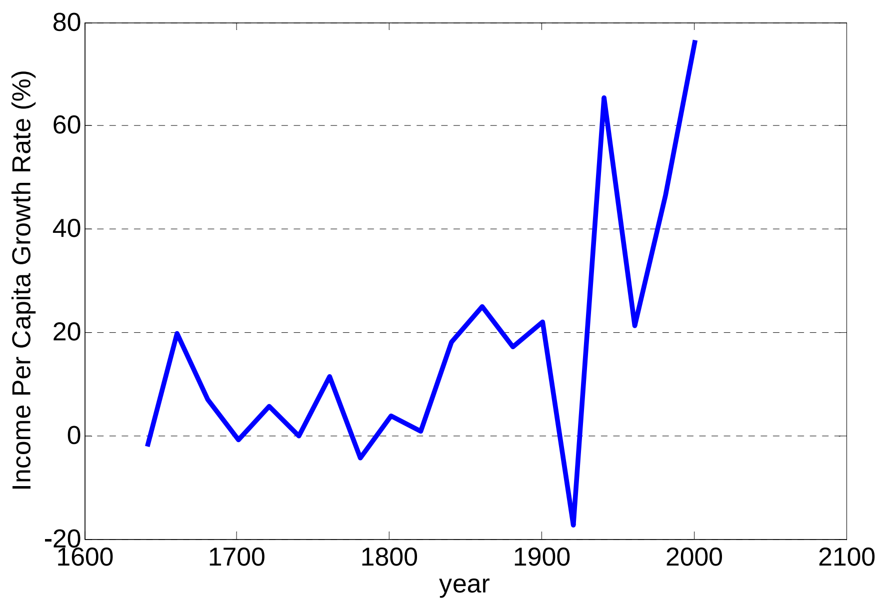


Figure 1.2: England, 1640-2000. Income per capita growth rate (every 20 years, %).

The overall picture is of population growth rate being small between 1640 and 1740, increasing between 1740 and 1820, stabilizing between 1820 and 1900 and clearly decreasing between 1900 and 2000. This hump-shape curve of the population growth rate is the main characteristic of what is called the demographic transition. Meanwhile the income per capita presents some isolated increases in the period 1640-1820, systematic growth at around 20% in 1820-1900, and systematic growth at around 60% in the post-II World War period.

The importance of the systematically positive income per capita growth rates and its increase is well apprehended: there is no other 200-years-period in human history where the material world has changed so much as in the last 200. The importance of the changes in population growth rate can be emphasized by reference to two other population phenomena, migration and the so-called baby-boom. Figure 1.1 also shows the population growth rate if there were not have been net outward migration. While the difference with the actual population growth rate is significant (especially in the second half of the 19^{th} century), it does not change the hump-shape form of the curve. In other words, fertility and mortality are more important than migration to account for the long-term changes in the population growth rate. The baby-boom is another population phenomenon that has been profusely studied by economists lately. It is observed, however, that the change in population growth rate due to it is minimal when we consider the long term trends of three centuries: between 1941 and 1961 the downward trend just slowed down a bit.[3]

These, the simultaneous changes in the population and in the income per capita growth rates, are the facts that we want to explain. Can we construct a model to account for them? Can we understand the forces that drive them? Can we understand the synchronicity between both series?

1.3 The model

I propose an overlapping generations version of Lucas (2002b) dynastic model. The economy is inhabited in each period by two generations, parents and children. Only parents make decisions. The parents care for their own good consumption (c), for the quantity of children (n), and for the amount of two assets, land (x) and human capital (h), that they transfer to their children. Thus, each parent in period t maximizes utility

[3] I would like to mention that most of the developed countries have gone through a demographic transition. The pervasiveness of this phenomenon is illustrated, for example, by Chesnais (1992), figures 8.10 and 10.2.

$$u_t = U(c_t, n_t, x_{t+1}, h_{t+1}) = c_t^{1-\beta} n_t^{\eta} \big(x_{t+1}^{\theta} h_{t+1}^{1-\theta}\big)^{\beta}, \tag{1.1}$$

with $0 < \beta < 1$, $0 < \theta < 1$, and $\eta > 0$.

The overlapping generations model with parents caring directly for the assets of their children in the way considered (Cobb-Douglas) has two advantages over a dynastic model in terms of realism: first, human capital can have a direct consumption effect, and parents have therefore a reason to invest in their children's human capital even if the productivity of labor is not increased by it (as we think it may have happened in Malthusian times); second, land can also have a direct consumption effect, and therefore the price of land does not go to zero, even if it is not useful in production, as it may be happening in modern times.

Each parent must make four decisions: how many descendants (or surviving children) to have (n)? how much to consume (c)? how much to work (l)? and how much time to invest in the human capital of each of his descendants (r)?

Each parent is endowed with one unit of time, with a piece of land (x) and with human capital (h). Thus, the person will maximize his utility subject to a time constraint,

$$l_t + r_t n_t + S n_t + T r_t \leq 1, \tag{1.2}$$

and a budget constraint,

$$c_t + k n_t + q r_t \leq y_t = F(x_t, B_t, h_t, l_t), \tag{1.3}$$

where y is output, $F(x, B, h, l)$ is a production function that I will describe below, k and q are good costs of children and investment in human capital respectively, and S and T are time costs of children and investment in human capital respectively.[4]

Across generations, human capital is accumulated with the parent's human capital

[4] An example of a good cost of children (k) is food; an example of a time cost of children (S) is breast-feeding; an example of a good cost of investing in human capital (q) is materials for study; an example of time cost of investment in human capital (r) is time spent by a parent reading to her child; an example of time cost of investment in human capital (independent of the number of children) (T) is going to high school or college. Observe that we will interpret Tr as schooling and that the objective of it is for parents to be able to *transmit* their own human capital (not to acquire it). This interpretation is consistent with observations of parents going to college, marrying afterwards, but never using their acquired skills in the market. However, they probably use them in transmitting knowledge and attitudes to their offspring.

and time investment as inputs, and land is split among descendants

$$h_{t+1} = h_t \psi(r_t) = h_t (C r_t)^{\epsilon}, \tag{1.4}$$

and

$$x_{t+1} = \frac{x_t}{n_t}, \tag{1.5}$$

with $\epsilon < 1$ and $C > 0$. Observe that the exponent of h_t in (1.4) is one; this is, of course, necessary to obtain a permanent growth steady state. Also observe that we are ignoring depreciation of human capital. ϵ measures the time elasticity of children's human capital.

Each parent must choose to allocate labor between two technologies that produce the only consumption good: a primitive, Malthusian technology, F^M, that uses labor and land as inputs,

$$y_t^M = F^M(x_t, l_t^M) = A {x_t}^{\alpha} {l_t^M}^{1-\alpha}, \tag{1.6}$$

with $0 < \alpha < 1$; and a modern technology, F^G, that uses efficiency units of labor (that is, labor enhanced by human capital) as only input,

$$y_t^G = F^G(h_t, B_t, l_t^G) = B_t h_t l_t^G. \tag{1.7}$$

These technological setup is very similar to the one proposed by Hansen and Prescott (2002), with the difference that a modern "Solow" technology is replaced by a modern, "Ak" technology. Of course, l^M and l^G must sum to l, and y^M and y^G will be added to obtain y. The "rationale" for these technologies is straightforward: F^M will be the only technology used in a stagnant steady state and F^G will be the only technology used in a permanent growth steady state.

Finally, the exogenous technological level in the modern sector, B, will follow the process

$$B_{t+1} = (1+\delta) B_t. \tag{1.8}$$

1.3.1 Solution

At each period t a parent takes as given his assets, x and h, and the efficiency level of the modern sector, B, and chooses consumption (c), labor in each sector (l^M and l^G), number of descendants (n) and investment in their human capital (r), to maximize utility (1.1), given the constraints (1.2) and (1.3), the laws of motion (1.4), (1.5), and (1.8), and the production functions (1.6) and (1.7).

I consider first the decision of allocation of labor between technologies. The marginal product of labor in each technology are $(1-\alpha)A(x/l^M)^\alpha$ and Bh. If both technologies are used, then these two values have to be equal and $l^M = \left(\frac{(1-\alpha)A}{Bh}\right)^{1/\alpha} x$. If only one technology is used, that will be F^M, and $l^M = l$. This will be the case if

$$\left(\frac{(1-\alpha)A}{Bh}\right)^{1/\alpha} x \geq l. \tag{1.9}$$

Therefore output will be

$$F(x,B,h,l) = \begin{cases} Ax^\alpha l^{1-\alpha} & \text{if } \left(\frac{(1-\alpha)A}{Bh}\right)^{1/\alpha} x \geq l; \\ Bhl + D(Bh)^{1-\frac{1}{\alpha}} x & \text{if } \left(\frac{(1-\alpha)A}{Bh}\right)^{1/\alpha} x < l; \end{cases}$$

with

$$D = \alpha(1-\alpha)^{\frac{1}{\alpha}-1} A^{\frac{1}{\alpha}}. \tag{1.10}$$

Observe that, in one case, human capital will not be utilized at all, and that, in the other case, the term including land per capita will be very small if h is big enough (considering $0 < \alpha < 1$).

I proceed to consider the problem of choosing the number of descendants and the time investment in their human capital. I will express the utility function in logarithmic form, and replace the constraints and laws of motion into the objective function

$$\begin{aligned} V(n,r,B,x,h) &= \max_{n,r} (1-\beta)\ln[F(x,B,h,1-rn-Sn-Tr) - kn - qr] + \\ &\quad +\eta \ln n + \beta\theta \ln \frac{x}{n} + \beta(1-\theta)\ln(h\psi(r)). \end{aligned} \tag{1.11}$$

The first order conditions (with respect to n and r respectively) are

$$(1-\beta)[F_l(x,B,h,1-rn-Sn-Tr)(r+S) + k] = (\eta - \beta\theta)\frac{c}{n}, \tag{1.12}$$

and

$$(1-\beta)[F_l(x,B,h,1-rn-Sn-Tr)(n+T) + q] = \beta(1-\theta)c\frac{\psi'(r)}{\psi(r)}. \tag{1.13}$$

The first equation indicates that the marginal cost of having a child in terms of foregone labor earnings and foregone consumption (on the left hand side) must equalize the marginal net benefits (on the right hand side), which comprises a higher utility of having an additional child but a lower utility due to the fact that that child will have less land. The second equation indicates that the marginal cost of investing in the human capital of the children, again in terms of foregone labor earnings and foregone consumption (on the left hand side), must equalize the marginal benefit of that additional investment, in terms of a higher quality of the children (on the right hand side).

From these first order conditions we can obtain policy functions $n^*(x, B, h)$ and $r^*(x, B, h)$. These conditions will be sufficient to find a maximum to the problem (1.11) if we verify that at (n^*, r^*)

$$\frac{d^2V}{dn^2} < 0,$$

and

$$Det = \frac{d^2V}{dn^2}\frac{d^2V}{dr^2} - \frac{d^2V}{dndr} > 0. \tag{1.14}$$

1.3.2 Two steady states

I will consider two steady states of this problem. One steady state will be characterized by low accumulation of human capital, r^M small, constant population growth rate n^G, and the efficiency level of the modern technology, B, sufficiently small such that only the primitive technology F^M is used. The other steady state will be characterized by high accumulation of capital, constant and relatively large r^G, constant population growth rate n^G, and only the modern technology F^G used in production.

If B is sufficiently small only the primitive technology is used and (1.12)-(1.13) can be written as

$$(1-\beta)\left[(1-\alpha)A\left(\frac{x^M}{1-r^Mn^M-Sn^M-Tr^M}\right)^{\alpha}(r^M+S)+k\right] = (\eta-\beta\theta)\frac{c^M}{n^M}, \tag{1.15}$$

and

$$(1-\beta)\left[(1-\alpha)A\left(\frac{x^M}{1-r^M n^M - Sn^M - Tr^M}\right)^{\alpha}(n^M+T)+q\right] = \beta(1-\theta)c^M\frac{\psi'(r^M)}{\psi(r^M)}. \tag{1.16}$$

Given parameter values and the amount of land per capita in the stagnant state (x^M), we can obtain r^M and n^M from these equations.[5]

If the efficiency of modern technology, B, is sufficiently large, there will be a new reason to accumulate human capital: now it will be useful in production. We will look now for a steady state with large human capital (and growing at a constant rate) and constant values for population growth rate, n^G, and investment in human capital, r^G. In the limit ($\lim_{h\to\infty}$), equations (1.12) and (1.13) can be written as

$$(1-\beta)(r^G+S) = (\eta-\beta\theta)\frac{(1-r^G n^G - Sn^G - Tr^G)}{n^G}, \tag{1.17}$$

and

$$(1-\beta)(n^G+T) = \beta(1-\theta)\frac{\psi'(r^G)}{\psi(r^G)}(1-r^G n^G - Sn^G - Tr^G). \tag{1.18}$$

Given parameter values, we can obtain r^G and n^G from these equations.

Given an initial value for land per capita, x^M, initial values for human capital, h_0, and the efficiency of the modern sector, B_0, and specific functional forms and parameter values, I can obtain transition paths for r, n, c, l^M, l^G, h and x. r, n and $l(= l^M + l^G)$ will converge to r^G, n^G and l^G, while the growth rates of h and c will converge to the growth rates in the permanent growth steady state.

1.4 Calibration

I will compare simulated and England's time series between 1640 and 2000. I set a period to comprise 20 years. We will assume that individuals live for 35 years (the average life expectancy between 1540 and 1780 in England). The first 15 years they are considered children. The following 20 they are considered adults. Adults have children when they are 20 years old, such that they die at the exact moment that their children become adults. These can allocate their time in four activities: rearing

[5] Taking into account equation (1.3), observe that c^M, consumption in the Malthusian state, also depends only on n^M, r^M, and x^M.

children, educating children, schooling, and labor.

Some of the parameters (α, ϵ, θ, and δ) are set "outside" the model, while others (β, C, η, k, A, S, T, q, and the values r^M and r^G) are set "inside" the model, by calibrating them using observations and steady state conditions.

The calibration of the model proceeds in the following way. First, I choose units of measure for x, c, and h such that $x^M = c^M = h^M = 1$.

Second, I determine observables in the steady states. I consider that population growth rates are zero in the Malthusian and in the permanent growth steady states; that is, we will start and finish with stationary populations, $n^M = n^G = 1$. I take into account use of time in the period 1980-2000 as an approximation to the use of time in the growth steady state. I will use data for the United States during that period, provided by Ramey and Francis (2008). I used this data because they have constructed representative agent series. I have checked that this data is roughly consistent with use of time data for United Kingdom (ONS (2006)). The model prescribes four uses of time; I identify labor (l^G) as the sum of market and home work, excluding child care (81.8% of non-leisure, non-personal care time); essential child care (Sn^G) as primary child care (4.6%); parent's time investment in human capital ($r^G n^G$) as educational and recreational child care (1.9%); and parent's training (Tr^G) as schooling (11.7%).[6] I will consider a constant growth rate of income per capita in the growth steady state equal to the growth rate in the last 40 years, around 2.4% annually, and 61% every 20 years.

Third, I choose parameters outside the model. I set the income share of land in a Malthusian economy, α, to 0.3, considering the value informed by Doepke (2004), based on income share of land (rents) in 1688. I set the value of the elasticity of human capital with respect to time investment, ϵ, to 0.95, based on the value estimated by Heckman, Lochner, and Taber (1998). This value is towards the upper bound of the range considered in the micro-literature for this parameter. Browning, Hansen, and Heckman (1999) give information of a series of micro-studies that estimate it to be between 0.5 and 0.99. I set the preference parameter, θ, to a value of 0.12. This is the

[6] My main concern with this distribution of time is if educational and recreational child care is not underestimated and basic child care overestimated. This might be the case for two reasons: first, part of basic child care might be investment in human capital (e.g., health) and therefore it should be better characterized as parent's time investment in human capital; second, I am using primary activity classification, but it seems probable that a lot of education at the home can be done as a secondary activity. For these two reasons I will consider an alternative in which parent's time investment in human capital accounts for 4% of time used in the growth steady state and essential child care for 2.5% (that is, I consider almost half of primary child care as investment in human capital).

share of land wealth (including urban land and ignoring physical capital) in total wealth for Western Europe in the year 1994, as informed by Hamilton and Dixon (2003). I will do sensitivity analysis with respect to this last parameter.

Fourth, I used observations and conditions in steady state to pin down most of the parameters. The distribution of time use in the growth steady state (described above) allows us to pin down r^G (0.018), S (0.046) and T (6.34). β is calibrated using equation (1.18); C using equation (1.4) evaluated at the growth steady state; and η using equation (1.17). I calibrated q, simultaneously with A, k, and the value r^M in the following way. Schultz (1960) estimates that 3/5 of total expenditures in education in the US in 1956 were foregone earnings (opportunity cost, wTr, with w the real wage), while 2/5 were direct costs (services of teachers and annual cost of plants, qr). Denoting with w the price of raw labor, considering that in 1955 the wage for a helper (a low skill worker) in the building industry was roughly 7 times that in 1640 (Clark (2005)), and identifying the wage in 1640 with the marginal product of labor in the primitive sector ($w_{1640} = A(1-\alpha)x^{M\alpha}l^{M-\alpha}$), the following condition must hold:

$$\frac{w_{1956}Tr}{w_{1956}Tr + qr} = \frac{w_{1956}T}{w_{1956}T + q} = \frac{7w_{1640}T}{7w_{1640}T + q} = \frac{3}{5}. \tag{1.19}$$

I used equation (1.19), with the the budget constraint (1.3) in the Malthusian steady state, and first order conditions (1.15) and (1.16) to obtain simultaneously parameters A, k, q, and the value for r^M.

The values are presented in table 1.1. A value of 0.44 for β is reasonable, an equivalent of a yearly discount of 0.96, well in the range usually considered. The good cost of investing in human capital ($q = 22.7$) results large but not improbable. If a person in Malthusian times would have wanted to increase the human capital of his child by the percentage amount that it is increased in present societies (34% every 20 years) he would have to reduce his consumption 43% ($\frac{qr^G}{c^M} = 0.43$). The cost was sufficiently large though to make the investment in human capital in Malthusian times extremely small ($r^M = 7.0E-10$).

I keep two "free" values. One is the rate of growth of the level of technology in the modern sector, δ. I set this parameter to 0.2 to capture the upward slope of population growth rate in the 18$^{\text{th}}$ century. I will show the consequences of changing this parameter.

The other free value is the initial value for B. I will set this initial value such that the Malthusian steady state is abandoned in 1640. I will set B_0 so that in 1640 the

Parameter	Benchmark	With no exog. growth	Target
Malthusian Steady State			
x^M	1	1	choose units
c^M	1	1	choose units
n^M	1	1	stationary population
r^M	7.0E-10	0.009	equations (1.15), (1.16), (1.3), and (1.19)
h^M	1	1	choose units
Growth Steady State			
n^G	1	1	stationary population
r^G	0.018	0.04	use of time 1980-2000
$\frac{\dot{y}}{y}$	0.61	0.61	average growth rate 1960-2000
Steady States and Transition			
β	0.44	0.38	equation (1.18)
α	0.3	0.3	land share of income, year 1688
η	0.097	0.094	equation (1.17)
k	0.044	0.052	equations (1.15), (1.16), (1.3), and (1.19)
A	1.08	1.13	equations (1.15), (1.16), (1.3), and (1.19)
S	0.046	0.025	use of time 1980-2000
C	17.5	14.86	equation (1.4)
ϵ	0.95	0.95	micro-studies
δ	0.2	0	free
T	6.34	2.93	use of time 1980-2000
q	22.7	4.09	equation (1.15), (1.16), (1.3), and (1.19)
θ	0.12	0.12	land share of wealth 1994

Table 1.1: Parameter and steady state values.

inequality (1.9) is reversed. This election is supported by Clark (2005): "Comparing wages with population, however, suggests that the break from the technological stagnation of the Malthusian era came around 1640, long before the classic Industrial Revolution, and even before the arrival of modern democracy in 1689".

1.5 Results

1.5.1 Benchmark

Figures 1.3, 1.4 and 1.5 present the results for the benchmark parametrization. The left panel of figure 1.3 shows the time series for the population growth rate. In 1640 the Malthusian state is abandoned and population growth rate slightly diminishes. Thereafter, it increases by the end of the 17th century and during the whole 18th century, to start to diminish in the second part of the 19th century, and to drop strongly during the 20th century. The simulated series accord well with the data.

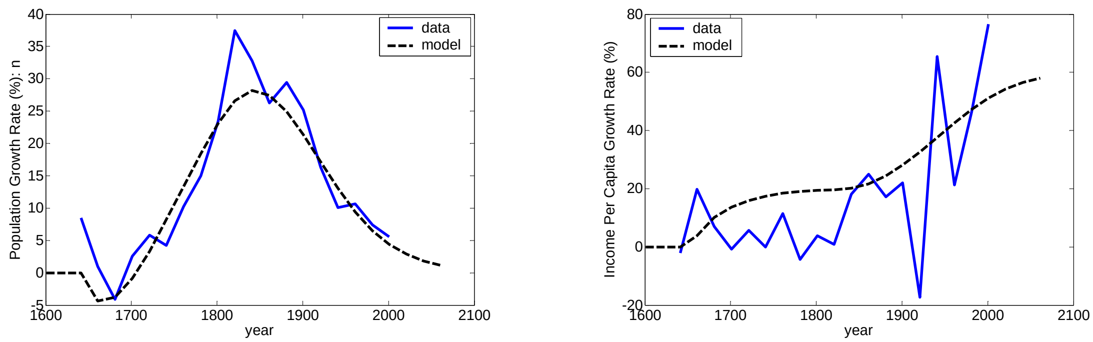


Figure 1.3: Comparing model and data. Growth rates, England, 1640-2000. Left panel: population growth rate (every 20 years, %). Right panel: income per capita growth rate (every 20 years, %)

The right panel of figure 1.3 shows the time series for income per capita growth rate. It increases during the second half of the 17th century, it stabilizes at near 20% (every 20 years) for most of the 18th century, and it increases gradually again since 1820 up to 2000. The model captures well the acceleration of the income per capita growth rate at the beginning of the 19th century. It fails at two points: (i) understandably, it does not capture the slowdown in the interwar period in the 20th century, which involves mainly the post-I World War depression; (ii) more importantly, it predicts a systematic increase in income per capita during the 18th century, while the evidence indicates that living standards increased only by spurts, and in a much lesser amount, during that period.

Figure 1.4 presents the simulation with respect to use of time. Labor per capita (left panel) increases slightly first due to an increase in labor demand as the new technology starts to be used after 1640. Later, in the 18th century, it decreases gradually due to the allocation of time to rear the increasing number of children; thereafter, in the 19th and 20th century, labor decreases drastically as more time is dedicated to schooling. While up to 1800 the investment in human capital (right panel) was insignificant, we can observe a "take-off" in the human capital investment in the beginning of the 19th century. Table 1.2 compares the changes between 1900-1920 and 2000-1980 with those of data for United States, as provided by Ramey and Francis (2008). This comparison

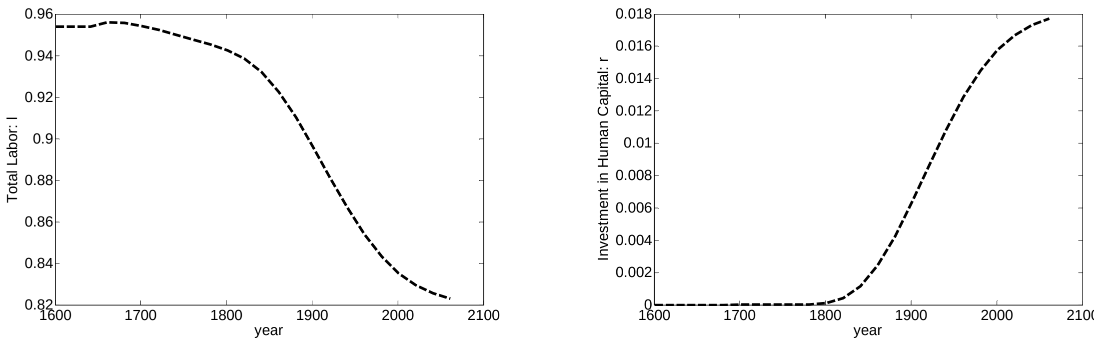


Figure 1.4: Model simulation. Shares of time use, England, 1640-2000. Left panel: labor per capita. Right panel: investment in human capital per capita.

assumes that the United States had caught up with England by 1900 and that they evolved similarly since then.[7] While in the data, in the 20$^{\text{th}}$ century, average hours worked (market plus home) decreased by 3%, and schooling time increased by 74%, in the model the corresponding values are 6% and 103%. Clearly, the order of magnitude of changes in use of time is captured correctly.

	Labor		Schooling	
	Data	Model	Data	Model
1900-1920	36.9	0.89	2.7	0.05
1980-2000	35.6	0.84	4.7	0.10
Change (%)	-3.4	-5.6	74	103

Table 1.2: Comparing model and data. Time use change. Data: weekly hours per capita. Model: shares in total non-leisure, non-personal care time.

The left panel of figure 1.5 shows the labor productivity growth rate decomposed into its exogenous and endogenous components. While until the first years of 1800 practically all growth is exogenous, by then it has become profitable to invest in human capital, and therefore during the next two centuries a large part of productivity growth becomes endogenous. By 2000 more than 1/2 of the growth rate is endogenous. I included in the figure the population growth rate, which starts declining simultaneously

[7] I do this comparison to check that the order of magnitude of the changes accords with the data. I used the data of Ramey and Francis (2008) because they put careful attention in constructing series of averages that involve the whole population.

with the increase in the growth rate of human capital, an illustration of the children quantity-quality substitution.

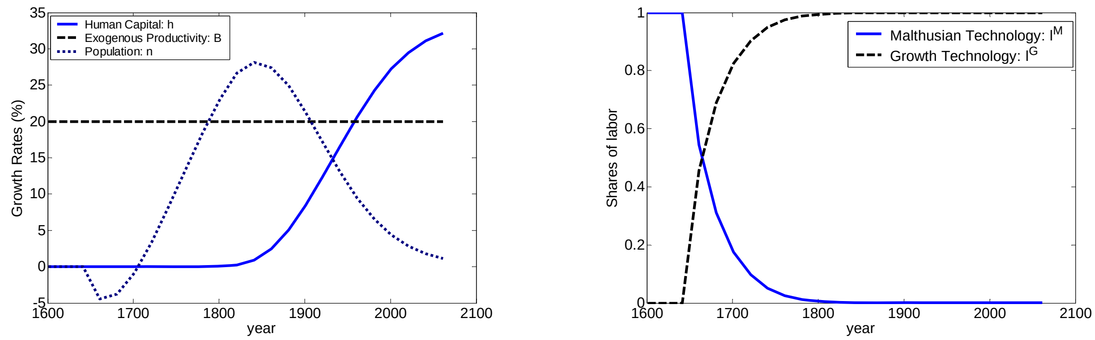


Figure 1.5: Left panel: it shows the growth rates of human capital, exogenous productivity and population. Right panel: it shows share of labor allocated to each technology.

Overall, the model can account for the data reasonably well. It can account for a demographic transition as well as an industrial revolution. It can account for decreasing working time and an increasing amount of time used in accumulation of human capital. It can account, of course, for a decreasing land per capita.

There are two aspects though where model and data do not accord. First, as I said, simulated income per capita grows too much in the 18^{th} century. Table 1.4 provides a comparison between data and simulated series, for both population and income per capita growth rates. The values for data and model are roughly similar, except for income per capita in the period 1740-1820 (highlighted). While in the data living standards seem to have increased around 17%, in the model there is an increase of around 101%. One may view this anomaly as a consequence of the early abandonment of the Malthusian state, which I set to occur in 1640, as suggested by Clark (2005). In both, model and data, there is similar growth in the period 1640-1700, of around 30% (not shown in table); but then, during the 18^{th} century, growth almost vanishes in the data and continues in the model. The alternative is to postpone the abandonment of the Malthusian state until the 19^{th} century, but, of course, under the present calibration, this will postpone as well the increase in population growth rate to that century.

In other words, if we consider the dramatic increase of population growth rate in the 18^{th} century as part of the phenomena of the Industrial Revolution, then the abandonment of the Malthusian state has to have happened around 1650-1700. But, under a process of exogenous growth rate, we will have an increase in both, population growth

	Income per capita growth rate		Population growth rate	
	Data	Model	Data	Model
1640-1740	34	77	10	2
1740-1820	**17**	**101**	115	109
1820-1900	110	132	172	148
1900-2000	330	479	61	61

Table 1.3: Comparing model and data. England 1640-2000. Income per capita and population growth rates (%).

and income per capita growth rates. While some of the latter actually happened in the second half of the 17th century, it stalled during the 18th century. Alternatively, the increase in population growth rate might be excluded from being a part of the Industrial Revolution phenomena, and some other process should be assumed to understand the strong population growth in a Malthusian environment, as well as the relationship with the posterior dramatic change in living standards. I will suggest alternative explanations that might help solving this anomaly in the discussion section, below.[8]

Second, somewhat related, in the model, most of the redistribution of labor between the traditional and the modern sector happens in the period between 1640 and 1800 (see right panel of figure 1.5). If one interprets the traditional and modern sectors as rural and urban sectors respectively the timing is decisively incorrect: while in the model the share of labor in modern sector is 60% in 1700 and 95% in 1800, in the data the shares of labor in the urban sector are only around 15% in 1700 and 30% in 1800 (Bairoch (1988)). It can be argued that the traditional sector should be interpreted in a more stringent way: production is done without capital. But even in that case, there is nothing in historical accounts of the period between 1640 and 1800 that tells that, from being negligible, capital became a fundamental input for almost all production. I consider that this structural change happens too early in the model. Therefore further research should be concerned with both, measuring the labor and output shares of the traditional and the modern sector, and looking for a process to delay this structural

[8] I would like to note that *all* theories that postulate an increase in exogenous productivity (and income) in the modern sector as the main factor explaining the increase in population growth will fail accounting for the fact that the strong increase in population growth rate precedes the strong increase in income per capita growth rates by almost a century. In particular, this is the case with Hansen and Prescott (2002), who propose a decision rule that makes population growth dependent on income per capita, but the anomaly was not uncovered because they do not compare model and data for the relevant period (see their figure 5).

change.

1.5.2 The effect of productivity on population growth rate

Why do we obtain a demographic transition in this model with this calibration? In this section I will answer this question by obtaining the derivative of population growth rate with respect to productivity (in the modern sector), and describing the different phases of development.

From equations (1.12) and (1.13) we can obtain policy functions $n(x,z)$ and $r(x,z)$, with $z = Bh$. (Budget constraints will give us policy functions $l(x,z)$ and $c(x,z)$ for labor and consumption respectively). We can write then the partial derivative of the population growth rate policy function with respect to (modern technology) productivity as

$$
\begin{aligned}
G\frac{dn}{dz} = {} & \frac{(1-\beta)\left\{\left[l + D\left(1-\frac{1}{\alpha}\right)z^{-\frac{1}{\alpha}}x\right]\left(z\left(r+S\right)+k\right)\right\}}{c^2} && \text{(income effect)} \\
& -\frac{(1-\beta)\left(r+S\right)}{c} && \text{(labor-children subst.)} \\
& -\frac{(1-\beta)\left[\left(z\left(n+T\right)+q\right)\left(z\left(r+S\right)+k\right)+zc\right]\frac{dr}{dz}}{c^2} && \text{(children qq subst.)}, \quad (1.20)
\end{aligned}
$$

where

$$
G = \frac{(\eta-\beta\theta)}{n^2} + \frac{(1-\beta)(z(r+S)+k)^2}{c^2} \tag{1.21}
$$

and $D > 0$ as defined in (1.10).

G is always positive[9], so the sign of $\frac{dn}{dz}$ will depend on the right hand side of (1.20). The first term is positive (or zero) and it can be considered an income effect: higher productivity induces higher demand for children.[10] The second term is negative and it can be considered a substitution effect, time substitution between rearing children and labor. The last term depends on $\frac{dr}{dz}$ and is always non-positive; this is the children quantity-quality substitution.

The dashed line in figure 1.6 shows $\frac{dr}{dz}$ for different values of z (and x set to 1) for the benchmark parametrization. It is observed that even after the modern technology

[9] $\eta - \beta\theta > 0$ for parents to have children at all.

[10] The derivative holds when the modern technology is being used. In that case expression (1.9) does not hold. It can be easily shown then that the term in square brackets in the first line is positive. In fact, it is zero when (1.9) holds with equality.

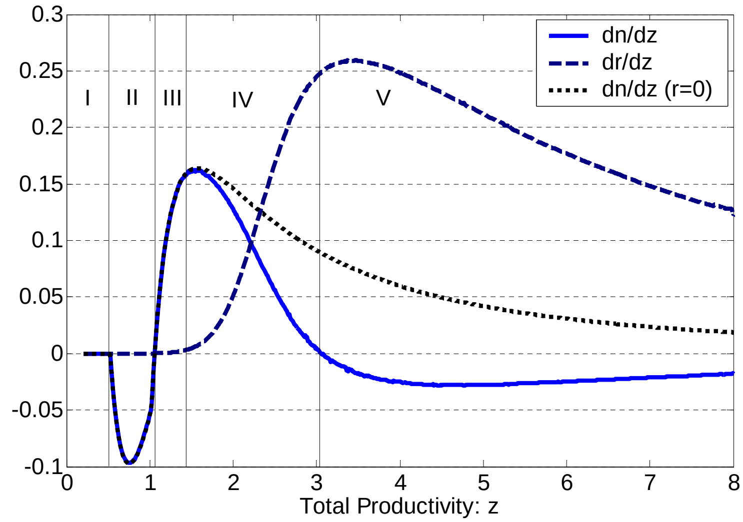


Figure 1.6: It shows the derivatives of population growth rate (solid line) and investment in human capital (dashed line) with respect to total productivity. The dotted line shows the derivative of population growth rate under the condition that there is no investment in human capital ($r = 0$). The roman numerals show the different phases described in the text as productivity increases.

starts to be used, around $z = 0.5$, the derivative is zero. This is due to the fact that the good cost of education (q) is sufficiently high.

We can now describe the different stages for $\frac{dn}{dz}$. Observe the solid line in figure 1.6. If only the primitive technology is being used, then, of course, increases in the efficiency of modern technology will not affect the decision variables, $\frac{dn}{dz} = 0$ (phase I).

Once the modern technology starts to be used (around $z = 0.5$), time investment in human capital does not change ($\frac{dr}{dz} = 0$), but population growth rate declines. This is due to the fact that the first term in equation (1.20) is very small (in fact, it is zero at the moment that the modern technology becomes useful, and it increases from there on), and therefore the second, negative term dominates (phase II). It should be observed that the drop is smaller, the smaller r and S are. This term is due to the substitution of labor for children. When the efficiency of modern technology increases, people is willing to work more and they substitute children for it. Soon enough, though, income and consumption increases. The term in brackets, which can be characterized as an income effect, increases and dominates the labor substitution effect: $\frac{dn}{dz}$ becomes positive and increasing (phase III). At some moment (around $z = 1.5$), investment in human capital reacts to productivity changes positively, and the income effect is counterbalanced by the substitution of quality for quantity of children. The derivative

Phase	State	$\frac{dn}{dz}$	$\frac{dr}{dz}$
I	Stagnant State	0	0
II	Exogenous Growth	< 0	0
III	Exogenous Growth	> 0	0
IV	Exog.+Endog. Growth	> 0	> 0
V	Exog.+Endog. Growth	< 0	> 0
VI	Growth Steady State	0	0

Table 1.4: The effect of total productivity on population growth rate and on human capital investment.

($\frac{dn}{dz}$) is still positive but diminishing (phase IV). G will become larger with increasing z and $\frac{dn}{dz}$ will converge to zero (in a state which we have called the permanent growth steady state, phase VI). The big difference is if it converges from above or from below. If it does it from above, the population growth rate will not diminish and therefore we will have permanent population growth, explosive population. If it does it from below, we will have a phase for decreasing population growth rate, and therefore we will obtain the hump-shape form that characterizes a demographic transition. This case is represented by the solid line in figure 1.6. At some point (around $z = 3$), $\frac{dn}{dz}$ becomes negative and the population growth rate decreases (phase V).

The dotted line in figure 1.6 represents $\frac{dn}{dz}$ in the case in which there is no opportunity for investment in human capital ($r = 0$ for all z). Observe that it converges to zero from above: there is no decrease in the population growth rate. In this case we will not obtain a hump-shape for this variable. Moreover, observe the relationship between the three lines: it is *because* of an increasing investment in human capital that we obtain a negative effect of productivity on population growth rate, and consequently a hump-shape curve for the population growth rate. In terms of equation (1.20), a positive and increasing $\frac{dr}{dz}$ diminishes $\frac{dn}{dz}$, eventually turning it negative. In other words, a new substitution, of children quality for children quantity, comes into play, and, for some time, dominates the income effect.

Table 1.4 summarizes the phases.

1.5.3 Sensitivity analysis

I would like to give a sense of what happens to the benchmark results (mainly the population growth rate) when I vary some specific parameters.

Figure 1.7, top left panel, presents the population growth rate in the case in which the exogenous growth rate of technology in the modern sector is lower ($\delta = 0.15$). Predictably, the demographic transition (as well as the industrial revolution [not shown]) is delayed. It can be seen that the slope of the upward part of the curve is not as steep as in the data.

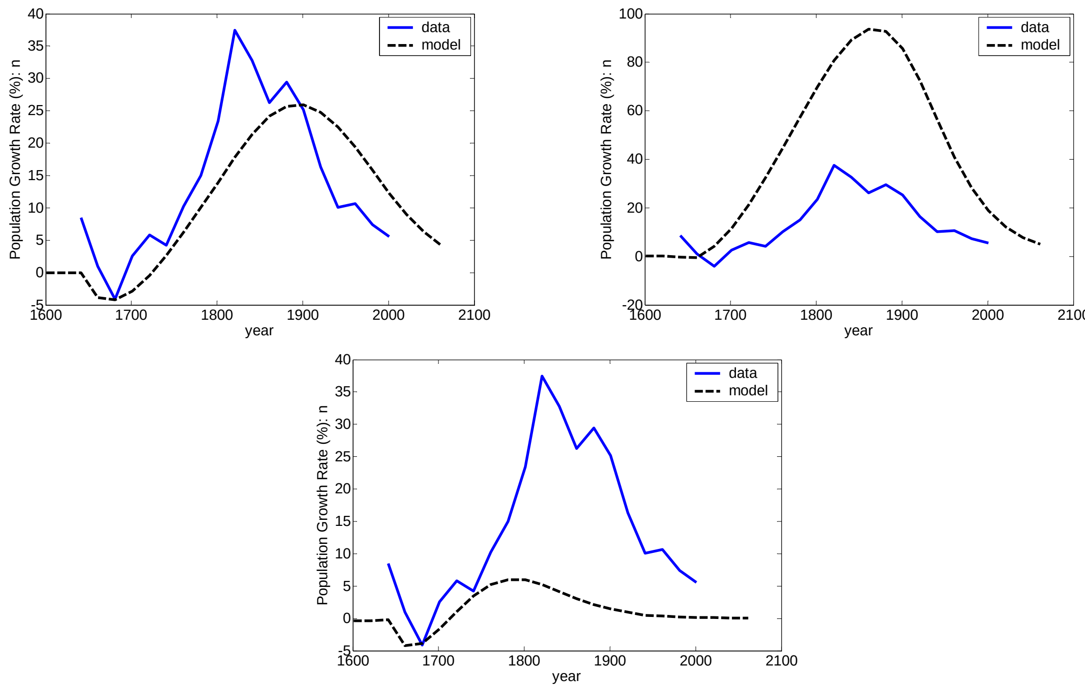


Figure 1.7: Sensitivity analysis. Population growth rate. England 1640-2000. Top left panel: lower exogenous growth rate ($\delta = 0.15$). Top right panel: higher steady state investment in human capital ($r^G = 0.04$), and lower time of rearing children ($S = 0.025$). Bottom panel: lower good cost of education ($q = 8.5$).

Figure 1.7, top right panel, presents the population growth rate in the case in which I decrease the time used in essential child care (S equal to 0.025 instead of 0.046) and increase the time used in educational child care at the growth steady state (r^G equal to 0.04 instead of 0.018). It is clear that the demographic transition is "exaggerated" in the sense that the changes are in the right direction, but are too large. By diminishing the time cost of rearing children (S), these are too cheap and with an increase in income population growth rate increases dramatically.

Figure 1.7, bottom panel, presents the population growth rate in the case in which I increase the share of foregone earnings in total education expenditures, informed by Schultz (1960), to 4/5 (from 3/5), which mainly affects the value of q, by reducing it to around 8.5. The demographic transition is "smaller" and shorter. In other words, understandably given the lower cost of investment in education, the quantity-quality substitution sets in too early.

Finally, I consider different values for the preference parameter θ (between 0 and 0.3). The results are almost identical to the ones of the benchmark calibration (not shown).

1.5.4 Without exogenous growth

The model that I calibrated and simulated is essentially Lucas (2002b) model. There are three main differences: (i) I changed the preferences such that I obtain an overlapping generations model instead of a dynastic model; parents care directly about the assets of their children, not about their utility (in a similar way to Galor and Weil (2000) and Lagerlöf (2006)); (ii) I proposed a process for the exogenous technological level in the modern economy, B, such that we have an effective mechanism to pass from the basin of attraction of one steady state to the other; (iii) I incorporated costs of investment in education, in terms of goods (q) and in terms of time (T). I want to explore now what happens with this kind of models when I do not have exogenous technology change (this subsection), and when I do not incorporate costs of education (next subsection).

If I set the exogenous growth of the modern technology to zero ($\delta = 0$), the only way the economy can escape from the Malthusian steady state is with endogenous increase of human capital. In this model, unlike Lucas (2002b) model, there is always endogenous increase of human capital ($r^M > 0$), but, under the calibration proposed, r^M is very small, and, with no exogenous technical change, it can not generate an endogenous demographic transition. So the question becomes: under which values of the parameters we might obtain a completely endogenous industrial revolution?

As we have seen, by analyzing the derivative $\frac{dn}{dz}$, we need, of course, a sizable increase of z to obtain a sizable change in n. Remembering that $z = Bh$, and fixing B as we assume all growth endogenous, we need sizable changes in human capital, h, during the first decades of the transition, if we are going to obtain a sizable increase in population growth rate, as we have seen in the data for the period between 1740 and 1820. Therefore we need to start with a higher investment in human capital (r^M) in the Malthusian state.

Considering the case where, in the growth steady state, the educational and recreational child care time (r^G) is 0.04, and the basic child care (S) time is 0.025 (as in the second exercise of section 1.5.3), *and* increasing the share of foregone earnings to 4/5 (as in the third exercise in 1.5.3), I obtain that the time investment in Malthusian steady state, r^M, is near 0.01 (one-fourth of growth steady state, r^G), and the simulated time series illustrated in figures 1.8 to 1.10 (see table 1.1, column 3, for the calibrated values).

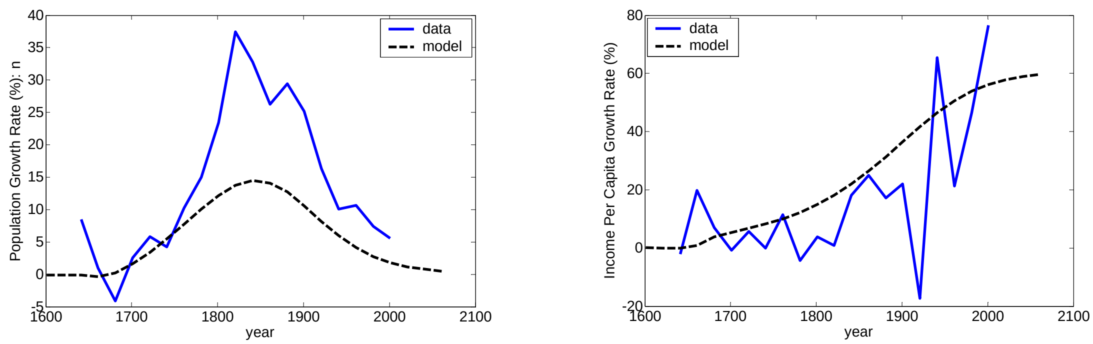


Figure 1.8: Sensitivity analysis. No exogenous growth rate ($\delta = 0$), with higher steady state investment in human capital ($r^G = 0.04$), lower time rearing children ($S = 0.025$), and lower good cost of education ($q = 4$). England 1640-2000. Left panel: population growth rate. Right panel: income per capita growth rate.

Figure 1.8 shows that under plausible values for the parameters we can generate simultaneously an industrial revolution and a demographic transition *without* exogenous technical change. Comparing this case with the benchmark case, we observe that the demographic transition curve is flatter, and the peak is considerably lower than in the data. In its favor we must take the observation that income per capita growth rate in the 18$^{\text{th}}$ century is much lower than in the benchmark case, and therefore accords better with the data. This implies also a structural change (between both technologies) slightly later in time than in the benchmark case and more in line with the evidence (compare right panels of figures 1.10 and 1.5).[11]

[11] An interesting prediction of this alternative calibration is the decrease in the growth rate of human capital at the moment that the modern technology starts to be used in 1640 (see left panel of figure 1.10). This is concomitant with an increase in labor and a decrease in investment in human capital

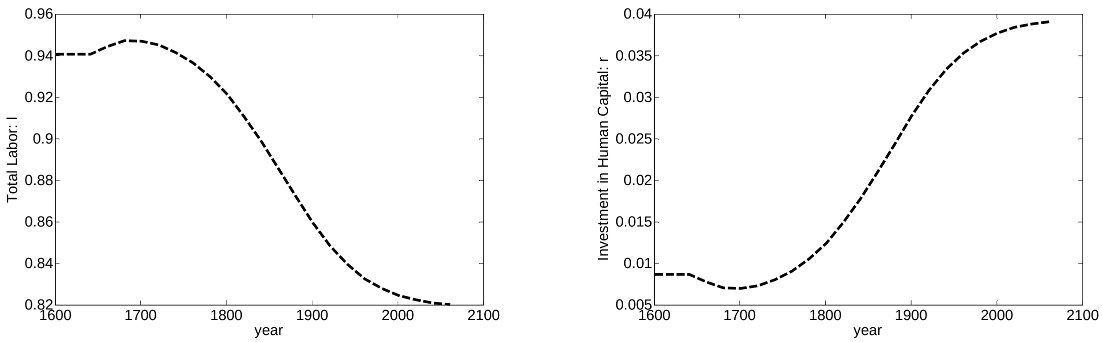


Figure 1.9: Sensitivity analysis. No exogenous growth rate ($\delta = 0$), with higher steady state investment in human capital ($r^G = 0.04$), lower time rearing children ($S = 0.025$), and lower good cost of education ($q = 4$). England 1640-2000. Left panel: labor. Right panel: investment in human capital.

But despite the similarity of the simulated series in both cases, the models are essentially different. While in the benchmark case an industrial revolution take-off is induced by the technological side of the economy, in this case it is induced by the preferences, the value that parents put in their kids' human capital, *even* if it is not useful in production. In this case, if we consider that preferences are the same for all countries, we will arrive at the prediction that all countries would eventually go through an industrial revolution, *even* if there is no contact (and no transmission of technology) between them. One way out of that prediction is to consider that the preferences are endogenous (as in Doepke and Zilibotti (2008)) and that they respond to different technology levels. Of course, in this case we are back to an explanation based on the technological side of the economy.

In sum, I conclude that it is possible to generate an industrial revolution and a demographic transition without exogenous technical change, but following this path of explanation gives a more important role to the preferences, and puts therefore more stress in justifying why parents care about their kids' human capital in a Malthusian steady state, that is, when human capital is not used in production. We leave this development for future research.

(see figure 1.9). There is some evidence of an increase in labor in the 17^{th} and 18^{th} century (see Wilensky (1961), p.34). Also there is some evidence that the first stages of industrialization may well have been accompanied by lower levels of literacy and higher levels of mortality (see Wrigley (1987), p.74). The completely endogenous growth model presented in this section seems to be better qualified than the benchmark case to accommodate these possibilities.

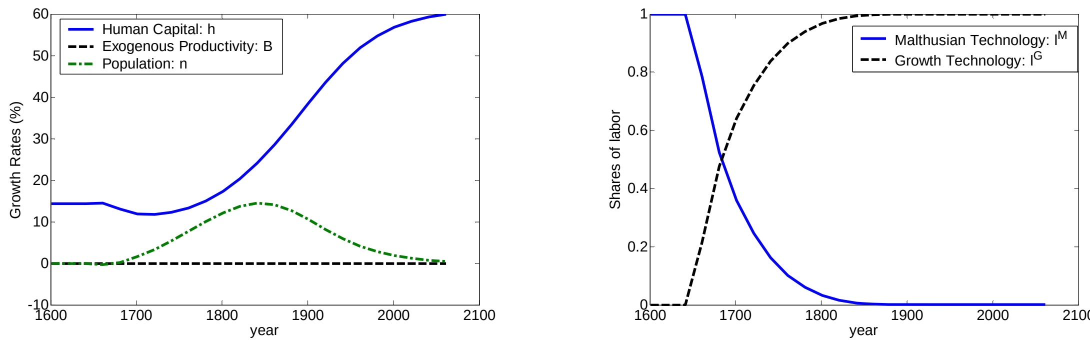


Figure 1.10: Sensitivity analysis. No exogenous growth rate ($\delta = 0$), with higher steady state investment in human capital ($r^G = 0.04$), lower time rearing children ($S = 0.025$), and lower good cost of education ($q = 4$). England 1640-2000. Left panel: growth rates of human capital, exogenous productivity and population. Right panel: share of labor allocated to each technology.

1.5.5 Without costs of education

Zero good cost of investment in human capital ($q = 0$)

In this section I want to address the question: given the general model, are the costs of investment in education necessary to generate reasonable simulated series?

Assume that q is positive (say, equal to 22.7, as in the benchmark case) until 1640, and then it becomes equal to zero. As we know, I have set initial conditions such that in 1640 the modern technology starts to be used ($l^G > 0$). So, at the moment when the modern technology becomes useful, investment in human capital becomes costless in terms of goods. The results of this experiment are shown in figure 1.11: there is a drastic drop in population growth rate (top left panel) and a drastic increase in time invested in human capital production (top right panel), which translates into a huge increase in income per capita (bottom panel).[12]

What is going on? If the cost of investment in human capital is low, at the moment that the modern technology is useful and some labor is allocated to it, people want to accumulate human capital immediately. The children quantity-quality substitution sets in at the exact moment that the Malthusian state is abandoned. In this case, there is no way we can obtain an increase in population growth rate.

If we want to obtain an increase in population growth rates in the first stages after the abandonment of a Malthusian equilibrium, we need to put some distance between

[12]Of course these counterfactual effects will still happen if we consider the abandonment of the Malthusian state to occur later, say in 1800.

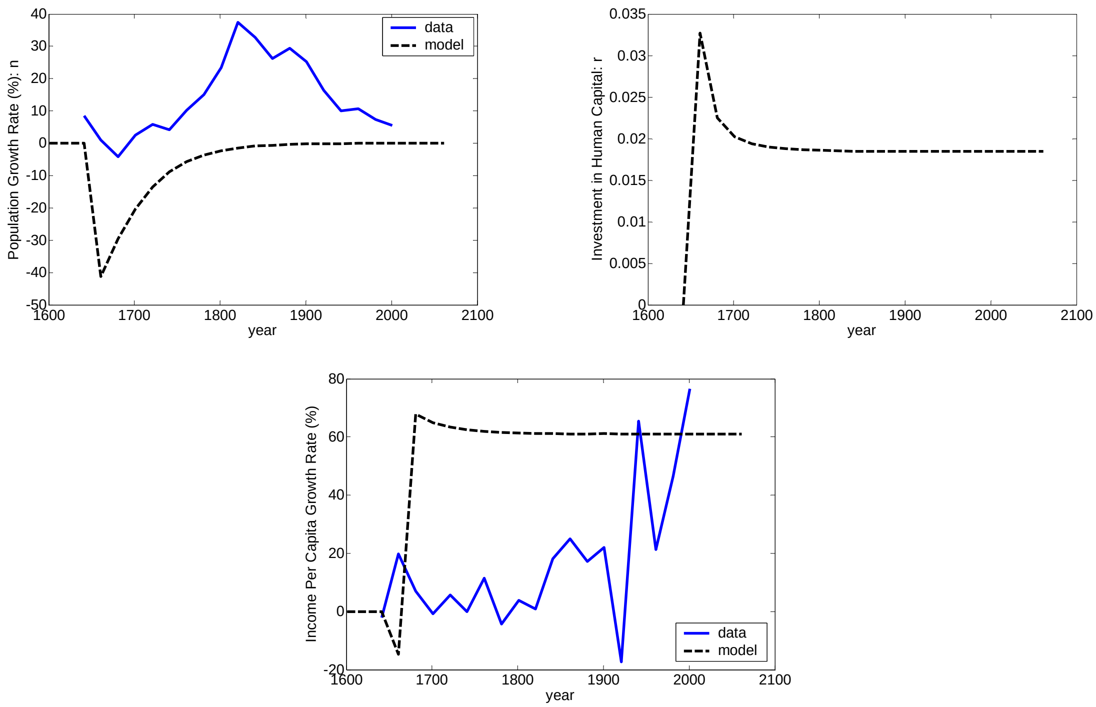


Figure 1.11: Sensitivity analysis. No good cost of education ($q = 0$). Top left panel: it shows population growth rate. Top right panel: it shows time investment in human capital. Bottom panel: it shows income per capita growth rate.

the moment that the modern technology is first used, and the moment in which the rate of accumulation of human capital increases. That is the essential role of a positive and sufficiently high good cost of investment in human capital.

Zero time cost of investment in human capital ($T = 0$)

In order to generate reasonable series, do we need a positive time cost of investment, independent of the number of children? If we set T to zero, I obtain an implausible low calibration for β ($= 0.08$), and a necessary high value for S (> 0.06) in order to satisfy the sufficient conditions for a maximum in the growth steady state (inequality [1.14]). From my point of view, this is an indication that T must be positive, and that a time cost of investment in human capital, independent of the number of children, is essential in this kind of models.

I conclude by affirming that, in the context of the general model given above, all three costs (q, T and S) seem necessary to replicate simultaneously the industrial revolution and the demographic transition. Lucas (2002b) did not include these costs.

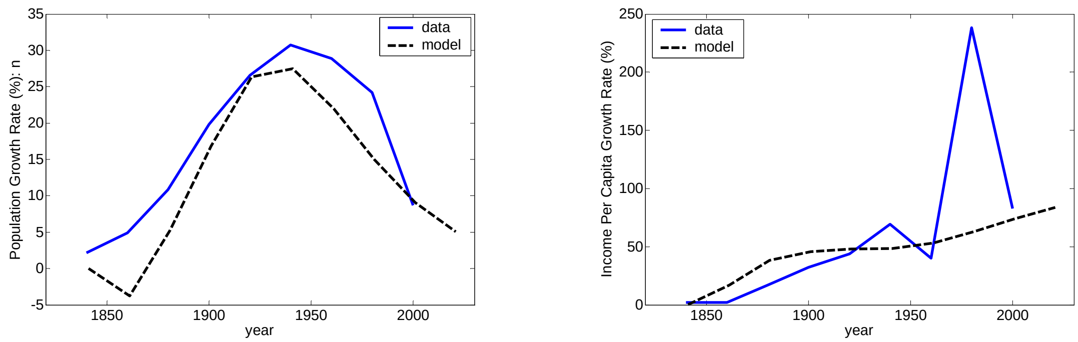


Figure 1.12: Japan 1840-2000. Left panel: population growth rate (every 20 years, %). Right panel: income per capita growth rate (every 20 years, %). All parameters as in benchmark case, except for the exogenous productivity growth rate (δ), which was set to 0.5.

I contend then that his model is not able to replicate the time series involved. On the contrary, either the first order conditions will not determine a growth steady state solution (if $T = 0$) or the population growth rate curve will present an inverted hump-shape, contrary to data (if $q = 0$). The extended model considered here (extended with linear costs) can give a much better account of the data.

1.5.6 Test: Japan

The calibrated model can account for some aspects of the transition from stagnation to growth of England between 1640 and 2000. Can the calibrated model account for the transition of other countries? In this section I consider the following exercise for Japan. I run the exact same calibrated model, with only two modifications: (i) I set the time of abandonment of the Malthusian state in 1840, around the time Japan began its transformation into a modern economy;[13] (ii) I set the exogenous growth rate of technology, δ, to a higher value, 0.5. This second change is reasonable given the higher stock of knowledge in the world that a follower can drew upon, and consequently the new possibilities of import of technology.

Figure 1.12 shows the results and table 1.5 presents the growth rates for the periods 1840-1900, 1900-1940 and 1940-2000. We obtain a demographic transition in 160 years, half of the time for England, accelerated because of the higher rate of exogenous growth. Simultaneously, the income per capita growth rate increases from zero to around 60%. The main discrepancy is that the latter is somewhat overestimated in the 19$^{\text{th}}$ century,

[13] Comodore Perry arrived in 1853; the Meiji Restoration happened in 1868.

and underestimated in the second half of the 20th century. But, overall, the model predicts quite well the trends.

	Income per capita growth rate		Population growth rate	
	Data	Model	Data	Model
1840-1900	60	136	39	18
1900-1940	144	120	65	61
1940-2000	667	335	74	53

Table 1.5: Comparing model and data. Japan 1840-2000. Income per capita and population growth rates (every 20 years, %).

1.6 Discussion

1.6.1 Consistent and complementary explanations

The "prime-mover" in the model presented above is the exogenous increase in the efficiency of the modern technology, B. In fact, this is the engine of growth until human capital picks up at the beginning of the 19th century. I would like to observe that a host of theories about the industrial revolution are consistent with this setup, including the following. (i) Increasing efficiency in trading, as emphasized by Rosenberg and Birdzell (1986). (ii) Capitalist-friendly institutions, as protection of property rights and economic decentralization, as emphasized by North and Thomas (1973). (iii) The emphasis in science and invention (Landes (1969), Mokyr (1990)). And (iv) the emphasis in technological change in particular sectors, which increased efficiency of the whole economy, like energy (Wrigley (1988)) and transportation.

However, a main anomaly persists. Considering the joint movement of income per capita and population growth rates in the period between 1740 and 1820, how was it possible for the population to increase systematically with only mild spurts in income per capita? As we have seen, a model that puts emphasis on the exogenous increase of the efficiency of the modern sector can not capture that pattern. Is there any complementary explanation that can capture it? I propose the following four explanations for increasing population growth rate in the period 1740-1820, with only mild increases in income per capita growth rate.

1. An increase in agricultural productivity, A. This is a phenomenon quite documented by historians (e.g.: Deane (1979)). The appeal of this explanation is that the structural change between sectors will be located much later too (recall right panel of figure 1.5). The disadvantage of this explanation is that, again, if the right model includes a constant increase in agricultural productivity, income per capita should have grown temporarily too (though less than in our benchmark model). While an increase in the growth rate of agricultural productivity will not have long term effects in the income per capita, it will have considerable short term adjustment effects, which are not observed in the data. On top of that, it must be observed that, according to inequality (1.9), an increase in A implies that we are further away from the point where the modern technology begins to be useful. The appeal of emphasizing the increased efficiency of modern technology, B, is that it increases the population growth rate *while* increasing the productivity of human capital, and therefore setting up the stage for the children quantity-quality substitution. By emphasizing the increase in agricultural productivity we can also obtain increases in population growth rates but at the expense of postponing the evolvement of modern growth (that is, growth driven by human capital).

2. A decrease in the costs of children, k or S, by way of decreasing mortality. Our model is one where parents choose surviving children. So, if mortality decreases, parents will adjust by diminishing fertility. But it must be observed that a decrease in mortality may quite probably indicate a lower cost of a surviving child. For example, a lower infant mortality would indicate that a mother might have to give birth to two instead of three children to get one surviving child. This is, of course, a reduction in the cost of a surviving child. In this case fertility will not diminish as much as mortality and we will obtain an increase in population growth rate. This possibility is appealing in order to address the anomaly, but I want to mention the following considerations. I must observe, first, that to obtain an *increasing* population growth rate we need a systematic decrease in the cost of surviving children. Second, we still need most probably some exogenous increase in modern technology efficiency to arrive to the point where that technology is used, and eventually to a decrease in the population growth rate.[14] Third, that the mortality decreases, in order not to be accompanied by

[14]Of course the increase in population will diminish land per capita and therefore the left hand side of (1.9), what can trigger the passage to a modern technology economy. This is a theoretical possibility but I would not like to emphasize it because it would indicate that mere density would cause development, something that it is not observed (e.g.: Bangladesh).

increases in income per capita, must not be caused by increases in the productivity of the economy; that is, they must not be the product of an income effect. Here the debate ascribing the decrease in mortality in the 18$^{\text{th}}$ century to either improvements in medical technology or to improvements in living standards is very relevant. For this alternative story to have a chance of improving on the predictions of our model, we need that the mortality declines should be ascribed to improvements in medical technology. This debate has not been settled though.[15]

3. Increase in the demand of child labor. An increase in the demand of child labor (an increase in the benefits of having children) seems a reasonable alternative story to explain the increase in the population growth rate. But the issue is here again, how can we obtain an increase in the demand for labor without an increase in income per capita? If we assume that the increase in the demand for labor is due to an increase in aggregate productivity we get back to our model. A better alternative is if we assume that the modern technology permits the use of child labor while the old one does not. We might conjecture that the old technology needs the strength of an adult, while the new technology allows for the delicacy of a child. In this case, we might see a decrease in the relative wage of the adults and an increase in the wage of the children, with no much change in average living standard. Additionally, we might see an increase in the number of children as parents realize that the children's relative wage has improved, *and* parents are entitled to that income. (In a similar vein, Galor and Weil (1996) considered physical differences between women and men and "bias" technical change to explain the closing of the wage gap).

4. Population/technology completely endogenous model. The model proposed by Galor and Weil (2000) and simulated by Lagerlöf (2006) seems to predict a stage with relative stagnant living standards but increasing growth rate of population (see his figure 10). Consequently, this model can be promising with respect to the anomaly that we are concerned with. However, Lagerlöf (2006) does not put next to each other simulation and data. Until this is not done we will not know how well the model performs empirically.[16]

[15]For example, Fogel (1994) ascribes most of the decrease in mortality to a decrease in malnutrition, which it may be attributed mostly to increase in productivity. This evidence would go against this alternative explanation. Soares (2007) reviews a wealth of data and literature for the 20$^{\text{th}}$ century, and affirms that, as a determinant of reductions in mortality, improvements in medical technology has only lately become more important relative to living standards.

[16]A related issue is that under some parameter values the population growth rate fluctuates wildly, fluctuations that are smoothed by way of averaging, a methodology that seems to be modifying the predictions of the model.

1.6.2 Final comments

I have constructed a model of development, from stagnation to growth, and evaluate it quantitatively. I obtained the following results:

1. The model can replicate simultaneously a demographic transition and an industrial revolution.

2. However, the model overestimates the increase in income per capita in the 18^{th} century, and generates a structural change (between technologies) that seems too premature.

3. The model can account for other dimensions of the data: (i) a decrease in labor time; (ii) an increase in schooling time; (iii) a decrease in land per capita; (iv) an increase in real wages.

4. Costs of education, in terms of goods and in time, are fundamental to account for the path of the population growth rate. Without them we obtain a drastic drop in population growth rate at the moment that the Malthusian state is abandoned, a highly counter-factual prediction.

5. The time path for population growth rate is determined by the interaction of three effects: (i) a substitution between time raising children and labor; (ii) an income effect on quantity of children; (iii) a substitution between quantity and quality of children.

6. An alternative calibration, with no exogenous change in modern productivity, and with some reasonable parameter values can also generate a demographic transition and an industrial revolution. In fact, this alternative has better predictions with respect to income per capita in the 18^{th} century, and the timing of the structural change. However, because the trigger is endogenous human capital accumulation due to a preference motive (and not to usefulness of human capital in production), I consider that more research has to be done to justify those preferences.

There are many aspects in which this line of research can be continued. First, the production functions can be made more realistic by expliciting physical capital. This might also permit to measure explicitly productivity changes in each sector (apart from human capital), and used them as inputs in the simulations (instead of assuming a constant growth rate of technical change). Second, the Malthusian part of the model should be tested against data for the period between 1200 and 1640. During this period, living standards did not present a long-term trend, but fluctuated considerably. Population growth rates did likewise. Shocks and mechanisms have to be explicited to account for those fluctuations. Third, incorporate the use of time of children as decision variables. This might help understand changes in child labor and in population growth rates. Fourth, consider the depreciation of human capital (which was set implicitly to zero in the present model), as well as the changes in length of life. Fifth, consider more data to compare with simulation. In this sense, it will be interesting to get measures of human capital, and of the changing sizes of the primitive and modern sectors.

I would like to conclude with two related comments. They are related by the fact that, in this class of endogenous growth models, it is not clear what is exactly the variable h (and B) and how to measure it.

First, I would like to note that at the microeconomic level there is no consensus about the significance of the children quantity-quality trade-off. Recently, Angrist, Lavy, and Schlosser (2005), Schultz (2005) and Qian (2008) have argued that the effects of restrictions of quantity on the quality of children are much smaller than previously thought. As the main mechanism in this paper's model, the scant micro-evidence for the significance of the quantity-quality trade-off puts some doubt on its relevance as the source of macro-development. However, in these microeconomic studies the quality of children is measured mainly by children's schooling. If human capital is transmitted in a different way (say, by informal interaction between parents and children) it is understandable that they will not be picked up in those micro-studies estimates. And the informal transmission of human capital seems more important if the latter includes not only knowledge but also personality traits, like energy or ambition.

The idea that investment in human capital might be concerned with something very different from formal knowledge is supported by the finding of Clark (2005). He emphasized that, in England, literacy increased substantially much earlier (17^{th} century) than any increase in income per capita (early 19^{th} century). Lucas (1993) himself has emphasized that a large part of human capital is acquired by "learning by doing". But, if this is the case, how is "learning by doing" connected to parents' time investment?

Therefore, I think that more research has to be done in separating schooling, learning by doing and home investment in human capital (health and nutrition, personality traits), and identifying the significance of each of them on overall human capital accumulation, and the effects of each on income per capita growth. Unlike in the model presented above, learning by doing does not seem to need significant time investment by parents. This research will help to clarify the relevance of the quantity-quality trade-off paradigm, and to determine if too much emphasis has been put in parents' altruism as a mechanism of growth.

Second, I would like to consider the forms of the production functions in the advanced technology. In both, the good production function and the human capital production function, h enters with a unitary exponent. An alternative would have been to separate h into three components: "technology" (an external effect), physical capital and embedded human capital, each one with a different exponent, all three summing to one. The advantages of doing this is that we have relatively reliable data on physical capital, and that we can connect with the business cycle literature, that uses physical capital generously. More importantly, disaggregation might be important to understand better how diminishing returns are avoided in different stages of development, and how the different terms interact. As Solow (2005) recently put it: "If you want an exponential solution, you better have a linear differential equation. [...] The real point, however, is that any such linearity assumption, because it is so powerful, ought to require much more convincing justification than it gets in the standard models of endogenous technological change or accumulation of human capital" (p.10). I interpret the high sensibility of my results to small changes in the values of some parameters as a result of the 'power' of non-decreasing returns. Therefore, I conclude that there is a need for research in the microeconomic foundations of these production functions.

1.A Appendix

1.A.1 Data

Year	Population ('000)	Income per capita (2001 £ '000)
1641	5,092	1.40
1661	5,141	1.68
1681	4,930	1.79
1701	5,058	1.78
1721	5,350	1.88
1741	5,576	1.88
1761	6,147	2.09
1781	7,069	2.00
1801	8,728	2.08
1821	12,000	2.10
1841	15,929	2.48
1861	20,119	3.09
1881	26,046	3.62
1901	32,612	4.42
1921	37,932	3.66
1941	41,748	6.05
1961	46,196	7.33
1981	49,603	10.75
2001	52,360	18.98

Table 1.6: Data used for figures 1.1 and 1.2.

The sources of the data are the following.
Population (England & Wales). **1541-1981**: B.R. Mitchell, British Historical Statistics [from now on B.R.M.] (Cambridge Univ. Press, 1988), tables 1 and 2. These are based on: for period 1541-1801, Wrigley and Schofield, The population history of England, table A3.3; for period 1821-1981, Report of the Censuses of 1981 for England and Wales.
Real GDP (UK). **1701-1841**: Broadberry, Foldvari, and van Leuween (2007), table A5. **1831-1980**: B.R.M., table 6, column 7, based on: C.H. Feinstein, National Income, Expenditure and Output of UK, 1855-1965 (Cambridge, 1972) and extensions and revisions by the author. This data is measured at different constant prices for different periods. I transformed all the series to 2001 prices. For a few transformations I used the consumer price index in http://www.statistics.gov.uk/articles/economic_trends/ET604CPI1750.pdf. **2001**: http://www.statistics.gov.uk/ downloads/theme_economy/BB_2003.pdf, table 1.1.

Real GDP per capita. **1701-2001**: I divided real GDP by population. **1641-1701**: I used as a proxy data on real wages of craftsmen, given by Clark (2005).
The data for Japan was taken from Angus Maddison (1995), Monitoring the World Economy: 1820-1992, OECD Publishing. I used linear interpolation to obtain the data for years 1840 and 1860 for population, and 1840, 1860 and 1880 for income per capita.

Chapter 2

Social Ties and Economic Development

Note: This is joint work with Fernando Anjos

2.1 Introduction

In his popular book "Bowling Alone", Robert Putnam claims that *social capital* in the United States has increased up to the 1960s and decreased afterwards. This erosion of social capital notwithstanding, the American economy has kept a steady pace of economic growth in the last 50 years. This apparent ambiguity begs the question: what, if any, is the relation between social capital and economic development?

Traditionally social capital has been understood to be a driver of economic growth. The first step is to define social capital. Putnam (2000) (pg. 19) does so in the following way.

> Whereas physical capital refers to physical objects and human capital refers to properties of individuals, social capital refers to connections among individuals – social networks and the norms of reciprocity and trustworthiness that arise from them.

In economic terms, the above definition of social capital implies that a dense network of *social ties* adds value by lowering costs of coordination. This concept of social capital is also similar to Coleman (1988), who argues that closure (or degree of connectedness) is the key structural property of a social network in increasing efficiency of economic interactions. This does not imply however, from a normative perspective, that social capital should always be maximized. Durlauf and Fafchamps (2005) and Routledge and von Amsberg (2003) have pointed out that social capital is not without costs. On one hand social capital is sometimes associated with unlawful activity; on the other, it may be efficient to incur high coordination costs if it allows a higher productivity. In addition to the ambiguous effect of social capital in economic outcomes, some literature has pointed out that the term itself is ambiguous; see e.g. Solow (2000) or Arrow (2000). In particular, it is not clear whether social capital results from a deliberate process of accumulation by economic agents.

Our objective in this paper is twofold: (i) to document and attempt to explain the relationship between social ties and economic development; and (ii) to construct a framework that sheds light on the concept of social capital.

Why do social ties exist? One motive is certainly the pleasure individuals derive from relationships with other human beings; another relates to the personal advantages of a good social network. A related question is how these social ties are built. Friendships and acquaintances require emotional and temporal commitment, and these resources are scarce. We construct a general equilibrium model where social ties are considered explicitly, both as consumption goods and as building blocks of social capital. By social ties we thus mean a particular class of commodities that agents are able to produce, using as inputs time from each of the individuals in a bilateral relationship. It is important to point out that time is the only primitive resource in the model. This indirectly puts a price on social ties, thus allowing us to analyze the trade-offs between these and standard commodities.

In our general setup there is a global economy comprised of different villages, which in turn are populated by individuals. There is also a variety of standard tradable goods which can be exchanged within villages and between villages. Trade within a village incurs transaction costs, in terms of time, which can be economized with social capital. Social capital is modeled in reduced-form as an average of bilateral social ties. Trade between villages incurs in both transaction and transport costs, but agents are not allowed to build ties across villages. This is similar to the unfriendly-trade case in Routledge and von Amsberg (2003). Transport costs are taken exogenously. Beyond making decisions on social ties and consumption of standard commodities, individuals also choose how much time to devote to production.

Our model relies on the existence of multiple equilibria to rationalize the heterogeneity of observed outcomes across history and regions. These multiple equilibria are seen as resulting from differences in *cultural beliefs*. This is in the spirit of Krugman (1991), Cole, Mailath, and Postlewaite (1992), and Greif (1994). This last paper frames the issue in the exact terms that are relevant for our paper. The excerpt below illustrates what is meant by cultural beliefs:

> Yet if each player expects others to play a self-enforcing and hence an equilibrium strategy, is there any analytical benefit from distinguishing between strategies and cultural beliefs? Unlike strategies, cultural beliefs are qualities of individuals in the sense that cultural beliefs that were crystallized with respect to a specific game affect decisions in historically subsequent strategic situations. Past cultural beliefs provide focal points and coordinate expectations, thereby influencing equilibrium selection and society's enforcement institutions.

In our model, the belief that one should have a certain *number* of social ties is self-fulfilling. This in turn affects economic decisions. We refer to this as the degree of *communitarianism*. We will use the term *individualism* for instances where the level of communitarianism is low. Empirically, we find a positive association between a proxy for the degree of communitarianism and income per capita, in a cross section of countries. This is depicted in the left panel of Figure 2.1. The same figure – in the right panel – shows that the relationship between the average *strength* of social ties and income per capita also displays a systematic pattern, in this case a negative association.

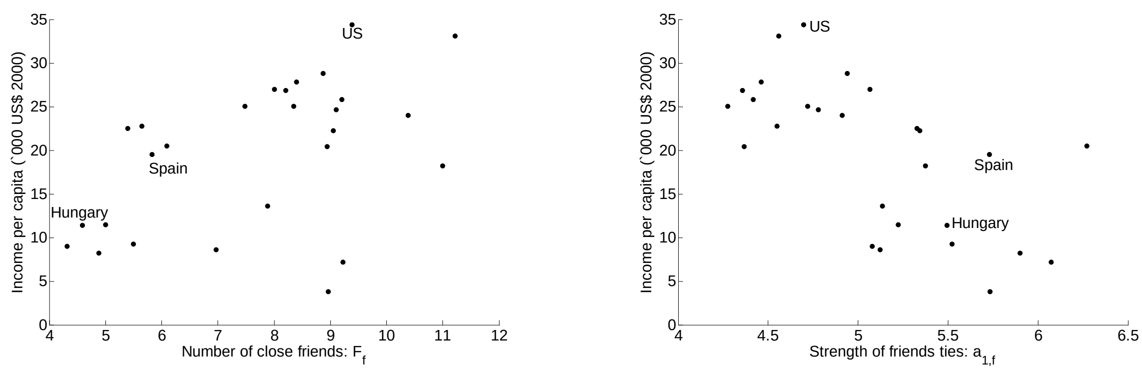


Figure 2.1: Left panel: plots the number of close friends vs. income per capita in 2000, for a group of 27 countries; the correlation coefficient is 0.49, and is statistically significant at the 1% level. Right panel: plots the average intensity of close friends' ties vs. income per capita in 2000, for a group of 27 countries; the correlation coefficient is -0.65, and it is statistically significant at the 0.1% level.

Our model presents a rationalization for the depicted relationships between social ties (number and strength) and income per capita. In particular, in the calibrated version of the model heterogeneity in number of ties can account for a significant share of the variability in current income per capita; around 65% measuring social ties as the number of close friends. In section 2.A.2 in the Appendix we conduct a more detailed empirical analysis of social ties – including individual and regional data –, and we find further evidence of a robust association between measures of economic development and characteristics of social ties.

Theoretically our framework helps understand the relationship between social ties, social capital, and other economic outcomes. The main theoretical findings are the following: (i) a preference for social ties may significantly mitigate an otherwise large underprovision of social capital; (ii) when social ties are a consumption good, it is theoretically possible to observe different qualitative associations between social ties and economic development, simply due to standard income and substitution effects – this implies that it may be naive to attribute a technological role to proxies of social capital such as social ties, without controlling for consumption motives; (iii) social capital is in some instances an important source of economic efficiency, very much complementary to labor and/or human capital; (iv) only in some societies – the more individualistic ones – is social capital the product of a deliberate process of accumulation; in others it is mostly an important positive externality from the consumption of social ties; and (v) we obtain the counter-intuitive effect that in highly communitarian societies, an increase in productivity may hinder welfare, via amplification of the level of coordination failure in the building of social relationships.

In the quantitative exercise, our main findings are: (i) heterogeneity in the number of social ties can account for a significant portion of the heterogeneity in income per capita across countries, as well as a large increase of this heterogeneity in the time series; (ii) the model can also account for between 1/5 and 1/2 of the changes in use of time in the United States between 1900 and 2000, and the changes in the share of the transaction services' sector for the Unites States, during the same period; (iii) the model is counter-factual with respect to: the time-series relationship between productivity, social capital, and leisure, in the period 1965-1985 in the United States; the evolution of the share of self-produced goods and external market goods; and in the cross section of countries, the relationship between labor and leisure with income per capita; (iv) according to one measure, our model implies that without social capital countries would be between 1/2 and 3/4 their actual size in terms of income per capita.

The paper is organized as follows. Section 2.2 develops the general theoretical setup and proposes a parametrization. Section 2.2.3 analyzes a simplified version of the static model, which captures the main intuitions behind the theory. Section 2.3 develops and calibrates a dynamic extension of the static setup, delivering the quantitative implications of the model for the cross section of countries, in terms of income per capita. Section 2.4 discusses our results and concludes. The Appendix contains all proofs, details on the construction of data for calibration, and a more detailed analysis of data on social ties.

2.2 Static model

2.2.1 General setup

The global economy is composed of V villages and N agents. Each agent $i \in \{1, ..., N\}$ belongs to a unique village v, denoted by $v(i)$. Any individual $i \in \{1, ..., N\}$ maximizes the following utility function

$$\mathcal{U}_i(c, s) = \{\phi\,[u_1(c_i)]^{\rho_{c,s}} + (1-\phi)\,[u_2(s_i)]^{\rho_{c,s}}\}^{\frac{1}{\rho_{c,s}}}\,, \tag{2.1}$$

subject to time and budget constraints, which will be defined shortly. The first component of utility refers to standard commodities, where c_i stands for the vector of different goods consumed by the agent. The second term in (2.1) is the utility that the agent derives from social ties with other members in her village. Agents cannot build social ties with members of other villages. $\rho_{c,s} \in (-\infty, 1]$ controls for the elasticity of substitution between tie utility and standard-commodities utility, given by the ratio $1/(1-\rho_{c,s})$.

Each agent produces one good only, denoted by $g(i)$. The budget constraint faced by i is given by

$$\sum_{g \in \cup G(v)} x_{ig}\, p_g \leq x^S_{ig(i)}\, p_{g(i)}, \tag{2.2}$$

where x_{ig} stands for the amount of good g demanded by i, above and beyond the amount consumed from own production, which we represent subsequently as $x^o_{ig(i)}$. $G(v)$ represents the set of goods produced in village v. The price of good g is denoted by p_g. Finally, the variable $x^S_{ig(i)}$ stands for the supply of good $g(i)$ by i.

For simplicity we assume that all goods are sold in the villages where they were produced, and buyers from other villages incur the associated iceberg transport cost. $\tau_{v_1 v_2}$ stands for the unitary transport cost incurred by an agent from village v_1 buying goods from an agent in village v_2. Transport costs are homogeneous across goods. Thus, consumption of good g by i, denoted by c_{ig}, is given by

$$c_{ig} = \begin{cases} x_{ig} & g \in G(v(i)) \\ x_{ig}\left(1 - \tau_{v(i)v}\right) & g \notin G(v(i)). \end{cases} \tag{2.3}$$

There are two technologies in the economy, one related to the production of standard commodities, the other related to the production of social ties:

$$y_{c,ig(i)} = f_c(r_{ig(i)}) \tag{2.4}$$

$$y_{s,ij} = f_s(a_{ij}, a_{ji}) \tag{2.5}$$

The variable $r_{ig(i)}$ stands for the time spent by i in the production of good $g(i)$. We refer to r as *transformational effort*, and it is intended to capture a combination of labor and investment in human capital. Physical capital is omitted from the production function. The variable a_{ij} represents the amount of time invested by i in the tie with j and is controlled by i. We refer to a_{ij} as *attention*. Social ties are thus produced using two inputs, namely the amount of time invested by each of the two agents in the tie.

Trading in this economy implies transaction costs (TC), which are fully borne by the buyer; we term this as *transactive effort*. Transaction costs correspond to time spent trading, and depend on the social capital (SC) and the amount of goods acquired:

$$TC_{ig} = f_{tc}(SC_{iv}, x_{ig}) \tag{2.6}$$

The amount of social capital usable by agent i is in turn a function of social ties:

$$SC_{iv} = \begin{cases} f_{sc}(s_i, \{s_j\}_{j \in v(i)}) & v = v(i) \\ 0 & v \neq v(i) \end{cases} \tag{2.7}$$

We let social capital be agent-specific (hence the dependence on s_i), but it also depends on the overall structure of ties, within the agent's village.

Time is the only scarce natural resource in this economy, and the following time constraint must be verified for any agent i:

$$r_{ig(i)} + \sum_{g \in \cup G(v)} TC_{ig} + \sum_{j \in v(i)} a_{ij} \leq 1, \tag{2.8}$$

where the total amount of time was normalized to 1. Time is thus put into three different uses: transformational effort, transactive effort, and producing ties. When using the term *effort* without qualification we mean transformational effort.

An equilibrium is characterized by solving all agents' (constrained) maximization problem, subject to the market-clearing condition

$$\sum_{i\in\{1,...,N\}} x^S_{ig(i)} = \sum_{i\in\{1,...,N\}} x_{ig} \ , \forall g \in \{1, ..., G\}. \tag{2.9}$$

2.2.2 Parametrization

To represent preferences for standard commodities we choose a utility function that is standard in the trade literature (see Dixit and Stiglitz (1977) and Krugman (1980)):

$$u_1(c_i) = \left(\sum_{g=1}^{G} c_{ig}^{\rho_c} \right)^{\frac{1}{\rho_c}} \tag{2.10}$$

This utility function implies a constant elasticity of substitution (CES) between different goods. In particular, the elasticity of substitution between any two goods equals $1/(1-\rho_c)$, with $\rho_c \in (-\infty, 1)$.[1] Having little to guide us in terms of a choice for u_2, we opted for a functional form that parallels u_1:

$$u_2(s_i) = \left(\sum_{j\in v(i)} s_{ij}^{\rho_s} \right)^{\frac{1}{\rho_s}} \ , \tag{2.11}$$

which means that preferences for social ties also display a constant elasticity of substitution, with $\rho_s \in (-\infty, 1)$. Note that the tie of the individual with herself is part of the utility function too, and we interpret it as *leisure*. An important characteristic of these utility functions is a preference for variety, and this will bear significantly in our results.

The production functions for commodities and ties are defined by

$$f_c(r_{ig(i)}) = B_{v(i)} r_{ig(i)} \tag{2.12}$$

$$f_s(a_{ij}, a_{ji}) = a_{ij}^{\beta} a_{ji}^{1-\beta}. \tag{2.13}$$

Social ties are built using a constant-returns-to-scale technology, and B_v is the total productivity factor (of effort) for standard commodities in village v. The technology for building social ties in equation (2.13) implies that no agent can be forced into a

[1] We are ruling out the trivial case of perfect substitutability, which would reduce to the agent only consuming the good she produces.

relationship, since she can always set $a_{ij} = 0$. Note that this would not be possible if for instance this production function was CES (with an elasticity of substitution different than one). This property seems apt, given that we wish to depict social ties as a product of voluntary individual action. This mechanism of building ties is in the spirit of game-theoretic literature on network formation, e.g., Jackson and Wolinski (1996) and Bala and Goyal (2000). Our model borrows the approach of tie production from Anjos (2008).

The meaning of β in (2.13) relates to the degree of complementarity in the production of relationships. If $\beta < 0.5$, relationships – from the perspective of the consumer i – rely more heavily on attention being given by j, the other side of the tie. If $\beta > 0.5$, relationships depend mainly on the attention that the focal agent gives to the other agent. It is important to note that we are assuming that β is a non-cultural primitive. Although in equilibrium villages will display different degrees of "individualism", this will result from different equilibria being played, and not from different primitive preferences or technology for social ties. One can interpret the level of the inverse of β as the usual level of egotism displayed by an individual in building relationships with others, which we assume is determined biologically. Also note that the individual's tie with herself is given by a_{ii}, independently of β. Thus a_{ii} can be interpreted as leisure associated with spending time alone. This feature is a direct consequence of assuming a constant-returns-to-scale technology in the production of ties.

Transaction costs are borne by i if she acquires the goods in some marketplace and are given by

$$f_{tc}(SC_{iv}, x_{ig}) = \begin{cases} \frac{\alpha_0}{\left(1+\alpha_2 SC_{v(i)}\right)} x_{ig} & g \in G(v(i)) \\ \alpha_0 x_{ig} & g \notin G(v(i)). \end{cases} \tag{2.14}$$

In case the goods come from self production, transaction costs are assumed to be zero. The first branch of the transaction cost function shows that transaction costs within the village can be economized by social capital; the productivity of which is gaged by α_2. The function that maps social ties to social capital is given by the following expression:

$$f_{sc}(s_i, \{s_j\}_{j \in v(i)}) = \left(\sum_{j \in v(i), j \neq i} s_{ij} \right)^{\alpha_1} \left(\frac{\sum_{j \in v(i)} \sum_{k \in v(i), k \neq j} s_{jk}}{N_{v(i)}} \right)^{1-\alpha_1} \tag{2.15}$$

The first component of social capital, weighted by α_1, relates to the ties of individual

i with respect to other individuals in the village. We interpret this as a measure for how much the individual belongs to the community. The second component averages over all ties in the village. This is meant to capture the global effect of closure, in the sense of sociologist James Coleman. Social capital, as measured from the individual perspective of agent i, has thus a private and a public good component. It seems reasonable to assume that these two components are complementary, as in functional form (2.15). Global closure only matters as a way of solving individual moral hazard and informational problems to the extent that the individual is embedded enough in the network of community ties. This argument notwithstanding, social capital can be set to be a strictly public good, by imposing $\alpha_1 = 0$. The upper bound for social capital is 1, independently of the size of the village.

We can now write the Lagrangian associated with the maximization problem of some agent i.

$$\begin{aligned}
\mathcal{L}_i \; = \; & \left[\phi \left\{ \left(x^o_{ig(i)} + x_{ig(i)} \right)^{\rho_c} + \sum_{\substack{g \neq g(i) \\ g \in G(v(i))}} x_{ig}^{\rho_c} + \sum_{v \neq v(i)} \sum_{g \in G(v)} \left[x_{ig} (1 - \tau_{v(i)v}) \right]^{\rho_c} \right\}^{\frac{\rho_{c,s}}{\rho_c}} + \right. \\
& \left. (1-\phi) \left\{ \sum_{j \in v(i)} [f_s(a_{ij}, a_{ji})]^{\rho_s} \right\}^{\frac{\rho_{c,s}}{\rho_s}} \right]^{\frac{1}{\rho_{c,s}}} - \theta_i \left\{ r_{ig(i)} + \sum_{j \in v(i)} a_{ij} - 1 + \right. \\
& \left. + \sum_{g \in \cup G(v)} \alpha_0 \left[1 + \alpha_2 f_{sc} \left(\{ f_s(a_{ij}, a_{ji}) \}_{\substack{j \in v(i) \\ j \neq i}}, \{ f_s(a_{jk}, a_{kj}) \}_{j,k \in v(i)} \right) \right]^{-1} x_{ig} \right\} \\
& - \lambda_i \left\{ \sum_{g \in \cup G(v)} x_{ig} p_g - \left(B_{v(i)} r_{ig(i)} - x^o_{ig(i)} \right) p_{g(i)} \right\} + \sum_{j \in v(i)} \eta_{a,ij} a_{ij} + \eta_{r,i} r_{ig(i)} \\
& + \eta_{o,i} x^o_{ig(i)} + \sum_{g \in \cup G(v)} \eta_{x,ig} x_{ig}, \qquad (2.16)
\end{aligned}$$

where we have made use of the substitutions

$$\begin{aligned}
x^S_{ig(i)} &= f_c(r_{ig(i)}) - x^o_{ig(i)} = B_{v(i)} r_{ig(i)} - x^o_{ig(i)} \\
s_{ij} &= f_s(a_{ij}, a_{ji}).
\end{aligned}$$

The Lagrange multiplier θ_i measures the shadow price of time and λ_i measures the shadow price of wealth. All η multipliers refer to non-negativity constraints. We assume that prices and attention from others are taken as given, i.e., we will be investigating Nash equilibria. Denoting by N_v the number of agents in village v, the price-taking behavior is consistent with $N_v/G_v >> 1$, which we assume.

The FOC with respect to self consumption x^o_{ig} yields the following relation:

$$(\mathcal{U}_i^*)^{1-\rho_{c,s}}\,\phi\left\{\left(x^o_{ig(i)}+x_{ig(i)}\right)^{\rho_c}+\sum_{\substack{g\neq g(i)\\ g\in G(v(i))}} x_{ig}^{\rho_c}+\sum_{v\neq v(i)}\sum_{g\in G(v)}\left[x_{ig}(1-\tau_{v(i)v})\right]^{\rho_c}\right\}^{\frac{\rho_{c,s}}{\rho_c}-1}\times$$
$$\left(x^o_{ig(i)}+x_{ig(i)}\right)^{\rho_c-1}=\lambda_i p_{g(i)}+\eta_{o,i},\quad (2.17)$$

where $\mathcal{U}_i^*$ is the utility function evaluated at the optimum, i.e., the value function. The FOC with respect to the additional consumption of good $g(i)$ is

$$(\mathcal{U}_i^*)^{1-\rho_{c,s}}\,\phi\left\{\left(x^o_{ig(i)}+x_{ig(i)}\right)^{\rho_c}+\sum_{\substack{g\neq g(i)\\ g\in G(v(i))}} x_{ig}^{\rho_c}+\sum_{v\neq v(i)}\sum_{g\in G(v)}\left[x_{ig}(1-\tau_{v(i)v})\right]^{\rho_c}\right\}^{\frac{\rho_{c,s}}{\rho_c}-1}\times$$
$$\times\left(x^o_{ig(i)}+x_{ig(i)}\right)^{\rho_c-1}=\theta_i\frac{\alpha_0}{(1+\alpha_2 SC_{v(i)})}+\lambda_i p_{g(i)}+\eta_{x,ig(i)}.\quad (2.18)$$

Suppose that i produces some good $g(i)$ and consumes part of it, such that $\eta_{o,ig(i)}=0$. Combining expressions (2.17) and (2.18), it is trivial to see that i will not acquire good $g(i)$. If this were the case, then $\eta_{x,ig(i)}=0$ and the following would have to be true:

$$\theta_i\frac{\alpha_0}{(1+\alpha_2 SC_{v(i)})}=0$$

This would generally not obtain, except if $\alpha_0=0$. The intuition for this is that as long as transaction costs are positive, then for any given price the agent would always be better off by marginally decreasing the supply of good $g(i)$ and marginally increasing self consumption. The FOC for goods $g\in v(i)$ different than $g(i)$ is

$$(\mathcal{U}_i^*)^{1-\rho_{c,s}}\,\phi\left\{\left(x^o_{ig(i)}+x_{ig(i)}\right)^{\rho_c}+\sum_{\substack{g\neq g(i)\\ g\in G(v(i))}} x_{ig}^{\rho_c}+\sum_{v\neq v(i)}\sum_{g\in G(v)}\left[x_{ig}(1-\tau_{v(i)v})\right]^{\rho_c}\right\}^{\frac{\rho_{c,s}}{\rho_c}-1}\times$$

$$\times (x_{ig})^{\rho_c - 1} = \theta_i \frac{\alpha_0}{(1+\alpha_2 SC_{v(i)})} + \lambda_i p_g + \eta_{x,ig}. \quad (2.19)$$

The FOC for consumption from other villages is

$$(\mathcal{U}_i^*)^{1-\rho_{c,s}} \phi \left\{ \left(x_{ig(i)}^o + x_{ig(i)}\right)^{\rho_c} + \sum_{\substack{g \neq g(i) \\ g \in G(v(i))}} x_{ig}^{\rho_c} + \sum_{v \neq v(i)} \sum_{g \in G(v)} \left[x_{ig}(1-\tau_{v(i)v})\right]^{\rho_c} \right\}^{\frac{\rho_{c,s}}{\rho_c}-1} \times$$

$$\times \left[x_{ig}(1-\tau_{v(i)v})\right]^{\rho_c - 1} (1-\tau_{v(i)v}) = \theta_i \alpha_0 + \lambda_i p_g + \eta_{x,ig}. \quad (2.20)$$

Note that θ_i, the shadow price of time, enters equations (2.19) and (2.20). This means that if for some reason the agent is "poor" in terms of time (high θ_i), then *ceteris paribus* she will consume less traded goods, in order to economize in transaction costs.

Next we derive the decisions regarding social ties. Consider first the time spent in non-social leisure a_{ii}; the FOC with respect to this control yields

$$(\mathcal{U}_i^*)^{1-\rho_{c,s}} (1-\phi) \left\{ \sum_{j \in v(i)} \left(a_{ij}^{\beta} a_{ji}^{1-\beta}\right)^{\rho_s} \right\}^{\frac{\rho_{c,s}}{\rho_s}-1} a_{ii}^{\rho_s - 1} = \theta_i - \eta_{a,ii}. \quad (2.21)$$

With respect to a_{ij} the FOC is slightly more complex:

$$(\mathcal{U}_i^*)^{1-\rho_{c,s}} (1-\phi) \left\{ \sum_{j \in v(i)} \left(a_{ij}^{\beta} a_{ji}^{1-\beta}\right)^{\rho_s} \right\}^{\frac{\rho_{c,s}}{\rho_s}-1} \left(a_{ij}^{\beta} a_{ji}^{1-\beta}\right)^{\rho_s - 1} \beta a_{ij}^{\beta-1} a_{ji}^{1-\beta} =$$

$$= \theta_i \left\{ 1 - \frac{\left(\sum_{g=1}^{G} x_{iv(i)g}\right) \alpha_0 \alpha_1 \alpha_2 \beta a_{ij}^{\beta-1} a_{ji}^{1-\beta}}{\left[1 + \alpha_2 \left(\sum_{j \in v(i), j \neq i} a_{ij}^{\beta} a_{ji}^{1-\beta}\right)^{\alpha_1} \left(\frac{\sum_{j \in v(i)} \sum_{k \in v(i), k \neq j} a_{jk}^{\beta} a_{kj}^{1-\beta}}{N_{v(i)}}\right)^{1-\alpha_1}\right]^2} \times \right.$$

$$\left. \times \left[\left(\sum_{j \in v(i), j \neq i} a_{ij}^{\beta} a_{ji}^{1-\beta} \right)^{\alpha_1 - 1} \left(\frac{\sum_{j \in v(i)} \sum_{k \in v(i), k \neq j} a_{jk}^{\beta} a_{kj}^{1-\beta}}{N_{v(i)}} \right)^{1-\alpha_1} \right] \right\} - \eta_{a,ij}, \quad (2.22)$$

where we have made use of the assumption that $N_{v(i)}$ is large enough that agent i disregards the impact of a_{ij} in terms of the public good component of social capital. There is an intuitive relation between a_{ij} and a_{ii}, but given the complexity of the expression above we postpone this discussion until the next section. For the moment note that if $a_{ji} = 0$, then the LHS of equation (2.22) is also zero. Since the term pre-multiplied by θ_i becomes 1, an interior solution for a_{ij} does not exist. This particular feature of the model allows for multiple equilibria in terms of social ties, and it is the result of assuming the Cobb-Douglas functional form for the tie production function.[2]

Finally we derive the expression that gives the optimal effort for production of good g, namely r_{ig}.

$$\theta_i = \lambda_i B_{v(i)} p_{g(i)} + \eta_{r,i}, \tag{2.23}$$

where again we have made use of the assumption of large $N_{v(i)}$.

An interior solution with an in-village symmetric equilibrium is further characterized by the following conditions, for all $i \in v$:

$$x^o_{ig(i)} = c_{0v} \tag{2.24}$$

$$x_{ig}\big|_{g \in G(v), g \neq g(i)} = c_{1v} \tag{2.25}$$

$$x_{ig}\big|_{g \in G(v^*), v^* \neq v} = c_{2vv^*} \tag{2.26}$$

$$a_{ii} = a_{0v} \tag{2.27}$$

$$a_{ij}\big|_{j \in v, j \neq i} = a_{1v} \tag{2.28}$$

$$r_{ig(i)} = r_v \tag{2.29}$$

$$\#\{j | a_{ij} > 0, j \in v, j \neq i\} = F_v \tag{2.30}$$

$$p_g\big|_{\exists j \in v^* : g(j) = g} = p_{v^*} \tag{2.31}$$

$$\theta_i = \theta_v \tag{2.32}$$

$$\lambda_i = \lambda_v \tag{2.33}$$

Equation (2.30) refers to the *number of ties* of each agent. Any F_v is sustainable in equilibrium. The intuition behind this is that i will not pay attention to someone from whom she does not receive attention, and this is an equilibrium. It is important to emphasize that if agent j sets $a_{ji} = 0$, a_{ij} is *strictly* a better response than $a_{ij} = 0$ for agent i. This is so because time is valuable and $a_{ij} > 0$ *per se* translates into a zero increase to the utility of agent i. On the other hand, the marginal utility of a new tie is infinity at zero, so F_v does not have an upper bound. Also, note that the equality in equilibrium prices, stated in (2.31), is implied by the remaining conditions. The same

[2]Some equilibria with $(a_{ij}, a_{ji}) = (0, 0)$ are however not *pairwise stable*, an equilibrium definition that is important in the economic networks literature; see for example Jackson and Wolinski (1996). See proposition 2.

applies to the Lagrange multipliers.

Manipulating the system of first-order equations, constraints, and equilibrium conditions, an interior solution is given by the following system of equations:

$$\frac{c_{0v}}{c_{1v}} = \left[1+\frac{\alpha_0}{(1+\alpha_2 F_v a_{1v})}B_v\right]^{\frac{1}{1-\rho_c}} \tag{2.34}$$

$$\frac{c_{2vv^*}}{c_{1v}} = \left\{\frac{(1-\tau_{vv^*})^{\rho_c}\left[1+\frac{\alpha_0 B}{(1+\alpha_2 F_v a_{1v})}\right]}{\alpha_0 B_v + p_{v^*}/p_v}\right\}^{\frac{1}{1-\rho_c}} \tag{2.35}$$

$$\frac{c_{0v}^{1-\rho_c}}{a_{0v}^{1-\rho_s}} = B_v \times \frac{\phi\left\{c_{0v}^{\rho_c}+(G_v-1)c_{1v}^{\rho_c}+\sum_{v^*\neq v} G_{v^*}\left[c_{2vv^*}(1-\tau_{vv^*})\right]^{\rho_c}\right\}^{\frac{\rho_{c,s}}{\rho_c}-1}}{(1-\phi)\left[a_{0v}^{\rho_s}+F_v a_{1v}^{\rho_s}\right]^{\frac{\rho_{c,s}}{\rho_s}-1}} \tag{2.36}$$

$$\frac{a_{0v}}{a_{1v}} = \left[\frac{1}{\beta}-(G_v-1)c_{1v}\frac{\alpha_0\alpha_1\alpha_2}{(1+\alpha_2 F a_1)^2}\right]^{\frac{1}{1-\rho_s}} \tag{2.37}$$

$$(BC) \qquad (G_v-1)c_{1v}+\sum_{v^*\neq v} G_{v^*}c_{2vv^*}\frac{p_{v^*}}{p_v} = B_v r_v - c_{0v} \tag{2.38}$$

$$(TC) \qquad r_v+(G_v-1)\frac{\alpha_0}{(1+\alpha_2 F_v a_{1v})}c_{1v}+\sum_{v^*\neq v} G_{v^*}\alpha_0 c_{2vv^*} + a_{0v}+F_v a_{1v} = 1 \tag{2.39}$$

$$(MC) \qquad \frac{N_v}{G_v}\left[B_v r_v - c_{0v}\right] = \left(N_v-\frac{N_v}{G_v}\right)c_{1v}+\sum_{v^*\neq v} N_{v^*}c_{2v^*v}, \tag{2.40}$$

where BC is the budget constraint, TC the time constraint, and MC the market-clearing condition. The latter is only necessary for relations between villages, since the in-village symmetry condition combined with the budget constraints imply in-village market clearing automatically.

Equation (2.34) shows that c_1 is (weakly) smaller than c_0. The agent adjusts her consumption bundle towards the good without transaction costs, i.e. self consumption. This bias is mitigated by social capital $F_v a_{1v}$; in societies with higher social capital, *ceteris paribus* one should observe a more balanced relation between self consumption and consumption of domestic goods. It is interesting to note that productivity B_v also affects the ratio c_0/c_1. The reason is that the agent can compensate for a higher marginal utility of c_1 for a greater quantity of c_0, if it is not costly to do so (which is the case with high B_v). Naturally the elasticity of substitution $1/(1-\rho_c)$ plays an important role in the relation between c_0 and c_1. In the extreme case of Leontieff preferences ($\rho_c = -\infty$), the ratio is always one. In the extreme case of perfect substitutability, $c_{1v} = 0$.

The relation between c_1 and c_2, stated in equation (2.35), is mediated by two channels: (i) the natural advantage of domestic consumption, via lower transaction costs (if social capital is positive) and zero transport costs; and (ii) the terms of trade, measured by the real exchange rate p_{v^*}/p_v.

The consumption of c_0 in relation to non-social leisure a_0, given in equation (2.36), is impacted mainly by three factors: (i) the elasticity of substitution between standard commodities and ties; (ii) the productivity of effort; and (iii) the relative preference for standard commodities, measured by ϕ.

Equation (2.37) shows that the agent will have higher non-social leisure a_0 relative to a_1 when β is small. This does not follow though from a lower primitive preference for social ties; it is just the case that with low β (high level of egotism), agents in any bilateral relation experience a coordination failure – for a detailed discussion of this mechanism see Anjos (2008). On the other hand, if transaction costs α_0 are high and the agent controls part of her social capital ($\alpha_1 > 0$), this implies *ceteris paribus* a higher a_1. This effect is reinforced if the agent is trading a lot of goods inside the village (high G_v) and/or consumes large quantities of these goods (high c_1).

2.2.3 Benchmark model

In this section we solve a benchmark case, where we simplify the model along some dimensions, but keep the most important features. The objective of this exercise is to understand the mechanics implied by our theoretical approach, especially with respect to the interaction of social ties (and capital) with other economic variables. The benchmark model is characterized by: (i) $\rho_{c,s} = \rho_c = \rho_s \equiv \rho$;[3] (ii) partial equilibrium with respect to the exterior and only one trade partner – terms of trade denoted by p^*, number of imported goods by G^*, and transport costs by τ. The benchmark case

[3]This assumption is relaxed in the calibration; see section 2.3.1.

can be reduced to the following system of equations (where a_1 is to be found):

$$a_1^*(a_1) = c_1^*(a_1)\left\{\frac{(1-\phi)\left[1+\frac{\alpha_0 B}{(1+\alpha_2 F a_1)}\right]}{\phi B\left[1/\beta-(G-1)\frac{\alpha_0\alpha_1\alpha_2}{(1+\alpha_2 F a_1)^2}c_1^*(a_1)\right]}\right\}^{\frac{1}{1-\rho}} \quad (2.41)$$

$$c_1^*(a_1) = B(1-Fa_1)\left\{(G-1)\left[1+\frac{\alpha_0 B}{(1+\alpha_2 F a_1)}\right]+\left[1+\frac{\alpha_0 B}{(1+\alpha_2 F a_1)}\right]^{\frac{1}{1-\rho}}\times\right.$$
$$\left.\times\left[1+\left(\frac{1-\phi}{\phi B^\rho}\right)^{\frac{1}{1-\rho}}+G^*\left(\frac{1-\tau}{p^*+\alpha_0 B}\right)^{\frac{\rho}{1-\rho}}\right]\right\}^{-1} \quad (2.42)$$

$$c_0^*(a_1) = c_1^*(a_1)\left[1+\frac{\alpha_0 B}{(1+\alpha_2 F a_1)}\right]^{\frac{1}{1-\rho}} \quad (2.43)$$

$$c_2^*(a_1) = c_1^*(a_1)\left\{\frac{(1-\tau)^\rho\left[1+\frac{\alpha_0 B}{(1+\alpha_2 F a_1)}\right]}{p^*+\alpha_0 B}\right\}^{\frac{1}{1-\rho}} \quad (2.44)$$

$$a_0^*(a_1) = c_1^*(a_1)\left\{\frac{(1-\phi)\left[1+\frac{\alpha_0 B}{(1+\alpha_2 F a_1)}\right]}{\phi B}\right\}^{\frac{1}{1-\rho}} \quad (2.45)$$

$$r^*(a_1) = 1-\left[(G-1)\frac{\alpha_0}{(1+\alpha_2 F a_1)}c_1^*(a_1)+G^*\alpha_0 c_2^*(a_1)+a_0^*(a_1)+Fa_1\right] \quad (2.46)$$

The following proposition establishes existence and uniqueness.

Proposition 1 *In the benchmark case with $\phi < 1$, for a given F there exists a unique interior symmetric equilibrium.*

Next we show that $F = N$ (maximal "communitarianism") must hold in any (symmetric) pairwise stable equilibrium, an important solution concept in the economic networks literature (see e.g. Jackson and Wolinski (1996)). Pairwise stability requires that no pair of connected agents prefers to sever their tie, and no pair of disconnected agents prefers to build a tie.

Proposition 2 *In the benchmark case with $\phi < 1$, any symmetric pairwise stable equilibrium requires $F = N$.*

The fact that a pairwise stable equilibrium requires $F = N$ follows from two key assumptions: (i) the preference for variety in social ties (recall $\rho < 1$); (ii) the absence of fixed costs in building or severing ties. With respect to the first assumption we are not sure if this behavioral representation is unreasonable. With respect to the second we believe it is somewhat unrealistic. If there were fixed costs of building and severing ties, there would probably exist pairwise stable equilibria for different F. The tractability of our framework would however be hampered if we introduced that sort of discontinuity. In this sense, we interpret our simple multiple Nash equilibria (for each F) as robust in light of these omitted fixed costs. Nonetheless, the model naturally favors "communitarianism" (high F), in the sense that it is more stable than individualism.

No transaction costs ($\alpha_0 = 0$)

Without transaction costs we are able to find a closed-form solution:

$$c_0 = c_1 = \frac{B}{G + G^* \left(\frac{1-\tau}{p^*}\right)^{\frac{\rho}{1-\rho}} + \left(\frac{1-\phi}{\phi B^\rho}\right)^{\frac{1}{1-\rho}} \left(1 + F\beta^{\frac{1}{1-\rho}}\right)} \tag{2.47}$$

$$c_2 = \frac{B\left[\frac{(1-\tau)^\rho}{p^*}\right]^{\frac{1}{1-\rho}}}{G + G^* \left(\frac{1-\tau}{p^*}\right)^{\frac{\rho}{1-\rho}} + \left(\frac{1-\phi}{\phi B^\rho}\right)^{\frac{1}{1-\rho}} \left(1 + F\beta^{\frac{1}{1-\rho}}\right)} \tag{2.48}$$

$$a_0 = \frac{\left[\frac{(1-\phi)}{\phi B^\rho}\right]^{\frac{1}{1-\rho}}}{G + G^* \left(\frac{1-\tau}{p^*}\right)^{\frac{\rho}{1-\rho}} + \left(\frac{1-\phi}{\phi B^\rho}\right)^{\frac{1}{1-\rho}} \left(1 + F\beta^{\frac{1}{1-\rho}}\right)} \tag{2.49}$$

$$a_1 = \frac{\left[\frac{\beta(1-\phi)}{\phi B^\rho}\right]^{\frac{1}{1-\rho}}}{G + G^* \left(\frac{1-\tau}{p^*}\right)^{\frac{\rho}{1-\rho}} + \left(\frac{1-\phi}{\phi B^\rho}\right)^{\frac{1}{1-\rho}} \left(1 + F\beta^{\frac{1}{1-\rho}}\right)} \tag{2.50}$$

$$r = \frac{G + G^* \left(\frac{1-\tau}{p^*}\right)^{\frac{\rho}{1-\rho}}}{G + G^* \left(\frac{1-\tau}{p^*}\right)^{\frac{\rho}{1-\rho}} + \left(\frac{1-\phi}{\phi B^\rho}\right)^{\frac{1}{1-\rho}} \left(1 + F\beta^{\frac{1}{1-\rho}}\right)} \tag{2.51}$$

From equation (2.51) it is straightforward to see that a higher F implies a lower effort r. Also, an increase in F implies always a higher social capital, which is shown in the next proposition.

Proposition 3 *In the benchmark case with $\alpha_0 = 0$, a higher degree of communitarianism F implies higher social capital Fa_1.*

Thus, for a cross section of economies with different degrees of communitarianism, i.e. different F, in the case without transaction costs the model endogenously generates a negative relationship between social capital and effort. Note however that we are holding everything else constant. Also, as shown towards the end of this section, this negative relationship does not always obtain when the assumption of equal elasticities of substitutions (equal ρs) is relaxed. We will next discuss how variation in productivity, number of goods, and transport costs affects magnitudes of interest, since heterogeneity in these three dimensions is, we believe, typically associated with heterogeneity in economic development.

If $\rho > 0$, i.e. social ties and standard commodities are substitutes, increasing the productivity parameter B leads *ceteris paribus* to an increase in production effort and a decrease in social capital, which is trivially seen by looking at equations (2.51) and (2.50). The decrease in social capital is necessary to accommodate the increase in effort, which is optimal given the higher productivity. But this only takes place because standard commodities and ties are substitutes. In fact, if $\rho \leq 0$ an increase in B will generate a decrease in effort. The complementarity between the consumption of social ties and standard commodities implies that a higher level of the latter (from a higher B) is optimally accompanied by a higher level of the former. For this to take place the agent needs to reduce time spent in the production of the standard goods.

When $\rho > 0$ consumption increases with B – see equations (2.47) and (2.48) – and leisure a_0 decreases, since it is an activity that also requires time, now necessary for production. Our interpretation of this comparative statics exercise is that more developed economies, which display higher productivity, will naturally have both lower social capital and higher production effort, as long as transaction costs are low enough and the elasticities of substitution are relatively similar and high enough. Whether these qualifications are appropriate is ultimately an empirical question, which we discuss further in section 2.3.1.

Another dimension that one would naturally associate with different stages of development is the number of traded goods. In the case without transaction costs, an increase in G or in G^* has the same effect in effort and social capital as an increase in productivity when $\rho > 0$. A higher variety of goods coupled with a preference for variety makes the agents substitute away from leisure and social ties into standard commodities; this requires more production, so again time becomes more expensive. The effect in per-type-of-good consumption c_0, c_1, and c_2 is naturally a decrease, since the agent is trading off quantity of consumption for variety of consumption.

Next we consider how variation in transport costs, also in line with a notion of economic development, impacts both social capital and effort. Inspecting equations (2.51) and (2.50) again, we find that for $\rho > 0$ lower transport costs are associated with higher effort and lower social capital, so in essence the effect is the same as an increase in productivity.

Finally we wish to address the following question: is the negative relation between communitarianism F and effort r a more general feature of the model? The next proposition shows that this is *not* the case, and again that the elasticities of substitution play a determinant role.

Proposition 4 *Relaxing the assumption of a single ρ in the benchmark case without transaction costs, an increase in F leads to a decrease in r if and only if the following is true:*

$$\rho_s - \rho_{c,s} < \rho_s \left(1 - \rho_{c,s}\right) \left[\frac{F + \left(\frac{1}{\beta}\right)^{\frac{\rho_s}{1-\rho_s}}}{F + \left(\frac{1}{\beta}\right)^{\frac{1}{1-\rho_s}}} \right] \tag{2.52}$$

The RHS of equation (2.52) is always positive as long as $\rho_s > 0$, so the assumption of equal ρs, which makes the LHS of said expression 0, implies that communitarianism F and effort r are negatively related. However, it is easy to see that, for instance if $\rho_{c,s} = 0$ and $\rho_s > 0$, expression (2.52) is false. In this case, as communitarianism increases agents dispense more effort in production. This is the result from social ties and standard commodities being (more) complementary.

So far the key message of this section is that even with the simplifying assumption that ties result primordially from preferences, as suggested by Arrow (2000), and do not play a technological role, whether or not one observes an increase in transformational effort with an increase in the degree of communitarianism is a function of whether standard goods and social ties are substitutes or complements.

Positive transaction costs ($\alpha_0 > 0$)

When positive transaction costs are considered, social ties are no longer a simple consumption good. Social ties are the building blocks of social capital, which economizes in-village transaction costs. To understand what the model implies when social ties have a technological role, we start by analyzing what happens when there are no preferences for social ties ($\phi = 1$). The results are presented in proposition 5 and corollary 1.

Proposition 5 *If In the benchmark case with $\phi = 1$, the following is true:*

1. *Social capital has the following upper bound $\overline{SC}$:*

$$\overline{SC} \equiv \frac{1}{\alpha_2} \left\{ \frac{\alpha_0 B(\alpha_1 \beta \alpha_2 - 1) - 1 - \frac{(1+\alpha_0 B)^{\frac{1}{1-\rho}}}{(G-1)} \left[1 + G^* \left(\frac{1-\tau}{p^* + \alpha_0 B} \right)^{\frac{\rho}{1-\rho}} \right]}{(1 + \alpha_0 B \alpha_1 \beta) + \frac{(1+\alpha_0 B)^{\frac{1}{1-\rho}}}{(G-1)} \left[1 + G^* \left(\frac{1-\tau}{p^* + \alpha_0 B} \right)^{\frac{\rho}{1-\rho}} \right]} \right\} \tag{2.53}$$

2. *For log utility ($\rho = 0$), the following condition is necessary and sufficient for the existence of an equilibrium with $a_1 > 0$:*

$$\alpha_2 \geq \frac{(1 + \alpha_0 B)(G + G^*)}{\alpha_1 \beta \alpha_0 B(G - 1)} \tag{2.54}$$

Corollary 1 *The results of proposition 5 imply that in the benchmark case with $\phi = 1$, the following statements are true:*

1. *If $\alpha_2 \leq \frac{1}{\alpha_1 \beta} \left(1 + \frac{1}{\alpha_0 B} \right)$, there is no interior symmetric equilibrium, i.e. $a_1 = 0$.*
2. *If $\tau < 1$ and $\rho > -\infty$, there always exists a* high enough G^* *such that there exists no symmetric equilibrium with $a_1 > 0$.*
3. *For log utility ($\rho = 0$), an increase in G^* implies a monotonic increase of the minimum value of α_2 that sustains an equilibrium with positive a_1.*
4. *A decrease in transport costs τ leads to a decrease in the upper bound for social capital if and only if $\rho > 0$.*

Point 1 in corollary 1 states that social capital is only observed in equilibrium if the productivity of social capital is high enough. In particular note that if either social capital is a pure public good ($\alpha_1 = 0$) or agents are completely egotistic ($\beta = 0$), social capital is zero even if its productivity (α_2) is arbitrarily high (but finite). The (symmetric) socially optimal amount of social capital does not depend on β nor α_1, given the way ties and social capital were constructed. The degree to which the observed social capital departs from this optimum is a function of the product $\alpha_1 \beta$. Interestingly this means that the two sources of coordination failure – free-riding in relationship building and in social capital – compound in this model. This implies that even if β or α_1 are not excessively low, social capital may be severely underprovided because the product $\beta\alpha_1$ is small. Other determinants of non existence of social capital are the number of traded goods with the exterior, transport costs, transaction costs, and productivity; as shown in points 1-4 in corollary 2. However, if these factors *per se* determine that social capital is not observed, this is not the result of a coordination failure. Rather, social capital may extinguish its usefulness, for instance if agents have to spend a significant amount of time trading with the exterior (high G^*). It is also interesting to note, both in point 1 in the corollary and equation 2.54 in proposition 5, that the effect of transaction costs α_0 always appears multiplied by productivity B: social capital only exists if the ratio $\alpha_0 B$ is high enough. The reason for this complementarity is that the level of transaction costs only matters to the extent that society is productive enough to generate a significant amount of trade. Otherwise self consumption is the main source of utility for standard commodities and there is little use for social capital.

The fact that agents may indeed derive consumption utility from social ties may help solve the problem of underprovision of social capital. The next proposition shows how a preference for social ties delivers a lower bound for social capital $\underline{SC}$, even when it is a pure public good. This implies that if α_2 is high, there is an important positive externality to the transaction technology that is associated with preferences.

Proposition 6 *In the benchmark case with $\phi < 1$, there is a lower bound for social capital, given by:*

$$\underline{SC} \equiv \frac{\beta F}{\left[G + G^* \left(\frac{1-\tau}{p^* + \alpha_0 B}\right)^{\frac{1}{1-\rho}}\right] \left(\frac{\phi B^\rho}{1-\phi}\right)^{\frac{1}{1-\rho}} + 1 + \beta F} \tag{2.55}$$

Also, for the log-utility case and $\alpha_1 = 0$ (social capital is a pure public good), the lower bound given by (2.55) coincides with the actual social capital.

Corollary 2 *The result of proposition 6 implies that the following statements are true:*

1. *The lower bound for social capital given by equation (2.55) is* increasing *in F, β, τ, and α_0.*

2. *The lower bound for social capital given by equation (2.55) is* decreasing *in G and G^*.*

3. *Both ρ and B have an ambiguous effect in the lower bound for social capital given by equation (2.55).*

As in the case with $\phi = 1$, the lower bound for social capital may become relatively low if the economic environment changes. This would for instance happen with an increase in the number of imported goods G^*. The level of coordination failure in building relationships, gaged by β, may also drive the lower bound for social capital to an arbitrarily low level. Naturally, in this model it is impossible to create social capital in a society of fully egotistical individuals ($\beta = 0$), even when these individuals enjoy social ties highly (low ϕ) and social capital is very productive (high α_2).

A natural question to ask about this model is whether the fact that social capital plays a relevant technological role helps reduce coordination problems with respect to the consumption of social ties. The answer is "not significantly", and the explanation ensues. The level of coordination failure in relationship building is a function of how low β is. But if β is low, then $\beta\alpha_1$ is low too, and as argued above this is what underlies a technological underprovision of social capital. On the other hand, even if $\alpha_1 = 0$, if agents have a strong preference for social ties and β is relatively high, they have a private incentive to build ties. This then translates into a positive externality, namely the reduction in transaction costs.

The remaining of our exploration of the static model with positive transaction costs is numerical, given that expressions either do not exist in closed-form or are too cumbersome. We followed a strategy of setting the parameters at values guided by the calibration exercise of section 2.3.1, and then doing selective comparative statics. Our main interest is in the equilibrium outcomes for social capital and transformational effort. Figure 2.2 depicts how changing unitary transaction costs affects both these variables.

The right panel in figure 2.2 shows how lower transaction costs α_0 are associated with lower social capital, for any F. This happens for two reasons. The first is that when α_0 is very high there is almost no trading, i.e. c_1 and c_2 are small. Since the agent does not spend a significant amount of time trading, she can produce and consume social ties, and consume leisure. This last effect is shown in the right panel of figure 2.3. Obviously the agent could spend this extra time in transformational effort, but with a decreasing marginal utility for c_0 this does not happen. The second reason why social capital increases with α_0 is that with higher transaction costs the technological importance of social capital increases (this is true only because $\alpha_1 > 0$).

It is interesting to note, in the left panel of figure 2.2, that the relationship between communitarianism and effort is not monotonic, fixing the level of transaction costs α_0.

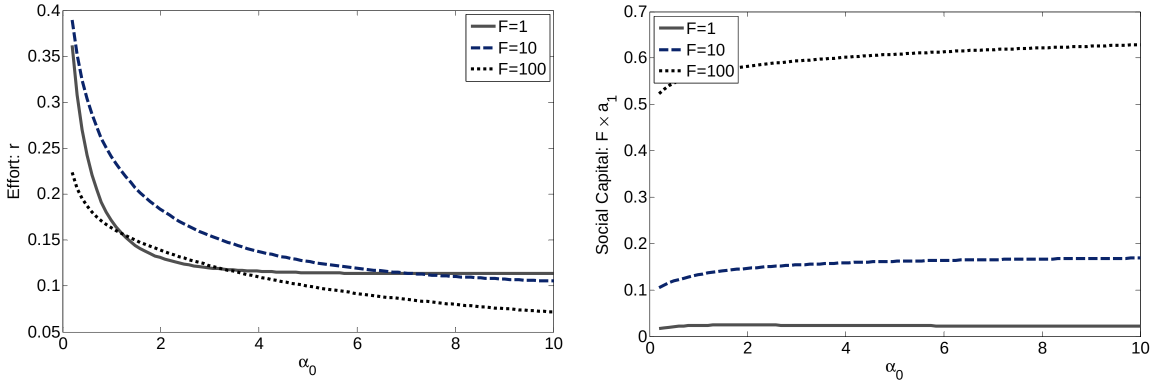


Figure 2.2: Left panel: shows how effort varies with transaction costs α_0. Right panel: shows how social capital varies with transaction costs α_0. In both panels the remaining parameters are set at: $G = G^* = 6$, $B = 3$, $\phi = 0.18$, $\alpha_1 = 0.5$, $\alpha_2 = 44.2$, $\rho = 0.54$, $p^* = 1$, $\tau = 0.1$, $\beta = 0.18$.

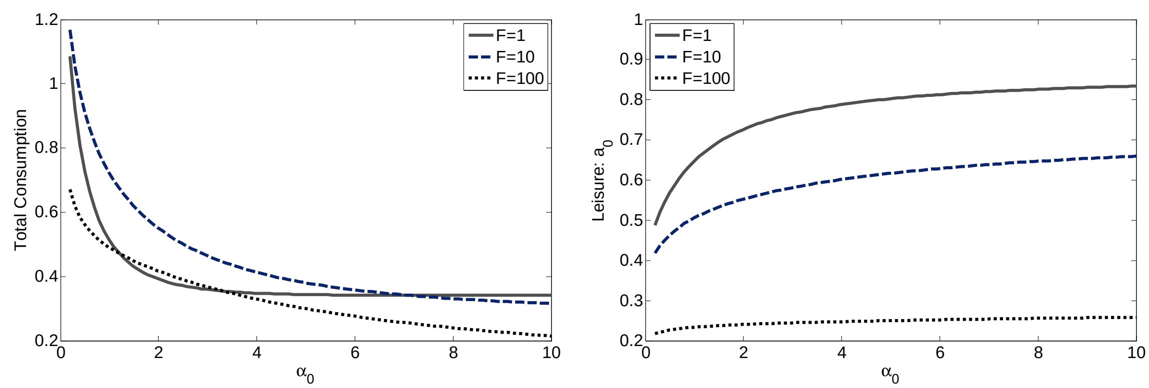


Figure 2.3: Left panel: shows how total consumption $[c_0 + (G-1)c_1 + G^* c_2 p^*]$ varies with transaction costs α_0. Right panel: shows how leisure varies with transaction costs α_0. In both panels the remaining parameters are set at: $G = G^* = 6$, $B = 3$, $\phi = 0.18$, $\alpha_1 = 0.5$, $\alpha_2 = 44.2$, $\rho = 0.54$, $p^* = 1$, $\tau = 0.1$, $\beta = 0.18$.

Let us compare the extreme cases of $F = 1$ and $F = 100$. For high enough transaction costs, both societies simply do not consume c_1 or c_2 (not shown). The effort of low-F societies is higher just because when there are few social ties, this leaves more time for transformational activities. As transaction costs initially decrease, the effort of the high-F economy is higher (relative to the low-F case), for an intermediate region of α_0 (e.g. $\alpha_0 = 2$). This obtains because trading is still so costly for the low-F society that the incentive to produce for obtaining goods beyond self production is relatively low. If we were to model a reduced-form production function for this economy, then for intermediate transaction costs social capital and effort are complementary production factors. As α_0 further decreases, the technological role of social ties becomes less important; in fact it disappears when $\alpha_0 = 0$. We are now back in the case where the effort of low-F societies is higher simply because agents do not spend time in ties.

With positive transaction costs there may now be a technological motive to build ties, namely saving transaction costs. However, from an individual agent's perspective, this is only a valid motive as long as social capital is not a pure public good. It turns out that an increase in α_1 translates into an increase in a_1, which means that part of the observed social ties in equilibrium result from a *deliberate* intent of reducing transaction costs. This is shown in the left panel of figure 2.4.

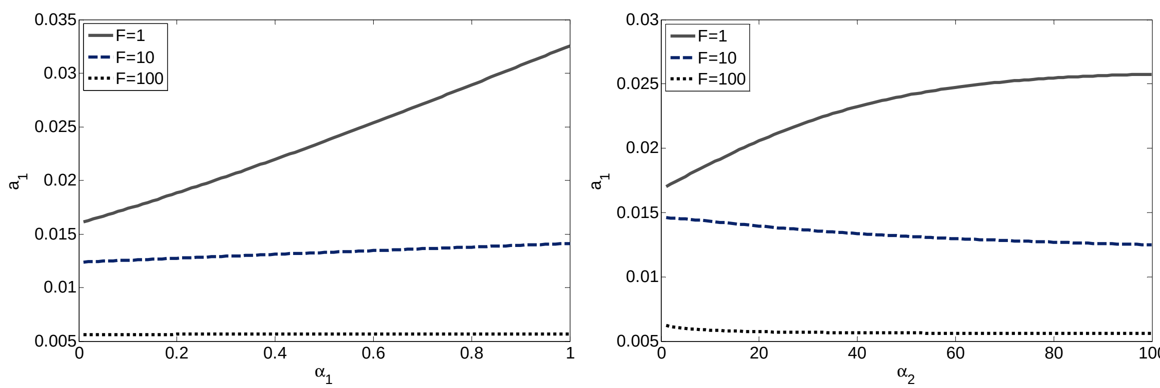


Figure 2.4: Left panel: shows how attention a_1 varies with control over agent-specific social capital α_1; remaining parameters set at: $G = G^* = 6$, $B = 3$, $\phi = 0.18$, $\alpha_0 = 1$, $\alpha_2 = 44.2$, $\rho = 0.54$, $p^* = 1$, $\tau = 0.1$, $\beta = 0.18$. Right panel: shows how attention a_1 varies with social capital productivity α_2; remaining parameters set at: $G = G^* = 6$, $B = 3$, $\phi = 0.18$, $\alpha_0 = 1$, $\alpha_1 = 0.5$, $\rho = 0.54$, $p^* = 1$, $\tau = 0.1$, $\beta = 0.18$.

A question that arises is why changing α_1 only impacts a_1 if F is low (individualistic societies). The intuition for this effect is the following. Agents value variety in ties, and so with a high F they end up with high social capital Fa_1 just for consumption motives. This means that for communitarian societies in this model the marginal benefit of further increasing social ties for a technological motive is low. On the other hand, when F is low, Fa_1 will also tend to be low for consumption reasons, given the decreasing marginal utility of each tie. This means that the marginal benefit of strengthening the existing ties for technological reasons is higher, and therefore we observe a stronger response of a_1 to α_1. Ironically, Fa_1 is more aptly interpreted as social capital (in a deliberate technological sense) in individualistic societies. In communitarian societies, Fa_1 is more a measure for a particular class of consumption goods, namely social ties, which creates an important positive technological *externality* in transaction activities. The qualitative effect of changes in α_2 (the productivity of social capital) also depends on the level of communitarianism, as shown in the right panel of figure 2.4. In fact, if F is high, an increase in this productivity leads to a substitution away from social ties. The income effect dominates for low F, and social capital increases with α_2.

The introduction of transaction costs not only creates direct effects, but also mediates the relationship between other parameters and endogenous variables. Next we analyze how $\alpha_0 > 0$ changes the response of social capital and effort to variations in productivity, which is depicted in figure 2.5. For a given F, the effect of B is qualitatively the same as in the case without transaction costs: higher productivity implies higher transformational effort and lower social capital. The non-monotonic relation between the level of communitarianism and effort, for a given B, parallels the case where we vary transaction costs (figure 2.2). The incentive to produce is a function of relative trade efficiency; for low B, the ratio B/α_0 is low and so individualistic societies (with low social capital) follow predominantly a strategy of self consumption.

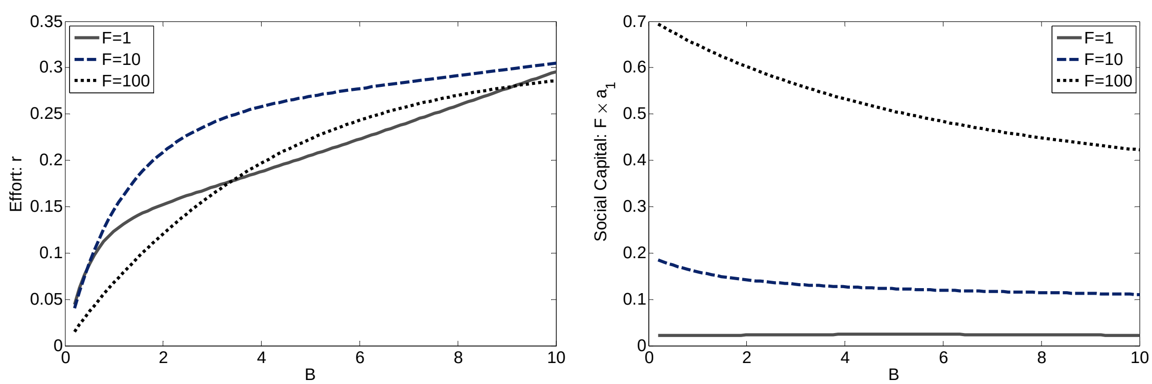


Figure 2.5: Left panel: shows how investment in human capital varies with productivity B. Right panel: shows how social capital varies with productivity B. In both panels the remaining parameters are set at: $G = G^* = 6$, $\phi = 0.18$, $\alpha_0 = 1$, $\alpha_1 = 0.5$, $\alpha_2 = 44.2$, $\rho = 0.54$, $p^* = 1$, $\tau = 0.1$, $\beta = 0.18$.

As mentioned before, another dimension that we would naturally associate with development is a higher variety of goods. Next we investigate whether the introduction of transaction costs changes the relationship between variety, social capital, and effort. With high transaction costs ($\alpha_0 = 10$) the effect of a higher diversity of goods on effort may actually be the opposite of the case with $\alpha_0 = 0$, as shown in the left panel of figure 2.6. The intuition is that with high transaction costs and a high number of goods, agents spend a significant amount of time trading; this is so because diversity is preferred to quantity. Although agents do need to produce in order to be able to trade, and consequently would like to increase effort, with high α_0 this effect may be totally offset, by the fact that they need to allocate time to trade. Not surprisingly this is more of an issue for low-F societies, that cannot rely on social capital to obtain transactive efficiency. The effect on social capital is generally the same as with $\alpha_0 = 0$ (but slightly positive for $F = 1$); a higher diversity of goods is associated with lower social capital, holding F constant. This effect is the most pronounced for high-F societies.

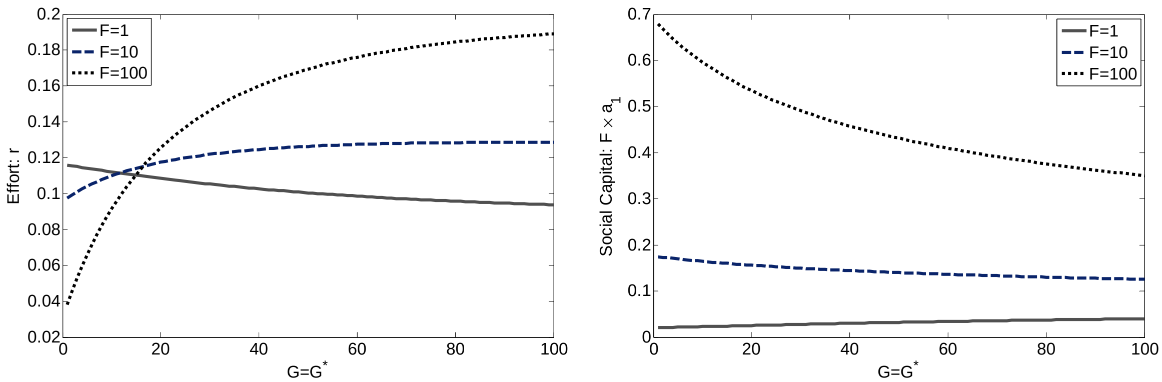


Figure 2.6: Left panel: shows how effort varies with number of goods $G = G^*$. Right panel: shows how social capital varies with number of goods $G = G^*$. In both panels the remaining parameters are set at: $B = 3$, $\phi = 0.18$, $\alpha_0 = 10$, $\alpha_1 = 0.5$, $\alpha_2 = 44.2$, $\rho = 0.54$, $p^* = 1$, $\tau = 0.1$, $\beta = 0.18$.

For lower transaction costs ($\alpha_0 = 1$), the response of effort and social capital to variety is qualitatively the same as without transaction costs (not shown). We also found that a decrease in transport costs delivers similar effects as an increase in the number of goods (not shown). This is intuitive, since high transport costs implies a relatively low consumption of foreign goods, which is the case with a lower number of goods.

Finally we do a simple welfare analysis, shown in figure 2.7. Not surprisingly the communitarian societies have a higher utility. This follows from a preference for diversity in ties and a higher transactive efficiency.

Both panels in figure 2.7 depict a counter-intuitive effect: for communitarian societies (high F) an increase in productivity or an increase in the number of goods leads to a decrease in welfare. The reason why this obtains is the following. Since $\beta < 1$, there is a coordination failure in building bilateral relationships. In other words, agents are consuming social ties below the first-best. An endogenous determinant of the coordination failure is how much the agent has to gain individually from deviating from

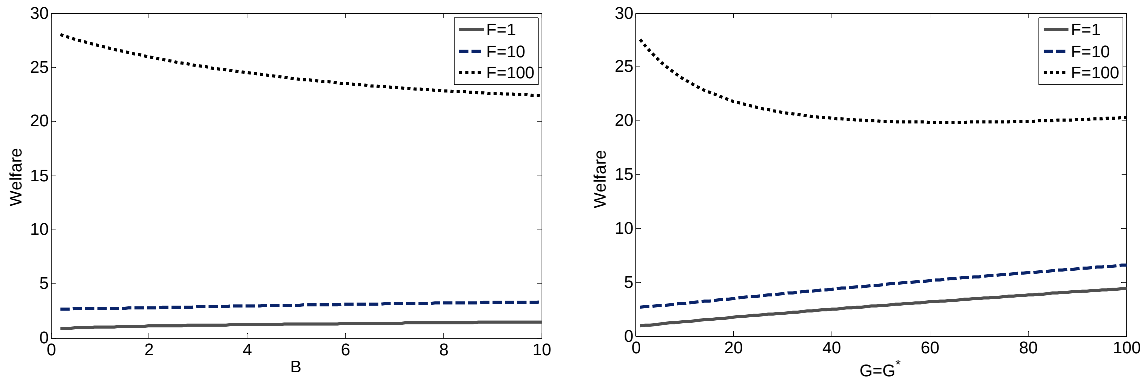


Figure 2.7: Left panel: shows how welfare varies with productivity B; remaining parameters set at: $G = G^* = 6$, $\phi = 0.18$, $\alpha_0 = 1$, $\alpha_1 = 0.5$, $\alpha_2 = 44.2$, $\rho = 0.54$, $p^* = 1$, $\tau = 0.1$, $\beta = 0.18$. Right panel: shows how welfare varies with number of goods $G = G^*$; remaining parameters set at: $B = 3$, $\phi = 0.18$, $\alpha_0 = 1$, $\alpha_1 = 0.5$, $\alpha_2 = 44.2$, $\rho = 0.54$, $p^* = 1$, $\tau = 0.1$, $\beta = 0.18$.

a first-best allocation of attention. This gain is actually in part a function of the level of productivity and the number of goods. In particular, note that if $B = 0$ and/or $G = G^* = 0$, agents spend all their time in social ties and leisure, thus coordination failure is significantly mitigated. The incentive to deviate from a strategy with high a_1 has to do with the opportunity cost of time for the individual agent, which is higher if there are more goods to trade and/or production is more efficient.

In this section we took a first cut into some predictions of the model. Those depend importantly on: (i) the degree of communitarianism (F); (ii) the elasticity of substitution between ties and standard goods; and (iii) the levels of some key parameters, namely the number of goods, the unitary transaction costs, the productivity of social capital, and the productivity of transformational effort. In section 2.3 we will tighten these predictions by calibrating the model and comparing with data. Before proceeding with this, we relax the "small open economy" assumption.

2.2.4 Equilibrium exchange rate

So far we have been analyzing a "small open economy", where the terms of trade are given. In this section we explore how trade between villages with distinct degrees of communitarianism (F) and productivity (B) affects the equilibrium (real) exchange rate. The global economy is comprised of two villages with otherwise identical parameters. The equilibrium exchange rate $p^* \equiv p_{v_2}/p_{v_1}$ is given by

$$p^* = \frac{c_{2,v_2}}{c_{2,v_1}}, \tag{2.56}$$

where p_{v_i} is the price index in village i, and c_{2,v_i} is the quantity of imported goods consumed in village i. This is readily checked by combining the budget constraints and market-clearing conditions for each village. Equation 2.56 represents the equilibration of the trade balance between the two villages.

We chose four numerical scenarios to illustrate how distinct B and F affects prices and quantities. In order to not make this exercise cumbersome, all parameters besides B and F were set at their calibrated levels from section 2.3.1. In terms of each village's F, we set $F_{v_1} = 20$ (high communitarianism) and $F_{v_2} = 1$ (low communitarianism). Table 2.1 shows the results.

Scenario	$p^* = \frac{c_{2,v_2}}{c_{1,v_1}}$	r_{v_1}	r_{v_2}	a_{1,v_1}	a_{1,v_2}
(1) $B_{v_1} = B_{v_2} = 5$	0.140	0.301	0.262	0.009	0.026
		(0.327)	(0.237)	(0.009)	(0.023)
(2) $B_{v_1} = 5, B_{v_2} = 1$	2.545	0.343	0.149	0.009	0.020
		(0.327)	(0.155)	(0.009)	(0.021)
(3) $B_{v_1} = B_{v_2} = 1$	0.812	0.151	0.154	0.013	0.021
		(0.150)	(0.155)	(0.013)	(0.021)
(4) $B_{v_1} = 1, B_{v_2} = 5$	0.151	0.129	0.263	0.012	0.026
		(0.150)	(0.237)	(0.013)	(0.023)

Table 2.1: This table shows the effects of requiring that the real exchange rate equilibrates the trade balance. The numbers in brackets represent the outcomes for each scenario when $p^* = 1$ is assumed.

Scenarios (1) and (3), where the productivity of both villages is similar, show how the equilibrium exchange rate is affected by a difference in F only. In both these scenarios the (relative) price of the goods of the low-F village is low. The intuition for this is the following. Since the high-F village has a significant amount of social capital, foreign goods need to be competitively priced, since the agents naturally bias consumption towards the goods with lower transaction costs, i.e. c_1. The same effect would obtain if there was a subsidy for the consumption of domestic goods.

A difference in B is an important determinant of exchange rates. Inspecting scenario (2) reveals that now village 2 has relatively expensive goods. This happens because village 1 is able to produce goods at a much lower cost (high B), and so these goods are cheap. In scenario (4) this same mechanism leads to a lower exchange rate compared to scenario (3). The goods of village 2 have a low production cost (high B), so they are traded at a relatively lower price.

Finally, note that the introduction of general equilibrium considerations did not lead to significant changes in quantities of effort and ties, as shown by the last 4 columns of table 2.1.

2.3 Dynamic model and quantitative implications

Our objective in this section is to understand whether the model can explain *quantitatively* the heterogeneity in income per capita across time and countries. To generate a time path for each country, we devise a simple dynamic extension of the static model. Each agent lives one period – say from t to $t+1$ – and maximizes a combination of its own lifetime utility plus the discounted utility of her progeny. Agent i's total indirect utility at t is denoted by $\mathcal{J}_i$ (we assume all decisions are made at t):

$$\mathcal{J}_i(B_t) = \max\left\{\mathcal{U}_i(c_i, s_i; B_t) + \gamma \mathcal{J}_{i'}(B_{t+1})\right\}, \tag{2.57}$$

where for notational economy we omitted the village subscript and the dependence of utility on other parameters besides productivity B. We assume these parameters are fixed across time. The label i' denotes agent i's progeny; γ is the discount factor.

The link between the two time periods is the transformational effort. In particular, we assume that, contemporaneously, productivity is the same for all agents, and its law of motion is given by:

$$B_{t+1} = B_t\left(1 - \delta + \sum_i \frac{r_{ig(i)}}{N}\right), \tag{2.58}$$

where the parameter δ is the depreciation rate of productivity. An interpretation for our law of motion for productivity is that agents learn by doing (hence the dependence on effort), and cannot be excluded from knowledge (hence productivity not being agent-specific). Naturally this implies that for large N agents cannot materially influence the utility of their progeny (note that the upper bound for r is 1), and our dynamic model reduces to a repetition of the static optimization and equilibrium problem, only with an endogenous evolution of productivity B. In particular, we still solve for a symmetric equilibrium at each stage, so the law of motion reduces to

$$B_{t+1} = B_t \left(1 - \delta + r_t\right). \tag{2.59}$$

We make the strong assumption that the only difference in primitives between countries at $t = 0$ (the year 1700 in data) is the degree of communitarianism (F), which we are able to proxy for using sociometric data. It is likely the case that certain aspects of the economic environment that we parametrize also changed between 1700 an 2000 (e.g., unitary transaction costs). However, abstracting from these variations helps us understand the quantitative importance of the degree of communitarianism *per se* in terms of economic development. It is also not clear whether the concomitant variation of some other parameters besides F would hinder or strengthen our argument. We detail this discussion towards the end of the paper, in section 2.4.

2.3.1 Calibration

We calibrate the model to data of the United States for the year 1985. We then assume that the parameters are equal for all countries, and simulate how economies with different "cultures" of ties (different F's), which are considered fixed, evolve over time. We set the length of a period to 20 years, and interpret each period's decisions as the decisions of individuals in a generation. For the calibration we use mainly the following pieces of data: (i) output per capita and its components; and (ii) average distribution of use of time.

In the context of our model, total output is defined by the following

$$GDP = Br + B \times TC = c_0 + (G-1)c_1 + G^* c_2 + B \times TC, \tag{2.60}$$

where the last three components are measured output, and the first three components are associated with transformational production. The product $B \times TC$ is the value of transactive effort (in terms of goods).[4]

From the Penn World Table we obtain the measured output per capita for the United States in 1985, slightly higher than 24 thousand dollars (of the year 2000, see table 2.2). We adjusted this amount, using estimates by Devereux and Locay (1992), to account for officially unmeasured home production, and obtained a value for total output per capita slightly higher than 29 thousand dollars. This amount was

[4]The relative price of time in terms of goods is given by the ratio $\theta/(\lambda p)$, which is simply B – see equation (2.23).

distributed into four components (which correspond to the four types of goods in our model): home production (c_0, 22%), production for the local market ($(G-1)c_1$, 35%), production for the foreign market (G^*c_2, 4%), and transaction services production (value of TC, 39%). In Appendix 2.A.3 we describe in detail the sources and steps for the construction of these estimates.

	1985	1965
Measured GDP (2000 US\$, '000)	24.39	15.49
Adjustment GDP for home production	1.20	1.29
Total GDP (2000 US\$, '000)	29.27	19.94
Share home production $\left(\frac{c_0}{GDP}\right)$	0.22	0.27
Share internal market $\left(\frac{(G-1)c_1}{GDP}\right)$	0.35	0.34
Share external market $\left(\frac{G^*c_2}{GDP}\right)$	0.04	0.02
Share transaction services $\left(\frac{B\times TC}{GDP}\right)$	0.39	0.37

Table 2.2: Shares of output, United States, 1965-1985.

From Ramey and Francis (2008) we obtain data on use of time for the average person of age 10 or more for the year 1985. Apart from sleeping and personal care, which are assumed constant, table 2.3 shows the distribution among market work, home work, schooling, and leisure, of which we provide the components due to watching television and participating in social activities. We identify *total effort* in our model to the sum of the first three components. But, in our model, effort can be used in two sectors: one associated to the production of consumption goods, the other associated to transaction services. We use an estimate of market labor share in each sector (transformation vs. transaction) to separate effort in each of them. The results are that time used in transformation production (r) was in 1985 slightly higher than 30%, time used in transaction services (TC) was equal to 20%, time in social activities (Fa_1) was almost 10%, and time in (non-social) leisure (a_0) was slightly less than 40%. Again, in Appendix 2.A.3 we detail the construction of this classification.

Given these magnitudes, we proceed now to the calibration of the parameters, using first-order conditions and constraints. Table 2.4 shows the values of the parameters. We consider two cases. In the first one we set the elasticity of substitution between standard goods and social ties, $\rho_{c,s}$, equal to the calibrated elasticity of substitution within standard goods ρ_c, and also assume $\rho_c = \rho_{c,s} = \rho_s$. This is the benchmark

	1985		1965	
	Hours per week	Share	Hours per week	Share
Total effort	**45.4**	**0.51**	**47.5**	**0.53**
Market work plus travel	22.0	0.25	20.7	0.23
Home work	19.5	0.22	22.2	0.25
Schooling	3.8	0.04	4.6	0.05
Total leisure	**43.4**	**0.49**	**42.8**	**0.47**
Social activities	8.6	0.10	11.8	0.13
Non-social leisure	34.8	0.39	31.0	0.34
Television	17.5	0.20	13.5	0.15
Labor share in market transaction services	-	0.39	-	0.36
Effort in transformation	27.6	0.31	30.6	0.34
Effort in transaction	17.8	0.20	16.9	0.19

Table 2.3: Components of use of time (other than sleeping and personal care), United States, 1965-1985.

model described in section 2.2.3. In the second case we calibrate ρ_c and $\rho_{c,s}$ separately, which is a generalization of the benchmark model.

We set $G = G^*$ to 6, the number of broad consumption goods (food and alcoholic beverages, housing, apparel, transportation, health care, and entertainment). Hummels (2007) reports that ocean freight and air freight as a percentage of value shipped were (in 1985) in the range of 0.09 to 0.11; so we set τ to 0.1. We normalize the terms of trade, p^*, to 1 in 1985. Given consumption values and time used in production, we solve for B_{1985} in the budget constraint (2.38), and obtain a value of 5.72.

We used simultaneously equations (2.34), (2.35), and (2.39) to obtain values for ρ_c, α_0, and α_2. These are 0.54, 0.64, and 44.2, respectively. The first one implies an elasticity of substitution between standard goods slightly higher than 2.[5] We will consider three possible measures of the number of ties, which we describe below. The one that we mainly use is the number of close friends, the one shown in table 2.4. We set F_f^{US} to 8, the median quantity in 2001. We assume α_1 equal to 0.5 and ρ_s equal to ρ_c,[6] and use equation (2.37) to obtain a value for β equal to 0.18.

[5] It is interesting to note that an increase in the number of goods, $G = G^*$, would imply a higher elasticity of substitution, a relation that is supported by the data; e.g. Broda and Weinstein (2006).

[6] We tried different values for α_1, holding the calibration for the other parameters constant, and did not find significant quantitative differences.

At this point both cases, the benchmark and the generalized benchmark, differ. In the first one we just assume $\rho_{c,s} = \rho_c$, and calibrate ϕ, using equation (2.36), to a value of 0.18. In the second case, we use equation (2.36) for the years 1985 *and* 1965 to calibrate both values ϕ and $\rho_{c,s}$. These are 0.46 and -0.20, similar to the ones used commonly in the business cycle literature (e.g., Cooley and Prescott (1995), who offer values of 0.36 and 0 respectively). The slight negative elasticity of substitution between standard goods and (total) leisure implies that, with increasing productivity of transformational effort, total leisure will increase, as a result of the income effect slightly dominating the substitution effect.[7]

Finally, we have to determine values for the depreciation rate of productivity, δ, and the productivity level in 1700, B_{1700}. Given all the parameters calibrated above, we use a "shooting" algorithm to obtain these values, targeting the ratio between measured output in 1990 and 1750, informed by Lucas (2002a), table 5.2, a ratio equal to 21.6.

Parameter	Case		Target
	$\rho_{c,s} = \rho_c$	$\rho_{c,s}$ calibrated	
G	6	6	# of broad sectors
G^*	6	6	# of broad sectors
τ	0.1	0.1	Hummels (2007)
B^{US}_{1985}	5.72	5.72	equation (2.38)
α_0	0.64	0.64	eqs. (2.34), (2.35), (2.39)
α_2	44.2	44.2	eqs. (2.34), (2.35), (2.39)
ρ_c	0.54	0.54	eqs. (2.34), (2.35), (2.39)
F^{US}_f	8	8	observation ISSP
α_1	0.5	0.5	assumed
ρ_s	0.54	0.54	assumed equal to ρ_c
$\rho_{c,s}$	0.54	-0.20	see text
β	0.18	0.18	eq. (2.37)
ϕ	0.18	0.46	eq. (2.36)
δ	0.03	0.10	ratio GDP^{US}_{1990} to GDP^{US}_{1750}
B_{1700}	0.61	0.069	"shooting" to obtain B_{1985}

Table 2.4: Parameter values

[7]To compute the equation for 1965, we need to calculate the productivity in 1965, B_{1965}, which we find to be equal to 3.72. The implied (average) annual rate of effort productivity growth between 1965 and 1985 is 2.2%, not an unreasonable estimate.

2.3.2 Simulation

We measure the distribution of the average number of ties across 27 countries, using the International Social Survey Programme 2001 (ISSP 2001).[8] We have three measures for number of ties: number of members of nuclear family (F_{nf}), number of close friends (F_f), and number of ties in secondary associations (F_{sa}). While the first two measures are straightforward, given the information of the ISSP, the third one needs some elaboration. There are 7 types of groups or associations informed: (i) political parties; (ii) unions; (iii) religious organizations; (iv) sports groups; (v) charitable organizations; (vi) neighborhood groups; and (vii) other associations. If a person belongs to a group, we considered that the person would have ties with 10 members of the group. Then we summed ties across groups and took country means. With this methodology we found that the average person from the United States would have around 23 ties, while the average person from France would have 12 ties, and the average person from Brazil 7.[9] Table 2.14 in Appendix 2.A.3 presents the means (medians in the case of nuclear family and close friends) for each country for each of the measures of number of ties. At the bottom, it shows that the number of close friends and the number of ties in secondary associations are highly correlated between them, and not correlated with the number of nuclear family ties. It also shows that the number of nuclear family ties is negatively associated with income per capita, while the number of close friends and the number of secondary association ties are positively associated with income per capita.

The values for the United States are respectively $F_{nf}^{US} = 6$, $F_f^{US} = 8$, and $F_{sa}^{US} = 23$. We simulate six cases, using one of the three measures for number of ties at a time, and a high or low $\rho_{c,s}$, as explained in the calibration. Different values for F^{US} and $\rho_{c,s}$ imply different values calibrated for β, ϕ, and δ. We simulate 15 periods (of 20 years each), that we map to the period between 1700 and 2000. We assume that there are no differences in parameter values across countries in 1700, including an identical effort productivity, B_{1700}. In that year, all differences in economic outcomes are assumed to

[8] See section 2.A.2 in the Appendix for details.

[9] The number of ten ties per person per group is rather arbitrary. But we do not have at the moment information about the number of this kind of ties, or on time allocated to them. We think of these ties as weaker than family and close friends' ties, in terms of average time allocated per tie. In fact, secondary associations' ties could be interpreted as a proxy for loose friends and acquaintances. The fact that we are using the same assumption for all countries for the average number of ties per secondary association does however restrict the model's degrees of freedom. In fact, setting this number to 10 can be interpreted as calibrating the model with low $\rho_{c,s}$ and F_{sa} to the coefficient of variation in data – see table 2.5.

be due to differences in number of ties, which will be considered fixed over time. But, with time, differences in the allocation of time to effort imply differences in generated productivities, which, by the year 2000, may account for a large share of the differences in economic outcomes.

Given this initial productivity value, we generate a path for each country for the variables of interest, inputing the differences in number of ties across countries. The results are shown in table 2.5. Using a high $\rho_{c,s}$, equal to the calibrated ρ_c, we observe in row (6) that the model can account for only 5% of the observed coefficient of variation of income per capita in 2000, if we use nuclear family ties as the measure of number of ties. By contrast, the model can account for a larger share of the variation in 2000, 39%, if we use instead secondary association ties, and it can account for 18% of the variation if we use instead close friends ties. Row (7) presents the cross-country correlation for the income per capita generated by the model and data. The three measures order the countries fairly well, with a higher correlation for the secondary associations ties. If we use a low $\rho_{c,s}$, calibrated as explained above, the differences in outcomes for different measures of number of ties are starker. In this case, differences in family ties generate a higher variation in income per capita by the year 2000 (around 39%), but the correlation between model and data is negative, implying that the model predicts incorrectly which countries will develop faster. By contrast, using close friends and secondary associations measures of number of ties imply both a greater variation in income per capita by the year 2000, and a positive and strong correlation in income per capita between model and data.

Lucas (2002a) reported income per capita across regions of the world (for 21 broad regions) for the years 1750 and 1990. Using these data, in row (8) we compute the ratio of the coefficient of variation of income per capita in 1990 to the coefficient of variation in 1750, and conclude that the coefficient was multiplied by 4 in that period. We compare that value to the ratio generated by the model, informed in row (9). The model with a high elasticity of substitution between standard commodities and social ties generates too much or too low variation in income per capita in 1990, given the variation in 1750. The model with a low $\rho_{c,s}$ does better (with values around 2.5), though it still does not capture completely the magnification in variation that happened between 1750 and 1990.

The main differences in the simulated series between a high and a low elasticity of substitution between standard commodities and social ties (high vs. low $\rho_{c,s}$) are

		$\rho_{c,s}$ high			$\rho_{c,s}$ low		
		$n.f.$	$fr.$	$s.a.$	$n.f.$	$fr.$	$s.a.$
F^{US}	(1)	6	8	23	6	8	23
$CV\ F$ (Data)	(2)	0.22	0.35	0.47	0.22	0.35	0.47
$CV\ IPC$ 2000 (Data)	(3)	0.43	0.43	0.43	0.43	0.43	0.43
$CV\ IPC$ 1700 (Model)	(4)	0.02	0.03	0.03	0.03	0.05	0.10
$CV\ IPC$ 2000 (Model)	(5)	0.02	0.08	0.17	0.17	0.28	0.45
% accounted	(6)=(5)/(3)	5	18	39	39	65	104
Correlation IPC 2000	(7)	0.43	0.53	0.68	−0.35	0.58	0.69
$\frac{CVIPC1990}{CVIPC1750}$ (Data)	(8)	4.0	4.0	4.0	4.0	4.0	4.0
$\frac{CVIPC1990}{CVIPC1750}$ (Model)	(9)	0.8	1.8	5.8	2.9	2.6	2.3

Table 2.5: The effects of number of ties on distribution of income per capita. $n.f.$ indicates nuclear family; $fr.$, friends; and $s.a.$, secondary associations. CV indicates coefficient of variation. IPC is income per capita. Row (7) presents the correlation between model and data for income per capita in the year 2000.

the time trends in social capital and effort in transformation of goods. With a low elasticity, the time trend for social capital is increasing, while the trend for effort in transformation is decreasing, as can be seen in figure 2.8. On the contrary, with a high elasticity, the time trend for social capital is decreasing, while the trend for effort in transformation is increasing, as can be seen in figure 2.9. In the first case, the income effect of an increase in productivity dominates the substitution effect, and therefore the consumption of social ties (and leisure) increase with productivity. In the second case, the substitution effect is dominant and therefore an increase in productivity causes an increase in effort and a decrease in social ties.

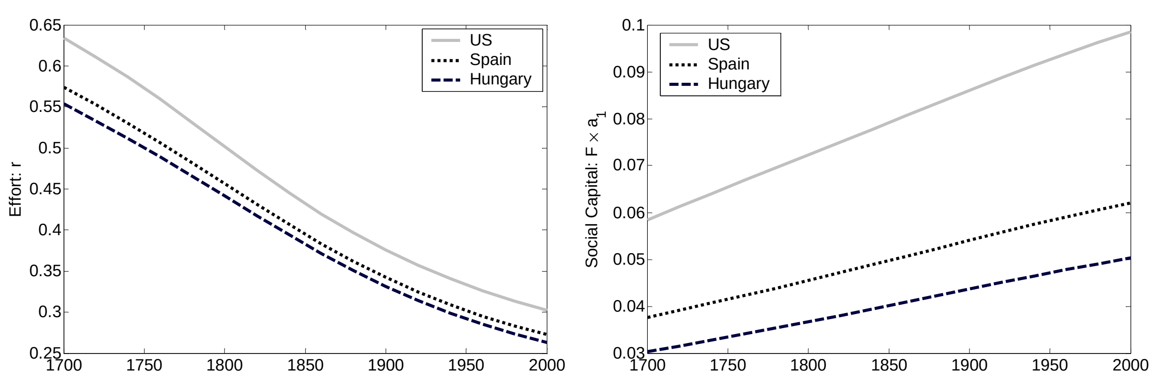


Figure 2.8: Low $\rho_{c,s}$. Left panel: shows changes in effort time between years 1700 and 2000. Right panel: shows changes in time use in social ties in the same period.

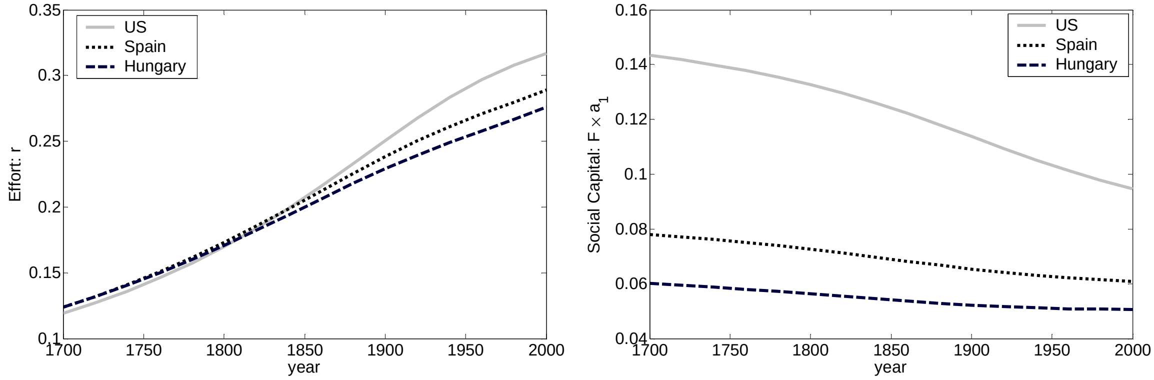


Figure 2.9: High $\rho_{c,s}$. Left panel: shows changes in effort time between years 1700 and 2000. Right panel: shows changes in time use in social ties in the same period.

Interestingly, one could associate the first case with observations for the United States in the earlier part of the 20$^{\text{th}}$ century, when effort in transformation of goods was diminishing but social capital was increasing (at least by Putnam's account), and associate the second case with observations in the later part of the 20$^{\text{th}}$ century, when social capital was decreasing (again by Putnam's account) while the decline in effort was slowed down or even reversed. At this point we will not take a position with respect to which is the most plausible parameter value, a high or a low elasticity of substitution between standard goods and social ties. We would just emphasize that increasing and decreasing social capital in time are both, in principle, consistent with equilibrium behavior and with increasing overall welfare.

From these results, we conclude that close friends and secondary associations are better measures for number of ties, given the purpose of our model. Next we will consider how the model fares in other dimensions, considering first time series for the United States and later country cross-sectional issues. We use number of close friends as our measure for number of ties, and a low elasticity of substitution between standard goods and social ties. Most of the observations that follow will not change if instead we use secondary associations' ties. Some observations will change if instead we consider a high elasticity of substitution, and we comment when that is the case.

Time series - United States

Table 2.6 presents data on time use between 1900 and 2005. We have bundled together market work, home work, and schooling into what we call effort. Then we have separated into two groups of effort, transformational production and transaction services (see Appendix 2.A.3 for details). It is clear that time in transformational production has decreased (32%), while time in transaction services has increased drastically (145%). Time in total leisure has increased by a smaller amount (7%). The columns on the right side show the changes provided by the simulated model in the last 100 years. Qualitatively they move in the right direction, but quantitatively they are smaller, in the order of 1/5 to 1/2. This is due mainly to the fact that, in the model, the inter-generational growth rates in productivity are decreasing in time (due to decrease effort in time), while they are increasing in the data. The change in these magnitudes would be better accounted for if labor and schooling were separated in the model, and most of the increase in inter-generational productivities attributed to increase in schooling.

We have calibrated δ such that we obtain an increase of around 22 times in income per capita between 1750 and 1990. Between 1900 and 2000 total production in the model (GDP) increases by 197% while in the data it increased by 481%. By contrast, between 1750 and 1850 the United States grew 81%, while the model shows growth by more than 465%. Again, this is due to the fact that the model, as calibrated, presents higher growth rates earlier than later. With a separation of labor and schooling periods, increasing schooling in time, and productivity change depending on schooling we would obtain increasing growth rates, and this counter-factual feature of the model would be eliminated.[10]

Table 2.3 presented data for the division of total leisure between social activities (socializing, religion, and organizations in Robinson and Godbey (1997) classification) and non-social leisure for the years 1965 and 1985. Between those years we observe a decrease in social activities and an increase in non-social leisure (most of it can be accounted for by an increase in time watching television). By contrast, our model presents increases in both time used in social activities and time in non-social leisure, with a higher increase in the first component. It would be interesting to obtain data on these components for other years, and check if the predictions of the model accord better with the data in the first 2/3 of the 20$^{\text{th}}$ century.

This anomaly can be understood better if we recall equation (2.37). It is clear that, for a fixed F, an increase in internal market consumption, c_1, with an increase in (non-social) leisure, a_0, must imply an increase in strength of ties, a_1. In other

[10] This feature of the model is also eliminated if we use a high $\rho_{c,s}$, because, as we have seen (figure 2.9), in that case effort increases with productivity, and therefore the growth rates of productivity are larger later than earlier.

	Data			Model		
	Share		% change	Share		% change
	1900	2000		1900	2000	
Total effort	**0.56**	**0.52**	**-14**	**0.53**	**0.51**	**-5**
Transformational effort	0.47	0.32	−32	0.38	0.30	−20
Transaction services effort	0.08	0.20	145	0.16	0.21	30
Total leisure	**0.44**	**0.48**	**7**	**0.47**	**0.49**	**6**
Social activities	na	na	na	0.09	0.10	14
Non-social leisure	na	na	na	0.38	0.40	4

Table 2.6: Comparison of model and data: use of time, United States, 1900-2000. na indicates not available.

words, our model does not allow for a decrease in social capital with increasing leisure and local consumption. Alternatively, equation (2.37) indicates that an increase in internal market consumption and a decrease in strength of ties must be accompanied by a stronger decrease in leisure than in strength of ties. In other words, in light of this model, it is not the decrease in social activities *per se* that is surprising, but that decrease accompanied by economic growth and higher leisure. In this context, the decrease in social capital that allegedly happened in the United States in the last part of the 20$^{\text{th}}$ century can only be understood with a change in the equilibrium number of ties, F.

What about the shares of home (c_0), internal market ($(G-1)c_1$), external market (G^*c_2), and transaction services ($B \times TC$) in total output? The share of transaction services in the model increases from 0.30 in 1900 to 0.40 in 2000, an increase of 36%. Using Wallis and North (1986) estimates, we calculated an increase from around 0.19 in 1900 to 0.40 in 2000, an increase of 106%. Again, the model predicts changes in the right direction but the magnitudes are smaller than in the available data.

Table 2.7 presents the predicted changes in shares of these components in GDP between 1700 and 2000. The most striking features are the increasing share of home production and the drastically decreasing share of external market output. The available data with respect to those shares is scarce, but all indications are that home production diminished steadily, while the share of external market output does not have a clear trend (but increasing between 1900 and 2000). Why does the share of home production increase in the model? An increase in productivity increases the opportunity cost of time, and therefore the cost of incurring in transaction costs. Therefore there is a stronger incentive to consume more of the self-produced good, *vis à vis* the marketed good. Interestingly though, imports suffer the greater loss in share, given the inability of the agents to economize in transaction costs of those goods. By contrast, the share of internal market goods consumption diminish mildly at first and more strongly only later in time. The reallocation of consumption of goods from the market to self-produced is a strong and highly counter-factual feature of the model. Of course, other things might be changing too: lower unitary transportation costs (a decrease in τ) might be increasing the incentives to import rather than self-consume (see, e.g., Hummels (2007)); lower unitary transaction costs (a decrease in α_0) might be increasing the incentives to consume marketed products (see, e.g., North (1994), p. 363); the invention of new goods (an increase in either G or G^* or both) might be increasing the incentives to consume those goods instead of consuming the self-produced good. Equally or more important, we are not modeling here the decision of the agents to specialize in production. The increase in productivity might be conditional on the execution of a narrower set of tasks. Those tasks will hardly be enough to produce any consumable good, which creates an incentive to reduce self-produced consumption and increase marketed consumption. All these possibilities are material for future research.

	Self produced c_0	Internal market $(G-1)c_1$	External market G^*c_2	Transaction services $B \times TC$
Model				
1700	0.09	0.44	0.44	0.03
1800	0.11	0.45	0.31	0.13
1900	0.15	0.43	0.12	0.30
2000	0.23	0.33	0.03	0.40
Change 1900/2000, %	53	−24	−71	36
Data				
1900	0.42	0.36	0.03	0.19
2000	0.22	0.32	0.06	0.40
Change 1900/2000, %	−48	−10	115	106

Table 2.7: Comparison of model and data: production composition (shares of total output), United States, 1900-2000.

Country cross section

What about the cross-sectional predictions of the model? A higher income per capita (associated with a higher number of ties) is predicted to be negatively correlated with the average strength of ties. In the model a 1% increase in average strength of ties is associated with a 2.6% decrease in income per capita, while in the data it is associated with a 3.2% decrease in income per capita. Figure 2.1 in section 2.1 is borne out by the model. In this respect the model is quite accurate.

Table 2.8 presents use of time data for four countries around the year 2000: United States, United Kingdom, Italy and Mexico. We include Mexico, despite the fact that it is not part of the sample in the ISSP, because it is a relatively low income per capita country with use of time data. The means are taken over different groups of population, given the way information is provided, ranging from age 12 and above for Mexico to 16 and above for the United Kingdom. This fact makes the comparisons for schooling unclear, but when we aggregate market work, home work, and schooling into overall effort the comparisons are clear. We observe that, with increase in income per capita, total effort diminishes (around −25% between Mexico and the United States), while total leisure increases (slightly more than 45%). The model predicts just the opposite: countries with higher income per capita exhibit higher effort time (23% between the range extremes) and lower leisure time (−11% between the range extremes). This is another counter-factual feature of the model that could be addressed by separating schooling from labor. In that case, higher schooling could be associated with higher income per capita, lower labor, and higher total leisure. With respect to the use of leisure, the data shows an increase of more than 50% in time dedicated to social activities (between Mexico and the United States). The model predicts a substantial increase with income per capita. In this respect, the model fares better.

Table 2.9 presents the model's shares of output for three countries, with different number of ties. With respect to the data, there is some presumption that less developed countries would have a higher share of self-produced consumption (see Devereux and Locay (1992)), and a lower share of transaction services. Neither presumption is borne by the model.

	United States	United Kingdom	Italy	Mexico
Year of survey	2000	2005	2002-2003	2002
Population	Age 14+	Age 16+	Age 15+	Age 12+
Total effort	**0.29**	**0.31**	**0.32**	**0.39**
Market work	0.15	0.18	0.17	0.16
Home work	0.13	0.12	0.14	0.18
Schooling	0.01	0.01	0.02	0.05
Leisure	**0.25**	**0.23**	**0.18**	**0.17**
Social activities	0.05	0.06	na	0.03
Television	0.10	0.11	na	0.07
Other leisure	0.10	0.06	na	0.07
Personal care	0.46	0.46	0.50	0.45
Income per capita, '000	34.4	24.7	22.5	8.1
# of close friends (2001)	8	9	4	na
# of ties in associations (2001)	23	14	10	na

Table 2.8: Shares of use of time for four countries, around year 2000.

	Self produced c_0	Internal market $(G-1)c_1$	External market G^*c_2	Transaction services $B \times TC$
High F (e.g. US)	0.23	0.33	0.03	0.40
Medium F (e.g. Spain)	0.21	0.32	0.07	0.40
Low F (e.g. Hungary)	0.20	0.31	0.08	0.40

Table 2.9: Production composition, country cross section.

Social capital

In our model there are two motives for building social ties. One is a preference motive; individuals enjoy spending time with the "usual suspects" from time to time. The other motive is technological; individuals trade more efficiently if they have ties with other members of their community. Usually, a social network that economizes in production or transaction is called social capital. In this section we try to measure the importance of social capital for observed outcomes. In particular, we ask: by how much do the predictions of the model change if social ties are ineffective in economizing transaction costs? In other words, we shut down the technological channel, by setting the productivity of social capital, α_2, to zero, and compare with previous results.

Table 2.10 shows the results. In the baseline case, with productive social capital

($\alpha_2 = 44$), the amount of time dedicated to social ties increases between 23 and 26% from 1700 to 2000. By contrast, with zero productivity of social capital ($\alpha_2 = 0$), the time dedicated to building social ties only increases between 5 and 8% in the same period of time. The fact that agents cannot economize in transaction costs has an important impact on growth. Indeed, the measured income per capita of the country with the larger number of ties is multiplied by 83 if social capital is productive, but only by 44 if it is not. Likewise, the income per capita for the country with the fewer number of ties is multiplied by 35 and 26, respectively. This is due, of course, to changes in endogenous productivities, which, in turn, are affected by the reallocation of time away from effort, given the complementarity between effort and social capital.

	Baseline case $\alpha_2 = 44.2$		No use for social capital $\alpha_2 = 0$	
	Higher F	Lower F	Higher F	Lower F
Social capital, $Fa_1, \%$	53	65	22	27
Measured GDP	$\sim \times 83$	$\sim \times 35$	$\sim \times 44$	$\sim \times 26$
Total GDP	$\sim \times 100$	$\sim \times 40$	$\sim \times 60$	$\sim \times 30$
Productivity (B)	$\sim \times 120$	$\sim \times 51$	$\sim \times 68$	$\sim \times 38$
Share of internal market, $\frac{(G-1)c_1}{GDP}$, %	-23	-28	-81	-67
% of variation accounted	65		45	
Correlation IPC 2000	0.58		0.58	

Table 2.10: The effects of social capital. Changes between 1700 and 2000.

It is interesting to note how all this translates into changes in the share of internal market goods in total output. In the baseline case, this share is reduced by around 25% between 1700 and 2000. This is due to the fact that, with higher productivity, the opportunity cost of time increases, and therefore these goods become costlier (*vis à vis* self-produced consumption) given that they incur in transaction costs. With zero productivity of social capital, though, the share of internal market goods in total output is reduced by a much larger amount, in the order of 67 to 81%. Figure 2.10 summarizes these effects for the United States. In the year 2000, with no productivity of social capital, transformational productivities are reduced by almost 40%, and internal consumption is reduced by more than 80%.

The case with zero productivity of social capital can account, in the year 2000, for 45% of the cross-country variation in income per capita (as opposed to 65% in the

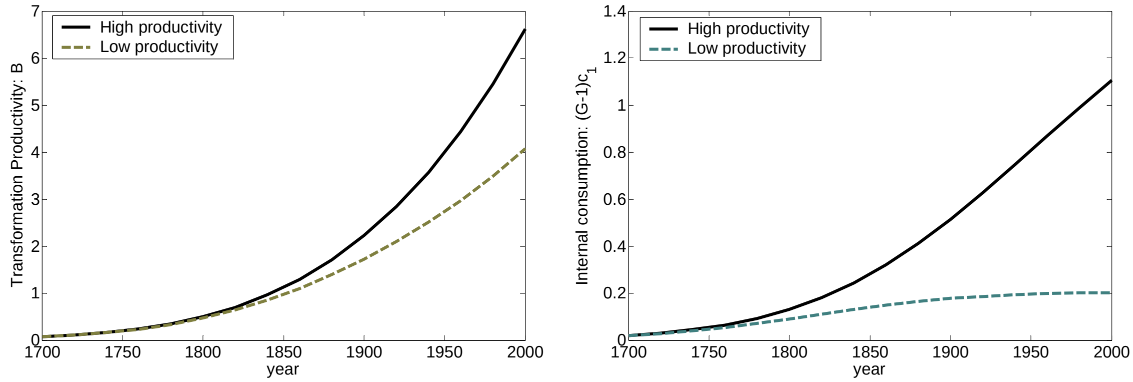


Figure 2.10: High ($\alpha_2 = 44$) and low ($\alpha_2 = 0$) productivity of social capital. Left panel: shows changes in transformational productivities between 1700 and 2000. Right panel: shows changes in consumption directed to the internal market in same period.

baseline case), and presents a similar correlation of income per capita between model and data (around 0.58).

The main motive for allocating time to social ties is the preference motive. In the year 2000, for the country with higher number of ties, the technological motive accounts for only 15% of the time allocated to social activities. But this exercise shows that social capital *per se* can be an important force in shaping world economic outcomes: without it, and according to the model, the income per capita of any country today would be between 1/4 and 1/2 smaller, the internal markets would be much smaller, and the standard deviation in income per capita would be around 20% smaller.

2.4 Discussion and conclusion

In this section we have three objectives. First, to summarize what we have learned, both analytically and quantitatively. Second, to expand on how this model helps us to think about social capital. Third, to discuss the model and its limitations, and outline possible courses for future research.

2.4.1 Summary of results

In the analytical section, we have found the following main results:

1. With no preference for ties, it is possible for social capital to be zero ($a_1 = 0$), even if the productivity of social capital is highly positive (proposition 5). This

may obtain for two reasons: (i) if there is a severe (combined) coordination failure (egotism in relationships and/or public good nature of social capital); and (ii) an intense trading activity with the exterior, which reduces the importance of in-village transaction costs. The problem of underprovision of social capital is mitigated when agents have a preference for social ties.

2. The level and relation between the different elasticities of substitution are a key determinant of the observed co-movements between social capital and other economic variables, even when social ties do not play a technological role.

3. With positive transaction costs social capital may play an important technological role, very much complementary to transformational effort.

4. The technological motive for investing in social ties is mostly relevant for societies with a low number ties.

5. For highly communitarian societies an increase in productivity may lead to a decrease in welfare, which obtains because of an amplification of the coordination failure in building relationships.

In the dynamic quantitative section we found the following main results:

1. Differences in number of ties can account for a fairly large share of the worldwide variation in income per capita in 2000.

2. More communitarian societies, measured by the number of close friends or the participation in civic associations, present faster economic growth. Indeed, more communitarian societies present higher social capital and higher transformational effort. In this sense, social structure can determine a country's path of economic growth.

3. In the time series, the model can account for between 1/5 and 1/2 of the changes in the United States components of use of time.

4. In the time series, the model cannot account for diminishing social capital with increasing (non-social) leisure.

5. In the time series, the model can account reasonably well for changes in transaction services and internal market shares; it cannot account for changes in self-produced and external market shares.

6. In the country cross section, the model can account well for the negative relationship between income per capita and average strength of ties, as well as for the positive relationship between income per capita and social capital. It does not do well in accounting for the relationships of effort and/or leisure and income per capita.

7. The technological role of social ties is quantitatively important: if the productivity of social capital were zero, the model predicts that all national economies would be between 1/2 and 3/4 their actual size. This effect is mainly attributable to a positive externality of the consumption of social ties, and not the result of deliberate accumulation of ties for purely technological reasons.

2.4.2 Social capital

A key link between social structure and economic development, emphasized by both sociologists and economists, is *social capital*. It is a key link because economic development is always associated to the spread of trade, and it is argued that social capital can diminish significantly the costs of trade, commonly known as transaction costs. How does social capital affect transaction costs? The idea is that social capital both facilitates the flow of *information* and creates *trust* among potential traders. Increased information and trust diminishes transaction costs, by eliminating uncertainty about the potential actions of the trading partners at different contingencies. In other words, social capital reduces transaction costs by assuring coordination and reducing malfeasance.

The concept of social capital has been criticized. One critique is why to call it "capital". Both Arrow (2000) and Solow (2000) ask for a change of name. The former says that social capital does not imply an essential characteristic of "capital", a "deliberate sacrifice in the present for future benefit". The latter asks "what is social capital a stock of?", and suggests to call it instead "patterns of behavior". In this paper we argue that social capital is sometimes a pure by-product of social interactions, sometimes the outcome of a deliberate accumulation process, requiring the sacrifice of transformational effort and/or trading time and/or leisure. In light of this natural ambiguity, social capital is more aptly interpreted as "capital" in some instances than in others. In any case, our model and calibration suggest that the amount of transaction time saved by social capital is quite significant.

Another related usual critique is associated to the fact that the originator of the concept (Coleman (1988)) and its main popularizer (Putnam (1993)) gave examples that portray the increase in social capital as unequivocally good. By now, there is quite an agreement that different kinds of social capital can increase or decrease welfare. A decrease in welfare can be due to different mechanisms. First, some associations can be created for unproductive or destructive activities; e.g. the Mafia or crime gangs. Second, as shown by Routledge and von Amsberg (2003), frequent migration can destroy social capital but increase welfare by a more efficient allocation of labor. Third, more generally, there might be more efficient solutions than social capital accumulation to the market failures of incomplete information and lack of enforcement, as emphasized by Durlauf and Fafchamps (2005). For example, an impersonal third-party court and police can create *generalized* trust, which is considered to have a low marginal cost, as opposed to the *personal* trust associated to social capital. In this paper we offer one more reason why the increase in social capital might not be welfare improving: it requires investment in time, which might be better used as investment in human capital, labor, or leisure.[11]

Social capital is called "social" for two reasons. One is that it might imply externalities. The benefits of an association might accrue to non-members. This is the public good character of social capital. The other, more fundamental, reason for calling it "social" is that it is a product of social ties, the "connections among individuals" in Putnam's definition. But why do social ties emerge? Arrow (2000) states: "there is considerable consensus also that much of the reward for social interactions is intrinsic – that is, the interaction is the reward – or at least that the motives for interaction are not economic. People may get jobs through networks of friendship or acquaintance, but they do not, in many cases, join the networks for that purpose. This is not to deny that networks and other social links may also form for economic reasons." In our model we follow this statement, and include two motives for the construction of social ties, an intrinsic, preference motive, and a technological, social capital motive. However, in the model, we found that for highly communitarian societies (high F), the technological motive (from an individual agent's perspective), becomes redundant.

When referring to social ties, there are two main concepts in which we are interested: the number of ties, known in the network literature as network size; and the average

[11] Kumar and Matsusaka (2006), who deal with personal networks, and Hoff and Sen (2005), who deal with the extended family, offer models where crystallized social interactions are obstacles to the spread of trade.

strength of ties, known as network density (Marsden (1990)). Additionally there are many types of social ties. Outside of the market work, we would consider at least three different types of ties: family, friends, and secondary associations. Do all of them contribute to social capital? The empirical literature (see empirical studies in Dasgupta and Serageldin (2000)) has mostly focused on the secondary associations, unions, churches, political parties, clubs, the so-called civic society (but see chapter 6 in Putnam (2000)). But, if the main attributes of social capital are the presence of trust and the flow of information between members, then it is clear that family and friends ties should be considered too. In our model we distinguish between number and strength of ties, but we do not model explicitly different types of ties. In the calibration and simulation, though, we consider the three types separately and ask the question: which type of ties is most consistent with both the increase in inequality across countries and with certain countries growing faster than others? The answer is that close friends and secondary associations ties are more consistent than family ties.

We have said that our model provides another possible reason for welfare to increase as social capital diminishes. Interestingly, though, our setting also can explain why there might be a feeling of "malaise" when social capital diminishes, despite the fact that productive efficiency might be increasing (as it is argued to have happened in the US in the second half of the 20$^{\text{th}}$ century). An increase in productivity creates a stronger incentive for individual agents to free ride in their relationships; in equilibrium this may yield a relatively low consumption of social ties, relative to the first-best. This seems however to be an issue only for highly communitarian societies (see figure 2.7).

In our model ties can have a high or low strength (a high or low a_1). We would like to mention that a weak tie in our model is quite different from Granovetter (1973)'s weak ties. While in his work weak ties are important because they connect ("bridge") isolated groups with strong within group ties, in our model we have weak ties with closure. Of course, this characteristic can be modified if we allow for the individual to have weak and strong ties simultaneously (say, having a family *and* acquaintances).

Another aspect of social capital we are not dealing with is production social capital, of which an example follows. Two researchers have offices next to each other, and they do small talk from time to time. One of them introduces his colleague into some results in a new area of research. This last person finds that those results are useful for his work in progress. His productivity has been increased by the social connection. We want to be clear we are not considering this aspect of social capital. By contrast, social capital in our model is related to transaction efficiency. In this we follow Putnam's comment, when he relates social capital to reciprocity, and states: "A society characterized by generalized reciprocity is more efficient than a distrustful society, for the same reason that money is more efficient than barter. If we don't have to balance every exchange instantly, we can get a lot more accomplished." (p.21). The distinction is important because the effects of productivity increase considered in the simulation can be very different with production instead of transaction social capital.

2.4.3 Limitations and further research

We have seen that the model does well in accounting for some dimensions of the data, but not for others. In this section we discuss which we consider limitations of the model, and what extensions and explorations we consider worthwhile.

First we would like to consider the utility functional form, as the simulation relies heavily on it. The "love of variety" functional form for standard goods is quite plausible in this context. Some modifications might be reasonable; e.g., a different elasticity of substitution between domestic and foreign goods, and within domestic goods. But, overall, it seems a reasonable approximation to reality. More controversial is the "love of variety" functional form for social ties. The essential question here is: do people prefer to have many ties with low intensity (in terms of time), or a few ties with high intensity. As we model it, our answer has been the former. But we consider this a very much open empirical question. That is the reason why, in our calibrated version, communitarian societies present higher welfare than individualistic societies. Given that a higher number of ties implies (in most cases analyzed) higher social ties *and* higher effort, we observe that both components of welfare, the component due to consumption of standard goods and the one due to social ties, are higher in these societies (see figure 2.11). If, on the contrary, individuals would prefer a lower number of intense social ties, then we might have an interesting trade-off: for technological reasons, to economize in transaction costs, people would prefer to have a high number of ties; for preference reasons, they would prefer a low number of ties. With economic development there could be some tension, as one component of welfare might be increasing while the other one decreases. We think it would be important that more empirical work informs utility functions for social ties, in a similar way that empirical work has informed utility functions for standard commodities.

Another aspect of the utility functional form that deserves scrutiny is how (non-social) leisure enters into it. We have modeled it in such a way that leisure is func-

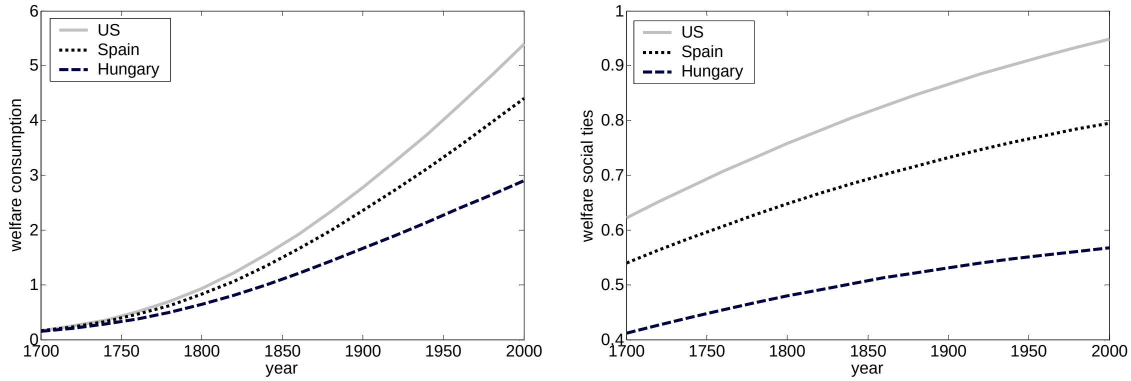


Figure 2.11: Left panel: it shows changes utility due to changes in consumption between years 1700 and 2000. Right panel: it shows changes in utility due to changes in social ties in the same period.

tionally equivalent to a tie with oneself. But this, of course, does not have to be the case. For example, one can think that (non-social) leisure is indeed complementary to consumption of standard goods, but that the composite standard goods-leisure is a substitute for social ties. As an example, the past 40 years of increase in time watching television, with increase in income per capita and decrease in socializing time, could be better accounted for by such a function.[12] An alternative view comes from asking the question: is watching television (or "surfing" the Internet, or playing video games) part of non-social leisure? Or is it an alternative way of socializing, a way in which, in terms of our model, the number of (asymmetric) ties is very large and the strength small? We started this paragraph by considering that it may be necessary to modify the model's utility functional form, and finished it by saying that it might be necessary to redefine what it means "social activities" in the data. We consider that further data investigation, as well as analytical inputs from sociology and social psychology, could clarify this issue.

In our calibration we fixed the number of ties of each country over time, and explore what were the consequences in the time series and cross-sectionally of differences in that variable. Each number of tie is an equilibrium, and we consider that culture

[12]For example, one such function is

$$U(c,l,s) = \left\{ \phi \left[(1-a)c^{\rho_{c,l}} + a^{\rho_{c,l}} \right]^{\frac{\rho_{(c,l),s}}{\rho_{c,l}}} + (1-\phi)s^{\rho_{(c,l),s}} \right\}^{\frac{1}{\rho_{(c,l),s}}}, \tag{2.61}$$

with $\rho_{c,l} < 0$, and $\rho_{(c,l),s} > 0$, where c and s are composites of standard goods and social ties respectively, and l is non-social leisure.

determines it. We found that the effects of "culture" on income per capita and welfare were important. A natural question arises: does culture change? If so, when, how, and how fast? It would seem natural that culture changes when the welfare costs of maintaining a specific culture are high. For example, one can consider that Japan changed its cultural beliefs after loosing World War II. This led to the adoption of new institutions; the militaristic tradition was abandoned, and a more democratic society evolved. Hayashi and Prescott (2006) have analyzed the case of the structural change between agriculture and industry in Japan before and after the war. Before the war a constraint in migration for the eldest son of a farmer was in place. After the war, the code was modified to permit his migration. The result was an increase in productivity, by reallocation of labor towards city industry, that the authors associate with the extraordinary income per capita growth rates after the war. We can imagine that the Japanese concluded that their (cultural) beliefs were constraining their development, changed those beliefs toward a less paternalistic society, and consequently changed their institutions (the code). On the other hand, if a culture has served well a country, it is reasonable to expect their citizens not to push for a change. An example, more in line with the cultural beliefs we analyzed, is the case of the United States. We have seen that, when measured as participation in secondary associations, the United States leads the pack in number of ties. But this was already observed by Tocqueville (1899) in 1835: "in no country in the world has the principle of association been more successfully used, or more unsparingly applied to a multitude of different objects, than in America." We conclude that culture can be fairly stable if it is associated with success. On the other hand, cultural change seems to be associated with negative shocks to the national self-esteem. In this context, a natural extension to our analysis would be to measure the distribution of number of ties at different moments in history, and relate changes in the distribution with changes in income per capita.

In the empirical literature on culture there is no practical distinction between different preferences across societies and different beliefs which imply different equilibria. Culture encompasses both. For example, Fernández and Fogli (2007) empirically assess that a national culture (with respect to the role of women in society) can influence women's labor force participation, while Tabellini (2006) considers the effect of regional culture (with respect to trust, respect of others, and self-determination) on income per capita, but it is not identified if individuals in different societies have different preferences or values (say, different values of the role of women in society, or more or less respect for others) or if they just have different beliefs of what the other individuals will do (say, condemn or not a woman that works at the market, or the level of respect for others). In our model we take a stance in which a particular culture is identified with a particular equilibrium. Nonetheless, in further research it would be interesting to study what is the relationship between a particular equilibrium and future preferences.

Another relevant aspect of reality that we are leaving aside is diffusion of technology. In the same way that we are postulating inter-generational externalities, we could postulate inter-societal externalities; that is, diffusion. With diffusion, the different productivities generated along time will be very much diminished (see Eaton and Kortum (1999)).

An important extension to our model would be to consider separately labor and schooling. In this case, future productivity might depend on both these types of effort (depending on the relevance of learning by doing versus formal schooling). We consider that this extended model might account for (i) an increase over time in income per capita growth rates (for the leaders); (ii) in the time series, a better quantitative account of use of time; (iii) in the country cross section, a better qualitative (and quantitative) account of the relationship between income per capita and both labor and leisure.

A substantial modification of our model would be to consider an additional endogenous choice: the possibility of specialization in a more or less narrow set of tasks of production. If productivity gains require specialization, there would be less incentive for individuals with higher productivities to self produce more. This would probably align the model with data better, with respect to the shares of production, both in the time series and cross-sectionally. It would also give a still more relevant role to trade, and therefore, to the technological motive for social capital.

Finally we want to refer that although we applied our theoretical framework to a country setting, other settings could be investigated. The model could be calibrated to regional or city data, or even to "social villages" within a region, e.g. ethnic communities.

2.A Appendix

2.A.1 Proofs

Proof of proposition 1. First we show that equation (2.41) has a solution. Start by setting $a_1 = 0$ in the RHS of (2.41) and (2.42). This yields $c_1^* > 0$ and $a_1^* > 0$. Now set a_1 close to $1/F$, such that $c_1^* = \epsilon$, with $\epsilon > 0$ arbitrarily small. This yields a_1^* arbitrarily close to zero. If (2.41) and (2.42) are continuous in a_1, then by the intermediate value theorem, there exists $a_1^s \in (0, 1/F)$ such that $a_1^*(a_1^s) = a_1^s$. It is straightforward to see that c_1^* is continuous in $a_1 \in [0, 1/F]$. To prove continuity of equation (2.41) we have to show that the denominator of the fraction is always non-zero. We claim that for $\phi < 1$ this is the case, in particular

$$\frac{1}{\beta} > (G-1)\frac{\alpha_0\alpha_1\alpha_2}{(1+\alpha_2 F a_1)^2}c_1^*(a_1). \tag{2.A.1}$$

Manipulating equation (2.41) we can write

$$(G-1)\frac{\alpha_0\alpha_1\alpha_2}{(1+\alpha_2 F a_1)^2}c_1 = \frac{1}{\beta} - \left(\frac{c_1}{a_1}\right)^{1-\rho}\frac{(1-\phi)(1+\alpha_2 F a_1 + \alpha_0 B)(1+\alpha_2 F a_1)}{\phi B(1+\alpha_2 F a_1)^2}.$$

Any interior solution implies $a_1 > 0$ and $c_1 > 0$, thus statement (2.A.1) is true for $\phi < 1$. Since c_1^*, c_2^*, a_0^* are positive continuous functions of a_1 for $a_1 < 1/F$, the last step in proving existence is to show $r^*(a_1^s) > 0$. Manipulating (2.41)-(2.46) and denoting

$$\begin{aligned} L_1(a_1) &\equiv \frac{\alpha_0 B}{(1+\alpha_2 F a_1)} \geq 0 \\ L_2 &\equiv \left(\frac{1-\phi}{\phi\epsilon_0^\rho}\right)^{\frac{1}{1-\rho}} \geq 0 \\ L_3 &\equiv \left[\frac{(1-\tau)^\rho}{p^* + \alpha_0\epsilon_0}\right]^{\frac{1}{1-rho}} \geq 0, \end{aligned}$$

we obtain

$$r^*(a_1) = (1-Fa_1)\times \left\{1 - \frac{(G-1)L_1(a_1) + [1+L_1(a_1)]^{\frac{1}{1-\rho}}(L_2 + L_3 G^*\alpha_0\epsilon_0)}{(G-1)[1+L_1(a_1)] + [1+L_1(a_1)]^{\frac{1}{1-\rho}}[1+L_2+L_3G^*(p^*+\alpha_0\epsilon_0)]}\right\},$$

which is positive for any $a_1 \in (0, 1/F)$. Next we show that the equilibrium is unique, which amounts to showing that equation (2.41) has a unique solution. Construct the homotopy function $H : [0, 1/F] \times [0, 1] \rightarrow \Re$ with

$$H(a_1, t) = a_1^*(a_1 | \alpha_0 = t \times \alpha_0^*) - a_1,$$

where now α_0^* denotes the exogenously specified transaction costs. Setting $t = 0$ reduces to the case without transaction costs, which has a unique solution, as shown in equations (2.47)-(2.51). Also, we have shown that there exists a solution to (2.41), which implies there is a solution for $H(a_1, t) = 0$, for any $t \in (0, 1]$. H is continuously differentiable in a_1 and t, which means that the solution to $H(a_1, t) = 0$ is a continuously differentiable function of t. Combining this with the uniqueness of the solution at $t = 0$ implies that the solution for any $t \in (0, 1]$ is also unique.[13]■

Proof of proposition 2. Suppose a pairwise stable equilibrium exists with $F < N$. Now pair up two disconnected agents i and j. Reducing the time each of these agents invests in r by a small amount ϵ corresponds to a finite decrease in utility of approximately $\theta\epsilon$ (envelope theorem). The increase in utility from the tie corresponds however to ∞ when $\epsilon \rightarrow 0$, as long as agents have a preference for ties ($\phi < 1$). Thus $F < N$ cannot correspond to a pairwise stable equilibrium. Now consider that $F = N$. Since in this model any agent could unilaterally sever a tie at zero cost (but does not, as implied by the existence result for any F, including $F = N$), then this equilibrium is (trivially) pairwise stable.■

Proof of proposition 3. It is sufficient to show that $\partial(Fa_1)/\partial F > 0$. Using equation (2.50), we obtain

$$\frac{\partial(Fa_1)}{\partial F} > 0 \Leftrightarrow a_1 + F\frac{\partial a_1^*}{\partial F} > 0 \Leftrightarrow$$
$$a_1 - Fa_1^2 > 0 \Leftrightarrow a_1 < 1/F,$$

which is always true.■

Proof of proposition 4. Using equations (2.34)-(2.40), combined with the assumption of one trade partner with given terms of trade p^*, effort r is given in closed-form by

$$r = 1 - \frac{B}{B + \frac{H_1}{H_2}},$$

where

$$H_1 = \left(\frac{\beta B\phi}{1-\phi}\right)^{\frac{1}{1-\rho_{c,s}}} \left[G + G^*\left(\frac{1-\tau}{p^*}\right)^{\frac{\rho_c}{1-\rho_c}}\right] \times$$
$$\times \left[G + G^*(1-\tau)^{\frac{1}{1-\rho_c}} \left(\frac{1}{p^*}\right)^{\frac{\rho_c}{1-\rho_c}}\right]^{\frac{(\rho_{c,s}-\rho_c)}{\rho_c(1-\rho_{c,s})}}$$

[13]See Garcia and Zangwill (1982) for a textbook introduction to the use of homotopies in solving equilibrium problems.

$$H_2 = \left[F + \left(\frac{1}{\beta}\right)^{\frac{\rho_s}{1-\rho_s}}\right]^{\frac{(\rho_{c,s}-\rho_s)}{\rho_s(1-\rho_{c,s})}} \left[F + \left(\frac{1}{\beta}\right)^{\frac{1}{1-\rho_s}}\right].$$

It is true that

$$\text{sign}\left\{\frac{\partial r}{\partial F}\right\} = -\text{sign}\left\{\frac{\partial H_2}{\partial F}\right\}.$$

Computing the derivative of H_2 with respect to F we obtain

$$\frac{\partial H_2}{\partial F} = \frac{(\rho_{c,s}-\rho_s)}{\rho_s\left(1-\rho_{c,s}\right)} \left[F + \left(\frac{1}{\beta}\right)^{\frac{\rho_s}{1-\rho_s}}\right]^{\frac{(\rho_{c,s}-\rho_s)}{\rho_s(1-\rho_{c,s})}-1} \left[F + \left(\frac{1}{\beta}\right)^{\frac{1}{1-\rho_s}}\right] + \\ + \left[F + \left(\frac{1}{\beta}\right)^{\frac{\rho_s}{1-\rho_s}}\right]^{\frac{(\rho_{c,s}-\rho_s)}{\rho_s(1-\rho_{c,s})}},$$

which is negative if and only if expression (2.52) in the proposition holds.■

Proof of proposition 5. We begin by proving point 1. Setting $\phi = 1$ in equation (2.41), the equality can only be verified if

$$c_1 = \frac{(1+\alpha_2 F a_1)^2}{(G-1)\alpha_0\alpha_1\alpha_2\beta}.$$

Combining this with equation (2.42), we obtain:

$$\frac{(1+\alpha_2 F a_1)^2}{(G-1)\alpha_0\alpha_1\alpha_2\beta} = B(1-Fa_1)\left\{(G-1)\left[1+\frac{\alpha_0 B}{(1+\alpha_2 F a_1)}\right] + \right. \\ \left. + \left[1+\frac{\alpha_0 B}{(1+\alpha_2 F a_1)}\right]^{\frac{1}{1-\rho}}\left\{1+G^*\left(\frac{1-\tau}{p^*+\alpha_0 B}\right)^{\frac{\rho}{1-\rho}}\right\}\right\}^{-1}$$

The above expression allows us to write the following inequality:

$$(1+\alpha_2 F a_1) \leq \frac{(G-1)(1-Fa_1)\alpha_0 B\alpha_1\beta\alpha_2}{(G-1)\left[1+\frac{\alpha_0 B}{(1+\alpha_2 F a_1)}\right] + (1+\alpha_0 B)^{\frac{1}{1-\rho}}\left[1+G^*\left(\frac{1-\tau}{p^*+\alpha_0 B}\right)^{\frac{\rho}{1-\rho}}\right]},$$

which simplified with respect to Fa_1 yields expression (2.53) for $\overline{SC}$. Next we prove point 2. If $\rho = 0$ and $\phi = 1$, we can manipulate (2.41)-(2.42) such that an interior solution for a_1 can be written as the solution to the following quadratic equation:

$$a_1^2(\alpha_2 F)^2(G+G^*) + a_1(\alpha_2 F)\left[(2+\alpha_0 B)(G+G^*) + \alpha_1\beta\alpha_0 B(G-1)\right] + \\ (1+\alpha_0 B)(G+G^*) - \alpha_1\beta\alpha_2\alpha_0 B(G-1) = 0 \quad (2.A.2)$$

Since the terms in a_1^2 and a_1 in the LHS of (2.A.2) are both positive (implying a positive slope for the $a_1 > 0$ region), then a necessary condition for $a_1 > 0$ to be a solution is that the constant term be negative, i.e.

$$(1 + \alpha_0 B)(G + G^*) - \alpha_1 \beta \alpha_2 \alpha_0 B(G - 1) \leq 0,$$

which simplified with respect to α_2 yields expression (2.54). This condition is sufficient for the existence of an interior a_1 as long as $a_1 < 1/F$. Setting $a_1 = 1/F$ the LHS of (2.A.2) simplifies to

$$(G + G^*)(1 + \alpha_2)(1 + \alpha_0 B + \alpha_2),$$

which is always positive. This implies that $a_1 < 1/F$.■

Proof of proposition 6. Using equations (2.41) and (2.42), we can write

$$a_1 = \frac{B(1 - Fa_1)}{\left\{(G-1)\left[1 + \frac{\alpha_0 B}{(1+\alpha_2 F a_1)}\right]^{\frac{-\rho}{1-\rho}} + D\right\}} \left[\frac{\left(\frac{1-\phi}{\phi B}\right)}{1/\beta - (G-1)\frac{\alpha_0\alpha_1\alpha_2}{(1+Fa_1)^2}c_1}\right]^{\frac{1}{1-\rho}}, \qquad (2.A.3)$$

where

$$D \equiv 1 + \left(\frac{1-\phi}{\phi B^{\rho}}\right)^{\frac{1}{1-\rho}} + G^* \left(\frac{1-\tau}{p^* + \alpha_0 B}\right)^{\frac{1}{1-\rho}}.$$

It follows that the following inequality holds:

$$a_1 \geq \left(\frac{1-\phi}{\phi B}\right)^{\frac{1}{1-\rho}} \frac{B(1-Fa_1)\beta}{(G-1+D)}$$

Simplifying the above with respect to a_1 and multiplying both sides of the inequality by F yields (2.55). To show that for the log-utility case with $\alpha_1 = 0$ the lower bound coincides with the actual social capital, we use equation (2.A.3) to obtain a closed-form expression for a_1:

$$a_1 = \frac{B(1-Fa_1)}{\left[(G-1) + 1 + \left(\frac{1-\phi}{\phi}\right) + G^*\left(\frac{1-\tau}{p^*+\alpha_0 B}\right)\right]} \left[\frac{\left(\frac{1-\phi}{\phi B}\right)}{\frac{1}{\beta}}\right],$$

which simplifies to

$$a_1 = \frac{\beta}{\left[G + G^*\left(\frac{1-\tau}{p^*+\alpha_0 B}\right)\right]\left(\frac{\phi}{1-\phi}\right) + 1 + \beta F}.$$

Multiplying both sides of the expression above by F yields the expression for the lower bound.■

2.A.2 Summary and analysis of data on social ties

The purpose of this Appendix is to provide more disaggregated information on the association between social ties and economic development. We would prefer to work with income as our measure of economic development at all levels of aggregation. However, data on income at the individual level is not consistent across countries, and therefore we use degree of education as our measure of economic development at the individual and regional levels (except in the case in which we analyze individual data within the United States). The findings are the following. At the individual level, (i) there is a strong negative association between number of family ties and economic development; (ii) there is a strong negative association between average visits to nuclear family members and economic development; (iii) there is a positive association between number of close friends and economic development; (iv) there is a strong negative association between average visits to close friends and economic development; (v) there is a strong positive association between belonging to a secondary association and economic development; (vi) there is a weak positive association between frequency of participation in secondary associations and economic development. At the regional level, observations (i) to (v) are confirmed; observation (vi) is no longer statistically significant. At the national level, observations (i) to (v) are confirmed if the dependent variable is income per capita; observation (vi) is no longer statistically significant. Two additional findings are (vii) in general, country fixed effects diminish the size of the coefficients, which indicates the presence of a national factor on individual observables; and (viii) the degree of association between measures of social ties and of development are stronger (economically) with more aggregate data.

In our view, these results provide support to the way we introduced social ties into the traditional microeconomic framework. In particular, there is a consumption component (ties enter the utility function) and a cultural component (degree of communitarianism selects which equilibrium is played). In data it also seems to be the case that there are two relatively independent components in social ties one at a regional or national level, the other at an individual level.

The best systematic evidence of the relationship between social ties and economic development we were able to obtain is provided by the International Social Survey Programme (ISSP).[14] This program includes two chapters on social networks, one for the year 1986 and another for the year 2001. Individuals in many countries were asked, among other questions, about number and frequency of contacts with different types of agents: family members, friends and civic institutions. Using the dataset for the year 2001, which includes 30 countries, more than 350 regions, and around 37,000 individuals, we explored the degree of association between social ties and economic development. We regressed measures of economic development (education or income per capita) on measures of social ties (number of members in group, frequency of visits, frequency of other type of contact, and belonging and frequency of participation in secondary associations). This exploration can be done at different levels of analysis:

[14] Webpage: www.issp.org

individual, regional and national, where the last two imply taking averages of the relevant variables across geographical units. Tables 2.11, 2.12 and 2.13 present the results of this analysis.[15]

The first column in table 2.11 records the association between degree of education (from incomplete primary to complete university) and social ties for the whole sample of individuals. In this regression we controlled for sex, age, and marital status of the individual. The first measure of social ties is the frequency of visits to their mother. A higher value for this variable implies a higher frequency of visits. We observe that a higher degree of education is negatively associated with frequency of visits, with a coefficient value of -0.064. The number below the coefficient indicates the t-statistic, while the third value indicates the number of observations on which the regression is run. In this case, the coefficient is statistically highly significant. Economically, a decrease in visits from "daily" to "less often than several times a year" (from 2 to 7) is associated with around one third of an upward change in the degree of education (say, from complete primary to incomplete secondary).

The second measure of social ties is frequency of "other contacts with mother, other than visiting", which includes contacts by telephone, letter, or e-mail. The coefficient is 0.086 and it is highly significant, which indicates that the frequency of other contacts is positively associated with degree of education, with a decrease in visits from "daily" to "less often than several times a year" (from 2 to 7) associated with around 0.4 of an upward change in the degree of education (say, from complete primary to incomplete secondary).

Putting the two associations in the preceding two paragraphs together, we observe that, with development, individuals shift their technology of building ties with their mother, from explicit visiting to long-distance contact. The next six variables show that this shift occurs for contacts with all other members of the nuclear family: father, brother or sister, and son or daughter.

The bottom part of the table shows that the number of members in nuclear family (F_{nf}) and the average (across members) strength of ties ($a_{1,nf}$) are both negatively associated with degree of education.

The second column of table 2.11 shows the degree of association between social ties and degree of education (as in column one) but including country fixed effects. In general, the effect of including country dummy variables is to keep the sign of the coefficient, but to diminish the degree of association between the variables. For example, the frequency of visits to mother is less strongly related to degree of education with country fixed effects than without them (the coefficient changes from -0.064 to -0.047). This might indicate that there are two components in the degree of association between social ties

[15]In this section we take an agnostic view on causal relationships; we think all of the following coefficients as partial correlation coefficients. In previous sections, where we presented a model and its solution, we took a position, considering effects in both directions: the number of ties effects economic development through an allocation of time, and economic development effects the average strength of ties by changing the relative productivity of effort. A reader who does not agree with that argument might profit nevertheless from this section.

Level of analysis	Individual				Regional		National	
Dependent variable	Education			Income	Education		Education	Income
Countries	All	All	US	US	All	All	All	All
Visits mother	-0.064*	-0.047*	-0.075*	-878	-0.372*	-0.218*	-0.138	-5415**
	-11.86	-9.54	-3.56	-1.78	-6.40	-5.11	-0.49	-1.93
	19199	19199	737	486	248	248	29	27
Other contacts	0.086*	0.073*	0.043	264	0.195*	0.16*	.275	7850*
mother	13.01	12.13	1.67	0.46	3.24	3.99	1.28	4.15
	14564	14564	673	453	248	248	29	27
Visits father	-0.042*	-0.029*	-0.018	-573	-0.346*	-0.160*	-0.075	-3614
	-7.28	-5.62	-0.76	-1.08	-6.47	-3.92	-0.30	-1.39
	13988	13988	570	382	248	248	29	27
Other contacts	0.066*	0.072*	0.074*	395	0.049	0.10*	0.149	7050*
father	9.20	11.33	3.12	0.75	0.77	2.62	0.62	2.88
	10785	10785	536	364	248	248	29	27
Visits brother	-0.133*	-0.073*	-0.115*	-510	-0.586*	-0.370*	-0.489	-7322*
or sister	-24.47	-14.59	-5.23	-0.96	-8.51	-5.21	-1.61	-2.19
	25443	25443	944	553	248	248	29	27
Other contacts	0.034*	0.045*	-0.023	-489	0.050	0.270*	0.342	6573**
brother or sister	5.31	7.73	-0.92	-0.80	0.58	4.68	1.12	2.02
	23221	23221	918	539	248	248	29	27
Visits son or	-0.057*	-0.016*	-0.062**	153	-0.302*	-0.005	-0.361	-8704*
daughter	-8.28	-2.48	-1.97	0.21	-4.89	-0.10	-1.31	-3.41
	14189	14189	435	196	248	248	29	27
Other contacts son	0.093*	0.079*	-0.060	-489	0.163**	0.190*	0.393	8213*
or daughter	9.23	8.49	-1.28	-0.48	2.41	5.12	1.48	3.07
	9367	9367	356	152	248	248	29	27
F_{nf}	-0.105	-0.086	-0.197	-258	-0.138	-0.194	-0.145	-2729
	-38.48*	-33.05*	-8.93*	-0.95	-3.72*	-7.59*	-1.22	-1.96**
	31964	31964	1138	647	248	248	29	27
$a_{1,nf}$	-0.119*	-0.072*	-0.110*	-936	-0.479*	-0.321*	-0.251	-6815*
	-23.24	-15.03	-4.90	-1.74	-7.28	-4.94	-0.85	-2.35
	31040	31040	1111	636	248	248	29	27
Country dummies	no	yes	-	-	no	yes	-	-

Table 2.11: Education, income and nuclear family ties. For each variable, the upper number is the coefficient of the regressor, the second number is the t-statistic and the third number is the number of observations used in the regression. All regressions controlled for age and sex. The regression at the individual level controlled for marital status. The regression at the individual level, with income as the dependent variable, controlled for number of hours worked. * means the variable is statistically significant at the 0.01 level. ** means the variable is statistically significant at the 0.05 level. Education is measured by the degree obtained. A higher number implies a higher degree. Income is measured in US$ 2000.

and economic development: (i) an intra-country component and (ii) and inter-country component, with the second one reinforcing the first one. The second component might be associated to national cultures.

The third column shows the degree of association between measures of social ties and degree of education for individuals of the United States. The sign of associations as well as the point estimates are similar to the ones of the whole sample with country dummies, but the statistical significance is smaller as the number of observations is

much smaller.
The fourth column shows the degree of association between measures of social ties and income of the respondent for individuals of the United States. (At the individual level, for the world-wide sample, we did not conduct regressions with income of the respondent as the dependent variable because, as income was reported in national currency, and it seemed to be related to different periods of time (monthly, annually), it was not clear we could compare it across countries). The point estimates have, in general, the sign of previous columns, but they are not statistically significant.
The fifth and sixth columns present associations between social ties measures and degree of education at the regional level. The differences in economic development and social ties can be large between regions of the same country; think of the northeast and south of the US, or north and south of Italy. For most countries the survey provides a variable that indicates the region of the country where the individual lives. The regional variable is one of a few that is decided by the national agency that conducts the survey; therefore the number of regions varies greatly across countries. For example, Hungary includes twenty regions while Brazil includes five. We obtained more than 350 regions, though only 248 presented information on degree of education.
The fifth column presents the associations at the regional level without country fixed effects. The signs of the coefficients are all equal to the signs of the coefficients at the individual level analysis. The point estimates of the coefficients are, in general, larger than the ones at the individual level analysis. For example, a decrease in the frequency of visits to mother from "daily" to "less often than several times a year" (from 2 to 7) is associated with almost two notches up in degree of education (say, from complete primary to complete secondary). Again, these coefficients are, in general, reduced by the inclusion of country dummies (sixth column).
The seventh and eighth columns present associations between social ties measures and economic development at the national level. The signs of the coefficients, either in column seventh where the dependent variable is degree of education, or in column eighth where the dependent variable is income per capita, are equal to the signs in both the individual and regional level analysis. The sizes of the point estimates in the seventh column do not differ much from the ones for the regional analysis, but they are mostly not statistically significant, due to the smaller number of observations. The point estimates in the eighth column are, in general, both large and statistically significant. For example, a decrease in number of visits to mother from "daily" to "less often than several times a year" (from 2 to 7) is associated with an increase in income per capita of more than 25 thousands dollars. (The country with the highest income per capita is the US with almost 35 thousand dollars (of the year 2000), while the country with the lowest income per capita is the Philippines with less than 4 thousand dollars (of the year 2000)).
The negative associations between number of family ties and average strength of family ties and income per capita can be observed, at the national level, in figure 2.12.
Table 2.12 shows the association between measures of friends' ties with economic development. In the first column we observe, first, that the number of close friends, either at

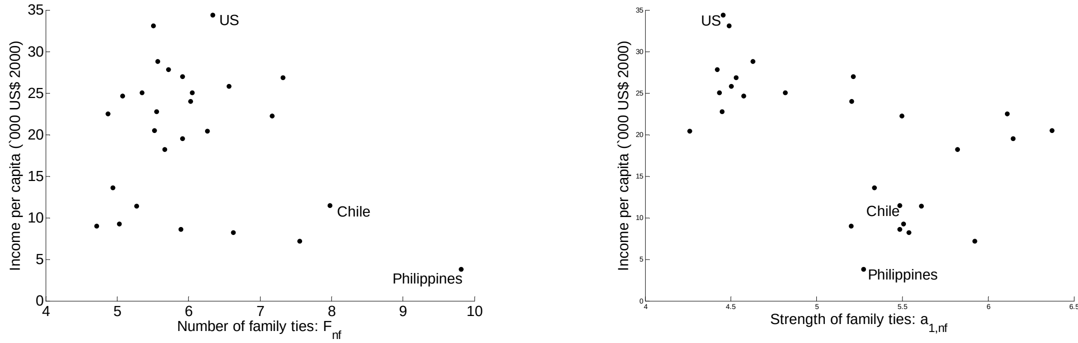


Figure 2.12: Left panel: plots the number of nuclear family ties vs. income per capita in 2000, for a group of 27 countries; the correlation coefficient is -0.28, and it is statistically significant at the 15% level. Right panel: plots the average intensity of nuclear family ties vs. income per capita in 2000, for a group of 27 countries; the correlation coefficient is -0.56, and it is statistically significant at the 1% level.

work or outside of work, reported by the individuals, is positively associated with the degree of education. Second, the frequency of visits to the closest friend is negatively associated to the degree of education, where a change from "daily" to "less often than several times a year" (from 2 to 7) implies almost one higher degree of education (say, from complete primary to incomplete secondary). Third, other type of contact with the closest friend (by telephone, letter or e-mail) is positively associated with the degree of education. All of these associations are statistically significant. Again, with friends, as with family, there is a shift from visiting to long-distance contact as the education level increases.

With friends, as with family, we obtain smaller size of coefficients if we control for country fixed effects, indicating the possibility of a cultural component, and we obtain higher degree of association if the analysis is done at the regional level. In this case, for example, a decrease in the frequency of visits to the closest friend from "daily" to "less often than several times a year" is associated with an increase of almost three notches up in the degree of education (say, from complete primary to university incomplete). And, again, the point estimates of the degree of association between these ties and income per capita at the national level are large. For example, a decrease in number of visits to friends from "daily" to "less often than several times a year" is associated with an increase in income per capita of more than 50 thousands dollars.

Level of analysis	Individual				Regional		National	
Dependent variable	Education			Income	Education		Education	Income
Countries	All	All	US	US	All	All	All	All
No. close friends F_f	0.024*	0.013*	0.042*	0.8	0.073*	0.005	0.050	2075*
	16.31	9.94	6.92	0.01	3.64	0.26	0.65	2.64
	30361	30361	1124	640	248	248	29	27
No. close friends at work	0.037*	0.006	0.007	389	0.120**	-0.050	0.078	568
	9.65	1.64	0.51	1.38	2.49	-1.38	0.37	0.26
	20858	20858	750	644	248	248	29	27
Visits close friend $a_{1,f}$	-0.185*	-0.119*	-0.100*	-1216**	-0.538*	-0.230*	-0.656**	-10325*
	-32.34	-22.53	-4.77	-2.47	-6.91	-3.28	-2.09	-2.99
	27278	27278	1074	622	248	248	29	27
Other contacts close friend	0.087*	0.076*	0.002	323	0.345*	0.295*	0.386	9414*
	17.16	16.61	0.10	0.63	5.27	6.40	1.63	4.57
	26273	26273	1048	606	248	248	29	27
Country dummies	no	yes	-	-	no	yes	-	-

Table 2.12: Education, income and close friends ties. See notes in table 2.11.

Figure 2.1 in the introduction to the paper shows the association between number of close friends and strength of friends ties (in terms of visits) with income per capita at the national level.
Table 2.13 shows the associations between secondary associations' ties (also known as civic society) and economic development. For each type of association (political party, union, clubs, etc.) we have a variable indicating belonging to the association, and another indicating frequency of participation in the association (conditional on belonging). At the individual level, belonging is generally positively associated with degree of education. The only case hat goes in the opposite direction is for religious organizations. These effects are statistically and economically strong. For example, belonging to a club is associated to having almost one half higher notch in degree of education. The association between frequency of participation and degree of education is less clear. It is positive and statistically significant for political parties, unions, sport clubs, and other associations, but statistically insignificant for the rest.
Again, in the second column, we find that the size of the coefficients are, in general (but not always), smaller with the inclusion of country fixed effects. Interestingly, the only coefficients that change sign between column 1 and column 2 are the ones related to belonging in religious organizations and attendance to religious services: while without country dummies the association between belonging to religious organizations and degree of education is negative, with country dummies this association turns positive. In other words, within countries, on average, there is a positive association being part of religious organizations and degree of education, but individuals in countries with lower formal education participate more actively in religious organizations than individuals in countries with higher formal education. In this unique case the aggregate component (possibly the national culture) does not reinforce, but undermines the individual component.

In the bottom part of the table we find a summary of the relationship between secondary associations ties and economic development. We compute the overall participation in associations (F_{sa}) and the average frequency of participation ($a_{1,sa}$). It is clear that there is a strong and positive association at all levels of aggregation between membership and economic development. By contrast, there is little association between frequency of participation and level of economic development as most coefficients in that last row are statistically insignificant. Figure 2.13 shows the association between belonging to secondary associations and strength of those ties with income per capita, at the national level.

Level of analysis	Individual				Regional		National	
Dependent variable	Education			Income	Education		Education	Income
Countries	All	All	US	US	All	All	All	All
Political party								
Belong	0.136*	0.248*	0.395*	3547**	1.11*	-0.464	1.83	41213**
	5.44	11.08	5.21	2.05	2.71	-1.28	1.30	2.26
	30328	30328	1131	64	248	248	29	27
Frequency	0.179*	0.105*	0.042	-3625**	-0.177**	-0.021	-0.729	5264
	6.84	4.26	0.49	-2.11	-2.01	-0.47	-1.41	0.86
	3709	3709	284	165	234	234	29	27
Union								
Belong	0.641*	0.515*	0.453*	8767*	1.02*	0.619**	1.60	34939*
	32.3	28.5	5.85	5.30	4.30	2.17	0.96	3.63
	30373	30373	1131	643	248	248	29	27
Frequency	0.097*	0.112*	-0.077	-742	-0.205**	-0.065	-0.768	-1693
	4.65	5.89	-0.98	-0.38	-1.93	-1.12	-1.39	-0.26
	6542	6542	276	183	247	247	29	27
Religious org.								
Belong	-0.143*	0.096*	0.243*	1395	-0.06	-0.355**	-0.688	15853**
	-8.12	5.69	3.49	0.87	-0.32	-2.04	-0.94	2.05
	30500	30500	1132	643	248	248	29	27
Frequency	0.016	0.125*	0.203*	-543	-0.084	0.048	-0.438	-2969
	0.87	7.69	3.62	-0.43	-0.83	0.79	-0.99	-0.55
	9414	9414	716	413	248	248	29	27
Sports/hobby club								
Belong	0.415*	0.313*	0.502*	2950**	1.06*	0.252	0.961	35742**
	23.55	29.22	7.44	1.92	4.89	0.99	1.11	4.46
	30750	30750	1132	643	248	248	29	27
Frequency	0.153*	0.085*	0.101	2052	0.286**	-0.050	0.456	13835**
	7.32	4.46	1.16	0.90	1.88	-0.60	0.72	2.11
	9359	9359	439	267	248	248	29	27
Charitable org.								
Belong	0.517*	0.415*	0.481*	3960**	2.15*	0.573	1.81	53514*
	21.45	19.33	6.98	2.50	6.17	1.68	1.36	3.33
	29070	29070	1131	642	233	233	27	26
Frequency	0.042	0.032	0.07	1689	0.003	-0.006	-0.24	3511
	1.50	1.21	0.92	0.79	0.06	-0.07	-0.49	0.61
	3998	3998	382	222	229	229	27	26

Table 2.13: Education, income and secondary associations ties. See notes in table 2.11.

Level of analysis	Individual				Regional		National	
Dependent variable	Education			Income	Education		Education	Income
Countries	All	All	US	US	All	All	All	All
Neighborhood org.								
Belong	0.214*	0.180*	0.326*	3186	0.619**	0.615**	0.658	24365**
	9.40	8.69	3.92	1.61	1.94	1.99	0.56	1.94
	30343	30343	1132	643	248	248	29	27
Frequency	-0.006	0.02	-0.126	-4995	-0.201**	-0.073	-0.136	2097
	-0.21	0.83	-1.24	-1.71	-1.96	-1.39	-0.26	0.36
	4671	4671	228	115	240	240	29	27
Other associations								
Belong	0.573*	0.387*	0.566*	6666*	2.02*	1.05*	2.1	59265*
	25.97	19.36	7.96	4.09	6.50	3.30	1.59	5.08
	30112	30112	1132	643	248	248	29	27
Frequency	0.109*	0.069*	0.123	2921	0.025	0.078	0.015	6644
	4.15	2.80	1.55	1.45	0.47	0.76	0.03	1.18
	4851	4851	335	190	245	245	29	27
Religious services								
Frequency	-0.058*	0.013*	0.055*	-513	-0.14*	-0.083	-0.204**	-3470
	-12.22	2.78	3.14	-1.25	-2.81	-1.57	-1.93	-1.65
	28722	28722	1133	645	239	239	28	26
Union membership								
Belong	0.592*	0.344*	0.013	5703**	-0.175	0.713*	0.72	-1894
	27.60	16.63	0.11	2.43	-0.76	4.99	1.34	-0.29
	22115	22115	757	441	247	247	28	26
F_{sa}	1.04*	1.09*	1.18*	12235*	1.953*	1.006**	1.76	63375*
	28.30	31.48	9.95	4.35	4.81	1.93	1.24	4.28
	31964	31964	1138	647	248	248	29	27
$a_{1,sa}$	0.030*	0.051*	0.118**	-1681	-0.098	-0.095	-0.508	3558
	2.08	3.99	1.99	-1.17	-0.65	-0.96	-.84	0.53
	19682	19682	939	539	248	248	27	27
Country dummies	no	yes	-	-	no	yes	-	-

Table 2.13: Cont.: education, income and secondary associations ties. See notes in table 2.11.

The point estimates of the degree of association between belonging to secondary association and income per capita, at the national level, are again large. For example, an increase from "never" to "more than twice in a year" participation in activities of a political party is associated with an increase of almost 40 thousands dollars (of the year 2000). In economic terms, these associations are highly significant.
We will now summarize the results of this analysis. With economic development, we observe (i) a decrease in number of nuclear family members; (ii) a decrease in frequency of visits to members of nuclear family; (iii) an increase in other, long-distance contacts with members of nuclear family and friends; (iv) an increase in number of close friends; (v) a decrease in frequency of visits to closest friend; (vi) an increase in memberships to secondary associations; (vii) a weak increase in frequency of participation in secondary organizations. An additional result of the analysis is, (viii) the degree of association between social ties and economic development is stronger when we pass from the individual level to a regional level analysis; this might indicate a regional (or national)

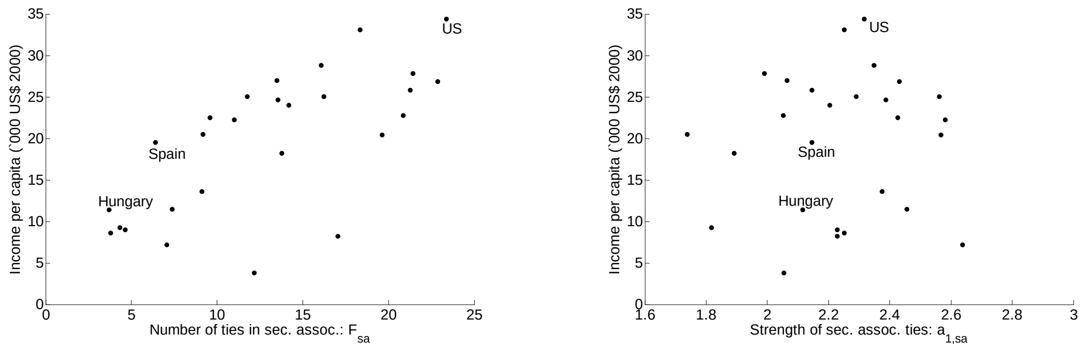


Figure 2.13: Left panel: plots the number of secondary associations' ties vs. income per capita in 2000, for a group of 27 countries; the correlation coefficient is 0.69, and it is statistically significant at the 0.1% level. Right panel: plots the average intensity of secondary associations' ties vs. income per capita in 2000, for a group of 27 countries; the correlation coefficient is 0.09, and it is not statistically significant.

cultural component.[16]

[16] We can set these stylized facts next to other pieces of evidence to obtain a clearer picture. These other pieces of evidence are: (i) a decrease in extended family size with economic development (Goode (1966)); (ii) a decrease in time-intensive participation in secondary associations at high levels of economic development (Putnam (2000): "From the point of view of social connectedness, however, the new organizations are sufficiently different from classic "secondary associations" that we need to invent a new label – perhaps "tertiary associations". For the vast majority of their members, the only act of membership consists in writing a check for dues or perhaps occasionally reading a newsletter. Few ever attend any meetings of such organizations –many never have meetings at all– and most members are unlikely ever knowingly to encounter any other member", p. 52); (iii) an increase in the number of these "tertiary associations" at high levels of economic development (Putnam (2000), p.49). Let's now divide the social ties in five group types: (i) nuclear family (nf), (ii) extended family (ef), (iii) friends (f), (iv) secondary associations (sa), (v) and tertiary associations (ta). Let's assign the variable F_i to the network size of group type i, and the variable a_i to the network density (mean strength of ties) of group type i (where $i = nf, ef, f, sa$ or ta). Let's associate strength of tie in a bilateral relationship with time invested in that relationship. Then the total time dedicated to group i will be: $F_i a_i$. Let's assume plausibly that $a_{nf} > a_{ef} > a_f > a_{sa} > a_{ta}$, at any point in time or level of economic development. The observations above indicate that, with economic development: (i) the network sizes of groups with strong ties (F_{nf} and F_{ef}) diminish, and the network sizes of groups with weak ties (F_f, F_{sa} and F_{ta}) increase; (ii) the network densities of family and friends (a_{nf}, a_f) diminish, while the network density of secondary associations (a_{sa}) seems roughly constant. If this is the case, the average strength of tie ($\bar{a} = \frac{\sum_i a_i F_i}{\sum_i F_i}$) will be declining with economic development for two reasons: (i) the diminishing time invested in ties in each group; (ii) a composition effect due to the increase of network sizes of groups with weak ties and decrease in network sizes of groups with strong ties.

2.A.3 Data construction for calibration

The objective of this Appendix is to describe in detail the sources and construction of the data that is offered in tables 2.2 to 2.8.

Table 2.2. Measured GDP: Penn World Table (real GDP per capita; constant prices: chain series). Adjustment GDP for home production: using Table I of Devereux and Locay (1992). Share home production: Table I of Devereux and Locay (1992). Share transaction services: 1965: table 3.13, Wallis and North (1986), averages between estimation I and II, average values for 1960 and 1970; 1985: *idem*, assumed value equal to 1970; both values have to be multiplied by (1 - share home production). Share external market: Penn World Table, openness in current prices, divided by two and multiplied by (1 - share home production) × (1 - share transaction services). Share internal market: residual.

Table 2.3. Market work plus travel, home work, schooling and total leisure: Ramey and Francis (2008); population: age 10 and above. Social activities and television based on percentages of free time informed by Robinson and Godbey (1997), tables 14 and 9 respectively. Labor share in market transaction: 1965: Wallis and North (1986), table 3.1, average 1960 and 1970; 1985: assumed average between *idem* for 1970 and own calculation for 2001, based on ISSP 2001, using Wallis and North (1986) methodology.

Table 2.5. F: own calculations, using ISSP 2001. F_{nf}: sum of variables v4r (number of brothers and sisters), v8r (number of adult sons and daughters), v66r (number of children aged 18 or less) plus 2 for father and mother. F_f: total numbers of friends; sum of variables v23r, v24r and v25r. F_sa: if a person participates in a secondary association we assume he has 10 ties in that association; we sum then across 7 types of associations. Income per capita (IPC 2000) for 27 countries: Penn World Table (real GDP per capita; constant prices: chain series). Ratio coefficient of variation in 1990 to 1750: using Lucas (2002a), table 5.2. Table 2.14 below offers the means (secondary associations) or medians (nuclear family and close friends) per country.

Table 2.6. Same sources as table 2.3: Ramey and Francis (2008) for years 1900 and 2000. Share of labor in transaction services: Wallis and North (1986) for 1900, table 3.1; ISSP for 2001.

Table 2.7. Constructed with same methodology as table 2.2. Share home production: 1900: assumed to be equal to the one in 1930, informed by Devereux and Locay (1992), table I; 2000: assumed to be equal to the one in 1985, informed by *idem*. Transaction services share: 1900: Wallis and North (1986), table 3.13, average between I and II, multiplied by (1 - share home production); 2000: *idem*, assumed to be equal to 1970, average between I and II. External sector share: 2000: Penn World Table, openness in current prices, divided by two and multiplied by (1 - share home production) × (1 - share transaction services); 1900: Irwin (1996), table I, share of exports in GDP, assumed equal to value in 1913.

Table 2.8. United States, 2000: Ramey and Francis (2008); population: 14 and above. United Kingdom, 2005: ONS (2006), table 2.1, population: 16 and above. Italy, 2002-2003: ISTAT (2007), table 1.1, population: 15 and above. Mexico, 2002:

INEGI (2005), tables 2.2 and 2.17, population: 12 and above.
A table with information on average number of ties per country, used in the simulation, follows.

Country	Type of tie			Income
	Nuclear family	Close friends	Secondary associations	per capita (2000 US$ ‘000)
United States	6	8	23	34.36
Norway	5	11	18	33.09
Switzerland	5	8	16	28.83
Denmark	5	8	21	27.83
Austria	5	7	14	27.00
Canada	7	7	23	26.82
Australia	6	9	21	25.83
Germany	5	7	16	25.06
France	6	6	12	25.04
United Kingdom	5	9	14	24.67
Japan	6	9	14	23.97
Finland	5	5	21	22.74
Italy	4	4	10	22.49
Israel	6	8	11	22.24
Cyprus	6	6	9	20.46
New Zealand	6	8	20	20.42
Spain	5	4	6	19.54
Slovenia	5	10	14	18.21
Czech Republic	5	6	9	13.62
Chile	8	3	7	11.43
Hungary	5	3	4	11.38
Russia	5	4	4	9.26
Latvia	4	3	5	9.00
Poland	6	5	4	8.61
South Africa	6	3	17	8.23
Brazil	7	8	7	7.19
Philippines	10	7	12	3.83
Correlations				
Friends	0.07	1	-	-
Sec. associations	0.06	0.56	1	-
Income per capita	-0.35	0.58	0.69	1

Table 2.14: Number of ties and income per capita.

Chapter 3

Capital Accumulation, Sectoral Productivity, and the Relative Price of Non-Tradables: The Case of Argentina in the 90s

3.1 Introduction

Kydland and Zarazaga (2002b) found that a neo-classical dynamic general equilibrium model overestimates the capital stock for Argentina in the 90s, given the productivity levels, measured as Solow residuals (see figure 3.1). The capital stock grew in the 90s, but it grew too little, given the huge increases in measured total factor productivity (TFP). The overestimation is considerable, 20% of total capital stock, and the slow pace of capital accumulation could have been a cause in the subsequent collapse of the economy in the early 2000s. But why was investment so meager in the 90s?

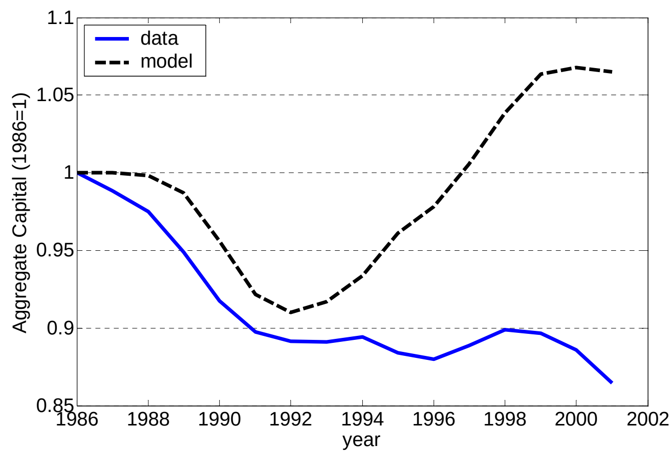


Figure 3.1: Comparison of model and data. One sector model. The data is detrended by average annual income per capita and population growth rates for the period 1960-2001. The figure is a replication of figure 2 in KZ(2002b).

One plausible explanation for underinvestment is the lack of credit: firms observe the increases in productivity and want to invest in capital to maximize their profits, but they can not do it because of lack of funds. This line of research would emphasize the inexistence of credit markets (e.g., Banerjee and Duflo (2005)), the lack of collateral (e.g., Caballero and Krishnamurthy (2001)), the possibility of default (e.g., Alvarez and Jermann (2000) or Kehoe and Perri (2002)) or the crowding out of credit by the government.

The objective of this paper is to assess the validity of an alternative explanation: low aggregate investment is related to the behavior of the relative price between non-tradable and tradable goods. During this time the relative price of non-tradables (in terms of tradables) was considered to be high. Figure 3.2 shows indeed that the price increased by more than 200% at the beginning of the 90s and remained high during the decade. All other things equal, this would have diminished profitability in the tradable sector, which would have decreased the incentive to invest (in that sector). Figure 3.3 shows indeed that the de-trended capital in the tradable sector diminished during the 90s. But why would *aggregate* capital diminish? With a high relative price of non-tradable goods, profitability in the non-tradable sector should have been high, and therefore there should have been a higher incentive to invest (in that sector). Figure 3.3 shows indeed that de-trended capital in the non-tradable sector increased during the 90s, but it was not enough to compensate for the decline in capital in the non-tradable sector. The effect of the high relative price of non-tradables on *aggregate* investment is not clear beforehand.

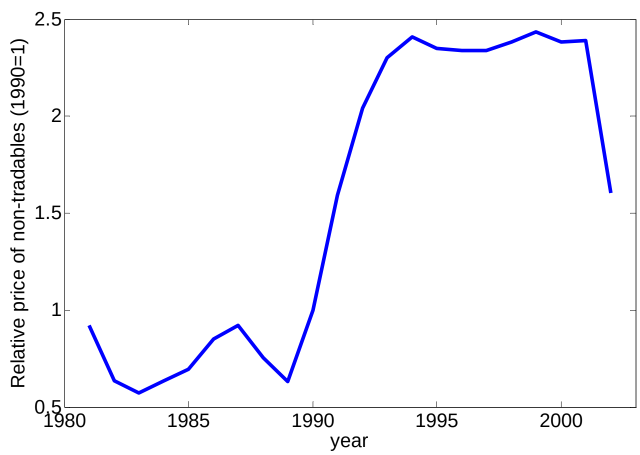


Figure 3.2: Argentina, 1981-2002. Relative price of non-tradables (1990=1). It is the ratio between consumer price index (CPI) for services and wholesale price index (WPI) for industrial goods.

How can a high *relative* price of non-tradables diminish aggregate investment? One possibility, on the demand for investment side, is that non-tradable goods are less intensive in capital (relative to labor) than tradable goods, and therefore an increase in their relative price, all other things equal, does not increase the desired capital in the non-tradable sector as much as it decreases the desired capital in the tradable sector. Another possibility, on the supply of investment side, hinges on what type of good is the investment good itself: a tradable or a non-tradable? If it is a tradable (say, machinery), then its price would have been low, there would have been a short supply of investment goods, and therefore low aggregate investment. If it is a non-tradable (say, construction), then its price would have been high, and therefore the supply of investment goods would have been high, inducing a high aggregate investment. To

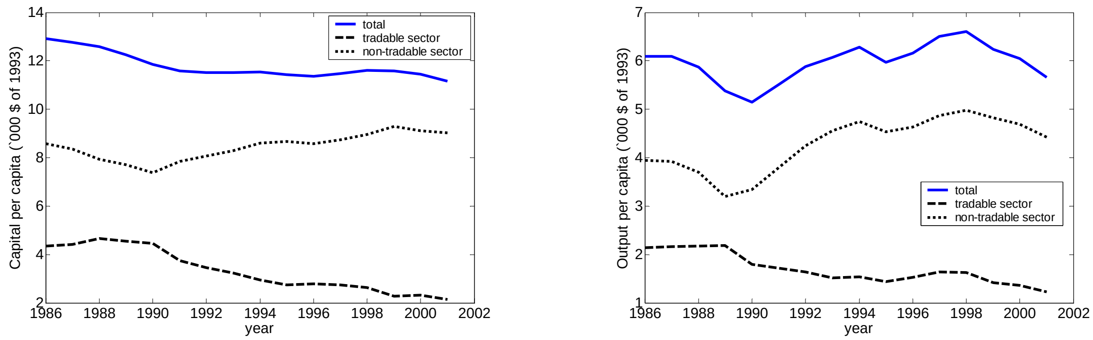


Figure 3.3: Argentina, 1986-2001. Aggregate and sectoral. Left panel: capital per capita. Right panel: output per capita. The series have been detrended by average annual growth in income per capita during the period 1960-2001.

decide if these possibilities actually happened I calibrate a general equilibrium model with two sectors, tradable and non-tradable, and simulate the sectoral and aggregate capital, inputting the observed sectoral productivity changes, that are considered to be the drivers of the economy.

A related question is why the relative price of non-tradables increased drastically in the early 90s (and decrease drastically in the early 2000s). In a neo-classical general equilibrium model, the relative price is determined endogenously, with sectoral productivity being an essential factor in its determination. So we will start this exploration by considering a growth accounting exercise for Argentina, and obtaining the sectoral "Solow" residuals. We will follow it by solving a general equilibrium model, and by computing the paths for the relative price of non-tradables, as well as for the sectoral and aggregate capital. The question we will pose is: can a general equilibrium model disaggregated in two sectors, tradable and non-tradable, account for the changes in the relative price of non-tradables as well as for the sectoral and aggregate capital, given changes in sectoral productivity?

The strategy in this paper is to build on Kydland and Zarazaga (2002b) (from now on KZ[2002b]) closed economy, flexible price, general equilibrium model.[1] Of course, in a closed economy all goods are non-traded internationally. In this paper, the differences between tradable and non-tradable sector will be related to differences in sectoral productivity, and parameter values. In that sense, they could easily be equated to the classification between physical goods and services. I will show in a subsequent

[1]See also Kydland and Zarazaga (2002a).

section that actually opening the economy will only strengthen my results.

The main results are the following.

1. During the 90s the tradable and non-tradable sectors evolve very differently. In particular, there were large *increases* in the productivity of the non-tradable sector with slight *decreases* in the productivity of the tradable sector.

2. The calibrated two-sector model can not account for the behavior of aggregate capital during the period, though it improves (by closing the gap between model and data by 5%) on the one-sector model.

3. A second and robust anomaly is uncovered with respect to the relative price of non-tradables. By the model's logic, an increase in this price (which we observe in the early 90s) is inconsistent with the observed changes in productivity mentioned in 1. I consider this last result important because the anomaly is robust, and therefore it becomes a good test for new models that try to understand the performance of Argentina in the 90s.

The paper is organized as follows. In the next section I present the growth accounting for Argentina for the period between 1976 and 2001, disaggregating into tradable and non-tradable sectors. Section 3.3 presents the two-sector model. Section 3.4 presents the calibration and the computation procedure. Section 3.5 presents the results. I conclude in section 3.6. The appendix 3.A.1 describes the data sources and construction of series.

3.2 The facts

I used data on aggregate output, capital, and employment elaborated by Maia and Nicholson (2001), which spans from 1960 to 2001. This data differs slightly from the one used by KZ(2002b). I have worked with both data sets and no essential finding in this paper depends on the use of either one.

The main data innovation is to separate output, employment, and capital into tradable and non-tradable sectors. I considered agriculture, mining, and manufacturing as tradables, and the rest of the economy (construction, transportation and public utilities, wholesale trade, retail trade, finance, insurance and real estate, and service and government) as non-tradables during the whole period.[2] I used data by sector to separate aggregate output and employment into tradable and non-tradable.

To separate capital used in each sector I proceed in the following way. I got electrical energy data disaggregated into two main sectors, industry and commerce. I identified energy used in industry with capital utilization in the tradable sector and energy used in commerce with capital utilization in the non-tradable sector. I calculated the share of energy used in each sector and multiply that share by the total capital to obtain the capital utilization in each sector.[3]

Table 3.1 presents a growth accounting exercise for aggregate, tradable, and non-tradable output per capita, for Argentina in the period between 1976 and 2001, assuming a Cobb-Douglas production function,

$$Y_t = A_t K_t^{\theta} L_t^{1-\theta}, \tag{3.1}$$

where Y_t is aggregate output, A_t is productivity level, K_t is the capital stock and L_t is employment.[4] I follow Hayashi and Prescott (2002), divide by the population, N_t, and decompose the output per capita, Y/N, into three components, a TFP component, a capital intensity component and an employment intensity component,

$$\frac{Y_t}{N_t} = A_t^{\frac{1}{1-\theta}} \left(\frac{K_t}{Y_t}\right)^{\frac{\theta}{1-\theta}} \frac{L_t}{N_t}. \tag{3.2}$$

In table 3.1 we can observe many curious growth episodes. First, observe that, in 1991-1996 for the aggregate economy, an annual increase in 6.33% in the TFP component was accompanied by an annual decline of 1.69% in the capital intensity component. This was the seed for the puzzle in KZ(2002b), which they called "capital

[2]Of course, this is a rough division between tradable and non-tradable goods, and some subcategories in each sector could be more reasonably included in the other sector; e.g. international air transportation might be included in the tradable sector while cheap heavy minerals might be included in the non-tradable sector. Those changes would be minor though. De Gregorio and Wolf (1994) and Herrendorf and Valentinyi (2005) explicitly disaggregate the economy in very similar ways.

[3]Two checks reassured me on the reasonableness of this method. First, the correlation between total electrical energy used and aggregate capital is high (0.95). Furthermore, some studies (Burnside, Eichembaum, and Rebelo (1996) and Brandt, Dressler, and Quintin (2004)) prefer to use energy rather than capital stock as a proxy for capital services, a path I do not follow here. Second, Baxter and Farr (2001) obtain for the United States a high correlation between energy use and capital stock for the manufacturing sector, the main tradable sector. I assume that the correlation is high for the non-tradable sector too.

[4]I considered similar production functions for each sector. I set $\theta = 0.4$ for both sectors and for the aggregate. In the calibration of the model I will find that this is not an egregious approximation.

shallowing". Second, a similar anomaly is the "labor shallowing" in the same period: despite the increase in productivity, the employment intensity diminished.[5] Third, moving to the dissaggregated cases, we observe the huge decrease in tradable TFP in the period 1976-1981 with an important increase in capital intensity.[6] Fourth, and more important for the present paper, there is the huge increase in non-tradable TFP in the period 1991-1996 with a decrease in capital and employment intensity. In the period 1996-2001 these trends are somewhat reversed with a loss of productivity in the non-tradable sector. However for the whole "long" decade, 1990-2001, the data is similar to the the first half of the decade: an increase in total productivity, with strong increases in non-tradable productivity but decreases in capital intensity, and no increase in tradable productivity. The most important piece of information that I obtain from this table is that the productivity gains in the 90s were in the non-tradable sector.

The stylized facts of the 90s by which I will judge the performance of the model are the following:[7]

1. A decrease in aggregate capital in the 90's (KZ[2002b] anomaly), reflecting an increase of capital in the non-tradable sector and a decrease of capital in the tradable sector (figure 3.3, left panel).

2. An increase in output, reflecting an increase in non-tradable output and a decrease in tradable output (figure 3.3, right panel).

3. The relative price of non-tradables appreciates drastically in the first years of the 90s and stays high for the rest of the decade (figure 3.2).

I would like to emphasize one more point related to the information that is obtained when I disaggregate between tradable and non-tradable sector. Observe figure 3.4. The left panel shows TFP in Argentina and the right panel shows TFP in the United States, both constructed in the same way. I observe that TFP in both sectors in Argentina were much more volatile than in the United States (coefficients of variation of 0.144 and 0.117 for tradable and non-tradable sectors in Argentina versus 0.108 and 0.075 for

[5]The reader might be reminded that between 1991 and 1996 the unemployment rate in Argentina increased from 6.0% to 17.3%.

[6]Some readers might recall that this period is considered to be of large deindustrialization.

[7]Variables in the model are detrended by both constant population growth rate and per capita income growth rate, so the following quantity variables have been detrended accordingly.

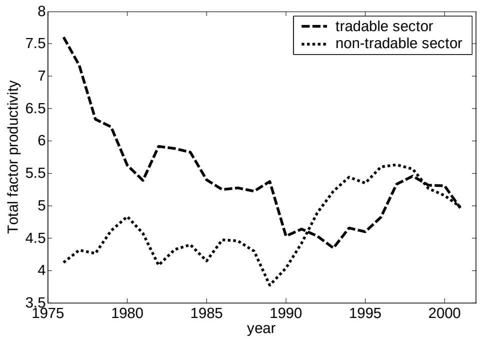
Panel A: Aggregate				
Period	$\frac{Y}{N}$	Capital intensity	Employment intensity	TFP
1976-1981	-0.17	1.81	0.82	-2.60
1981-1986	-0.61	-0.37	0.50	-0.58
1986-1991	-0.79	-0.06	0.87	-1.38
1991-1996	3.55	-1.69	-0.86	6.33
1996-2001	-0.35	0.93	1.29	-2.45
1990-2001	**1.77**	**-0.75**	**0.36**	**2.35**

Panel B: Tradable sector				
Period	$\frac{Y}{N}$	Capital intensity	Employment intensity	TFP
1976-1981	-5.81	6.29	-0.72	-10.67
1981-1986	-0.49	0.76	-0.57	-0.43
1986-1991	-3.08	1.22	-0.26	-3.37
1991-1996	-1.01	-2.31	-0.05	1.57
1996-2001	-2.73	-0.58	-3.25	1.40
1990-2001	**-3.24**	**-0.88**	**-1.38**	**-0.49**

Panel C: Non-tradable sector				
Period	$\frac{Y}{N}$	Capital intensity	Employment intensity	TFP
1976-1981	4.06	-1.07	1.59	3.80
1981-1986	-0.39	-0.83	0.99	-0.05
1986-1991	0.73	-0.55	1.35	0.49
1991-1996	5.46	-1.41	-1.19	8.40
1996-2001	0.41	1.32	3.03	-3.75
1990-2001	**4.17**	**-0.87**	**1.03**	**4.31**

Table 3.1: Argentina, 1976-2001. Sectoral Growth Accounting.

the United States). Furthermore, while productivity in both sectors moved generally in the same direction for the United States (correlation 0.96), they moved more often in opposite directions for Argentina (-0.43). In this paper I take productivity as exogenous, but these graphs and numbers show that there is a lot to be explained with respect to them, as stressed by Kehoe (2003).



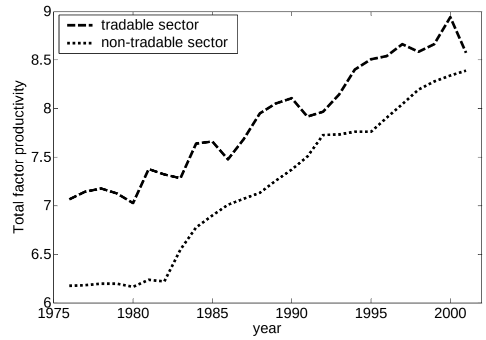


Figure 3.4: Sectoral total factor productivity, 1976-2001. Left panel: Argentina. Right panel: United States. Both figures constructed in identical way: equivalent data (constant price GDP and capital, employment measured by employed persons, shares of capital used in tradable and non-tradable sectors using electricity data) and identical production function (with capital share of income equal to 0.4). Setting the capital share of income in the United States to 0.3 scales up the graph.

3.3 The model

The model economy is populated by many identical consumers, who own two types of firms: those that produce tradable goods and those that produce non-tradable goods. All agents take prices as given.

Following KZ(2002b), I consider an economy with linear deterministic trends in population growth and income per capita growth. Therefore all variables are in per-capita, per-efficiency unit terms, except for employment and leisure, which are in per-capita terms. These transformations allow me to obtain a stationary solution to the recursive problem. In what follows T and N indicate tradable and non-tradable sector respectively.

Households

The representative consumer chooses tradable consumption, c^T, non-tradable consumption, c^N, leisure, l, labor, h, and investment, x, to maximize his expected infinite lifetime utility

$$\max E[\sum_{t=0}^{\infty} \hat{\beta}^t U(c_t^T, c_t^N, l_t)]. \tag{3.3}$$

I assume the following momentary utility form

$$U(c^T, c^N, l) = \frac{[(ac^{T\eta} + (1-a)c^{N\eta})^{\frac{\alpha}{\eta}} l^{1-\alpha}]^{1-\sigma}}{1-\sigma}, \tag{3.4}$$

with $0 < a < 1$, $0 < \alpha < 1$, $-\infty < \eta < 1$, and $\sigma > 1$. Here $\hat{\beta}$ is equal to $(1+\nu)^{1-\sigma}(1+\gamma)^{\alpha(1-\sigma)}\beta$, where ν is the population growth rate, γ is the deterministic income per capita growth rate, and $0 < \beta < 1$ is the consumer discount factor. η will deetermine the elasticity of substitution between tradable and non-tradable consumption, $\frac{1}{1-\eta}$.

The consumer faces a number of constraints. First, he is entitled to one unit of time each period so that labor supplied to each sector, h^T and h^N, must satisfy

$$h_t^T + h_t^N + l_t = 1. \tag{3.5}$$

Second, he accumulates capital for each sector separately according to the laws of motion

$$(1+\nu)(1+\gamma)k_{t+1}^T = (1-\delta^T)k_t^T + x_t^T, \tag{3.6}$$

and

$$(1+\nu)(1+\gamma)k_{t+1}^N = (1-\delta^N)k_t^N + x_t^N, \tag{3.7}$$

where k^T and k^N are capital in each sector, and $0 < \delta^T < 1$ and $0 < \delta^N < 1$ are rates of depreciation in each sector.

I found that a key decision for obtaining different paths for capital is the classification of investment as tradable or non-tradable. If I classify investment as a tradable (think about machinery), the model can replicate quite well the declining aggregate capital. If I classify it as a non-tradable (think about construction), then the model misses the aggregate capital, as the simulated capital grows during the period. These results are not surprising. The meager performance of productivity in the tradable sector constrains the increase in investment as a tradable; the strong performance of productivity in the non-tradable sector induces the increase in investment as a non-tradable.

These considerations led me to define a more realistic investment sector.[8] I postulate that investment in each sector has both a tradable and a non-tradable component, with the following functional forms

$$x_t^T = G^T(x_t^{TT}, x_t^{NT}) = {x_t^{TT}}^{\omega_1} {x_t^{NT}}^{1-\omega_1}, \tag{3.8}$$

[8] Burstein, Neves, and Rebelo (2003) suggest that modeling economies with a non-tradable component of investment "may be a better approach to generate plausible investment dynamics". My dataset indicates that near 50% of investment is nonresidential construction, which I classified as a non-tradable.

and

$$x_t^N = G^N(x_t^{NN}, x_t^{TN}) = x_t^{NN^{\omega_2}} x_t^{TN^{1-\omega_2}}, \tag{3.9}$$

where $0 < \omega_1 < 1$, $0 < \omega_2 < 1$, and where x^{ij} represents investment produced in sector i and used in sector j.

Third, the consumer satisfies his budget constraint,

$$c_t^T + x_t^{TT} + x_t^{TN} + p_t(c_t^N + x_t^{NT} + x_t^{NN}) \leq w_t^T h_t^T + w_t^N h_t^N + r_t^T k_t^T + r_t^N k_t^N, \tag{3.10}$$

where p, w and r are the price of the non-tradable good, the wage and the rental rate of capital, all in terms of the tradable good. While wages in both sectors will be equal in equilibrium as labor can be reallocated immediately between sectors, rental rates of capital can differ as both capitals are *not* the same good.

Firms

Each firm chooses capital and labor to maximize period-by-period profits

$$z_t^T F^T(k_t^T, n_t^T) - w_t^T n_t^T - r_t^T k_t^T, \tag{3.11}$$

and

$$p_t z_t^N F^N(k_t^N, n_t^N) - w_t^N n_t^N - r_t^N k_t^N, \tag{3.12}$$

where

$$z_t^i F^i(k^i, n^i) = y^i = z_t^i k^{i^{\theta^i}} n^{i^{1-\theta^i}}, \tag{3.13}$$

with $0 < \theta^i < 1$, $i = T, N$.

The technology process is driven by

$$z_{t+1} = b + Az_t + \epsilon_t, \tag{3.14}$$

where z is a two element vector, A is a matrix of 2 by 2, b is a vector of 2 by 1, the same as ϵ, the productivity shocks, which are normal *iid* with mean zero and variance Ω.

Equilibrium

A competitive equilibrium is (for every t)

1. a set of prices $(p_t, r_t^T, r_t^N, w_t^T, w_t^N)$,

2. an allocation $(k_t^{T^d}, n_t^T, y_t^T)$ for the typical firm T,

3. an allocation $(k_t^{N^d}, n_t^N, y_t^N)$ for the typical firm N,

4. and an allocation $(c_t^T, x_t^{TT}, x_t^{TN}, c_t^N, x_t^{NN}, x_t^{NT}, k_t^{T^s}, k_t^{N^s}, h_t^T, h_t^N)$ for the typical household, such that:

a. $(k_t^{T^d}, n_t^T, y_t^T)$ solves (3.11) at the stated prices;

b. $(k_t^{N^d}, n_t^N, y_t^N)$ solves (3.12) at the stated prices;

c. $(c_t^T, x_t^{TT}, x_t^{TN}, c_t^N, x_t^{NN}, x_t^{NT}, k_t^{T^s}, k_t^{N^s}, h_t^T, h_t^N)$ solves the household maximization subject to (3.5)-(3.10) at the stated prices;

d. all markets clear: $k_t^{T^d} = k_t^{T^s}, k_t^{N^d} = k_t^{N^s}, n_t^T = h_t^T, n_t^N = h_t^N, c_t^T + x_t^{TT} + x_t^{TN} = y_t^T, c_t^N + x_t^{NN} + x_t^{NT} = y_t^N$.

In order to obtain the policy functions, I am interested in a recursive equilibrium. I write down then the problem of the household in the following way[9]

$$\begin{aligned} V(z^T, z^N, K^T, K^N, k^T, k^N) &= \max U(c^T, c^N, l) + \\ &+ \beta E[V(z^{T'}, z^{N'}, K^{T'}, K^{N'}, k^{T'}, k^{N'}) \, | z^T, z^N, K^T, K^N, k^T, k^N] \end{aligned} \tag{3.15}$$

I can replace w^T, w^N, r^T and r^N in equation (3.10) with the first order conditions of the problems of the firms, and I can replace p with the first order condition of the problem of the household (all these conditions are evaluated in aggregate per capita variables)

$$c_t^T + x_t^{TT} + x_t^{TN} + \frac{U_2}{U_1}(c_t^N + x_t^{NT} + x_t^{NN}) \leq z^T F_2^T h_t^T + \frac{U_2}{U_1} z^N F_2^N h_t^N + z^T F_1^T k_t^T + \frac{U_2}{U_1} z^N F_1^N k_t^N \tag{3.16}$$

using

$$p = \frac{U_2}{U_1} = \frac{(1-a)}{a} \left(\frac{C^N}{C^T} \right)^{\eta - 1}. \tag{3.17}$$

To reduce the quantity of variables (looking forward to the computation) I do the following simplifications. First, I solve for l_t in (3.5) and replace it in (3.15).

[9] I denote with capital letters aggregate per capita variables and with small letters individual agents variables.

Then I replace (3.8) and (3.9) in (3.6) and (3.7) respectively. I solve for x^{NT} and x^{TN} and replace them in (3.10). Finally, I equate aggregate supply and demand for K^T, K^N, N^T, N^N and C^T, and solve the constraint (with equality) for c^T and replace it in the value function (3.15).

After these simplifications I count two exogenous state variables (z^T, z^N), two endogenous aggregate state variables (K^T, K^N), two endogenous individual state variables (k^T, k^N), and seven endogenous control variables $(x^{TT}, x^{NN}, h^T, h^N, k^{T\prime}, k^{N\prime}, c^N)$. Now I can define a recursive competitive equilibrium.

A recursive competitive equilibrium is

1. a value function $V\colon \mathbf{R}_+^{\mathbf{6}} \to \mathbf{R}_+$,

2. a policy function $h\colon \mathbf{R}_+^{\mathbf{6}} \to \mathbf{R}_+^{\mathbf{7}}$ for the representative household,

3. rules determining the aggregate per capita values of these variables, $H\colon \mathbf{R}_+^{\mathbf{4}} \to \mathbf{R}_+^{\mathbf{7}}$,

4. and price functions r^T, r^N, w^T, w^N and p ($\mathbf{R}_+^{\mathbf{4}} \to \mathbf{R}_+$) such that:

a. V satisfies the household recursive problem (with all constraints replaced in utility function);

b. h is the optimal policy function for this problem;

c. $h(z^T, z^N, K^T, K^N, K^T, K^N) = H(z^T, z^N, K^T, K^N)$;

d. r^T,r^N,w^T,w^N satisfy first order conditions of (3.11) and (3.12);

e. p satisfies (3.17).

3.4 Calibration and computation

I have 13 parameters to calibrate (ν, γ, β, α, σ, ω_1, ω_2, δ^T, δ^N, θ^T, θ^N, η and a) and 6 more to estimate with a VAR for the technology process. Table 3.2 presents the parameters calibrated and estimated.

First, I set ν to the actual average annual growth rate of population in the period 1960-2001 (1.38%) and γ to the actual average annual growth rate of output per capita in the same period (0.9%). Second, I set β, α and σ to be the same as in a one sector model, i.e., 0.889, 0.38 and 2 respectively.

Parameter	Value	Consideration
Preferences		
η	-1.5	González-Rozada and Neumeyer (2003)
a	0.12	equation (3.27)
β	0.89	equal to one sector model
α	0.38	equal to one sector model
σ	2	equal to one sector model
ν	0.0138	population average growth rate 1960-2001
Technology		
θ^T	0.43	equations (3.25) and (3.26)
θ^N	0.38	equations (3.25) and (3.26)
ω_1	0.62	equations (3.18) and (3.19)
ω_2	0.55	equations (3.18) and (3.19)
δ^T	0.056	equations (3.6) and (3.7)
δ^N	0.045	equations (3.6) and (3.7)
γ	0.009	income per capita average growth rate 1960-2001
a_{11}	0.79	VAR estimation
a_{22}	0.79	*idem*
$a_{12} = a_{21}$	0	*idem*
b_1	0.94	*idem*
b_2	0.91	*idem*
c^N superior good		
λ	0.89	equation (3.30)
a	0.16	equation (3.27)
Exogenous price		
a_{33}	0.79	VAR estimation
b_3	0.25	*idem*

Table 3.2: Parameter values

Third, I used series on machinery and transport equipment (tradable investment) and nonresidential construction (non-tradable investment) to calibrate ω_1, ω_2, δ^T, and δ^N. I obtained the share of construction in each sector by using data on construction permits (in square meters). I found that, on average, 75% of construction was assigned to the non-tradable sector and 25% to the tradable sector. I obtained the share of tradable investment in each sector by using data on sectoral destination of imports of machinery and transport equipment. I found that, on average, 60% of imported machinery was destined to the non-tradable sector and 40% to the tradable sector. I calculated ω_1 and ω_2 using these data and the following equations

$$\omega_1 = \frac{0.4x_T}{0.4x_T + 0.25x_N}, \tag{3.18}$$

and

$$\omega_2 = \frac{0.75x_N}{0.6x_T + 0.75x_N}, \tag{3.19}$$

where x_T and x_N are average values of machinery and construction respectively. I obtained values of 0.62 and 0.55 for ω_1 and ω_2, which indicates that the tradable sector is relatively intensive in tradable investment and the non-tradable sector is relatively intensive in non-tradable investment, though both sectors make use of a fair value of each type of investment. I used laws of motion (3.6) and (3.7) in steady state and the ratios $\frac{x^T}{k^T}$ (0.079) and $\frac{x^N}{k^N}$ (0.068) to obtain δ^T (0.056) and δ^N (0.045).

Fourth, I used the following first order conditions in steady state to calculate simultaneously the ratios $\frac{k^T}{n^T}, \frac{k^N}{n^N}, \frac{x^{TT}}{x^{NT}}, \frac{x^{NN}}{x^{TN}}$ (the subscript indicates partial derivative)

$$\beta(z^T F_1^T G_1^T + (1 - \delta^T)) = (1 + \nu)(1 + \gamma), \tag{3.20}$$

$$\beta(z^T F_1^T G_2^T + p(1 - \delta^T)) = p(1 + \nu)(1 + \gamma), \tag{3.21}$$

$$\beta(z^N F_1^N G_1^N + (1 - \delta^N)) = (1 + \nu)(1 + \gamma), \tag{3.22}$$

$$\beta(pz^N F_1^N G_2^N + (1 - \delta^N)) = (1 + \nu)(1 + \gamma), \tag{3.23}$$

and

$$p = \frac{z^T F_2^T}{z^N F_2^N}. \tag{3.24}$$

Fifth, I proceed in the following way to calibrate θ^T and θ^N. I imposed the income share of aggregate capital to be equal to 0.4, the value used in a one sector model.[10] The average shares of output of each sector are $\frac{y^T}{y} = 0.35$ and $\frac{y^N}{y} = 0.65$. I used then the first order condition (assuming that in steady state both types of capital have the same rental rate)

$$\frac{(1 - \theta^T)/\theta^T}{(1 - \theta^N)/\theta^N} = \frac{k^N/n^N}{k^T/n^T}, \tag{3.26}$$

[10] If the rental rates are equal across sectors, it would imply that

$$\theta = \frac{y^T}{y}\theta^T + \frac{y^N}{y}\theta^N = 0.4. \tag{3.25}$$

plugging in the capital-employment ratios obtained above, to attain θ^T and θ^N equal to 0.433 and 0.382 respectively. These values are reasonable. I can not calculate these parameters directly by computing the share of capital income in each sector because there are no income accounts in Argentina, but I calculate them directly for the United States and found that the share in each sector is around 0.3, similar to the aggregate capital income share.

González-Rozada and Neumeyer (2003) found econometrically a value of -1.5 for η, which implies an elasticity of substitution between tradables and non-tradables of 0.4. I used that value for η, a consumption ratio $\frac{c^N}{c^T}$ of 2.07, and the following first order condition

$$\frac{z^T F_2^T}{z^N F_2^N} = \frac{1-a}{a}\left(\frac{c^N}{c^T}\right)^{\eta-1} \tag{3.27}$$

to obtain a value for a of 0.121.

Table 3.2 also presents the estimated parameters of the stochastic process. The "spill-over" coefficients, those that determine the effect of productivity in one sector on the productivity in the other sector the following period, are very small and statistically insignificant, so I decided to set them to zero.

The computation procedure is the following.

1. Given the parameters calibrated and estimated, I compute decision rules for the centralized problem using the linear quadratic method as presented in, for example, Hansen and Prescott (1995).

2. I simulate paths for aggregate and sectoral capital, investment, labor, output and consumption. This is done by assuming that the economy was in steady state in 1986 (that is, setting capital and productivity levels in 1986 to their steady state values) and inputting the observed changes in productivity in the decision rules.

3. I calculate the simulated relative price of non-tradables using the shadow price, that is, the ratio between marginal utility of non-tradable consumption to marginal utility of tradable consumption (equation (3.17)).

3.5 Results

Figure 3.5 shows the simulated aggregate capital for the two-sector model. I include also the simulated path for the one-sector model (from figure 3.1). It shows that the new model still overestimates the capital stock in 2001 by near 15%. It certainly improves on the one sector model in the period between 1991 and 1994, when there were huge increases in productivity in the non-tradable sector but almost none in the tradable sector, but overestimates capital in the latter half of the decade.

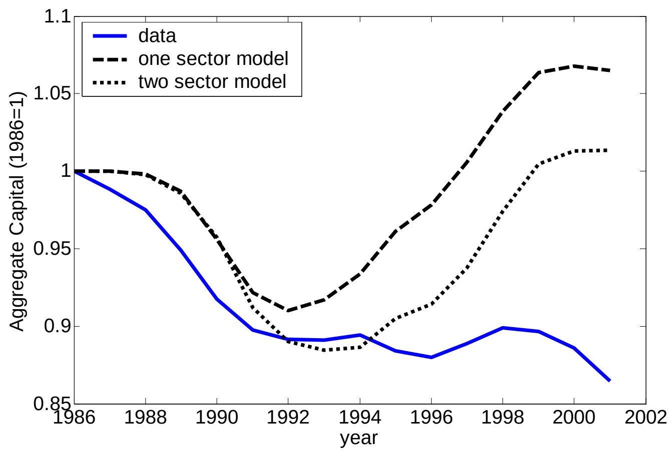


Figure 3.5: Comparison of model and data. Capital per capita (1986=1).

Figure 3.6 shows the sectoral capital paths. I observe that all of the overestimation of aggregate capital is due to overestimation of capital in the tradable sector (left panel), by 100% in 2001. In fact, capital in the non-tradable sector is slightly underestimated (right panel).

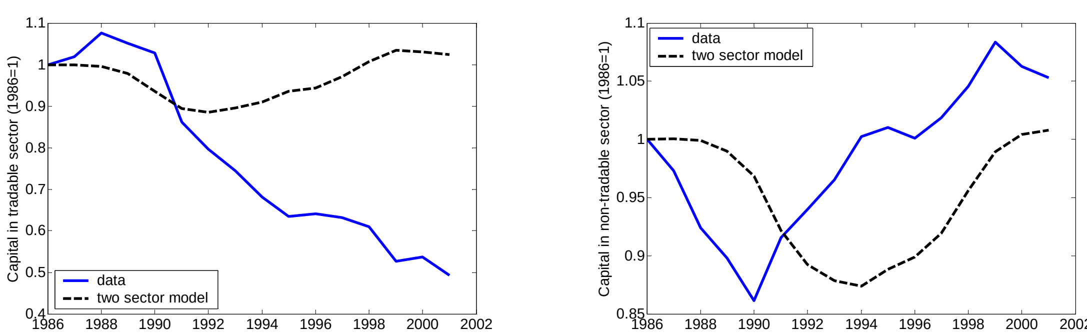


Figure 3.6: Comparison of model and data. Capital per capita (1986=1). Left panel: tradable sector. Right panel: non-tradable sector. Note that the right panel has a smaller scale than the left panel.

Figure 3.7 shows the simulated investment series. First, observe that the model series follows the direction of change of the data series quite well, though not the magnitudes: during the 90s both types of investment grew less than in the model. Second, observe that most of the underinvestment is in the construction type, the non-tradable investment. From figures 3.6 and 3.7 we conclude that the main component of investment that grew too little in Argentina in the 90s was construction in the tradable sector.

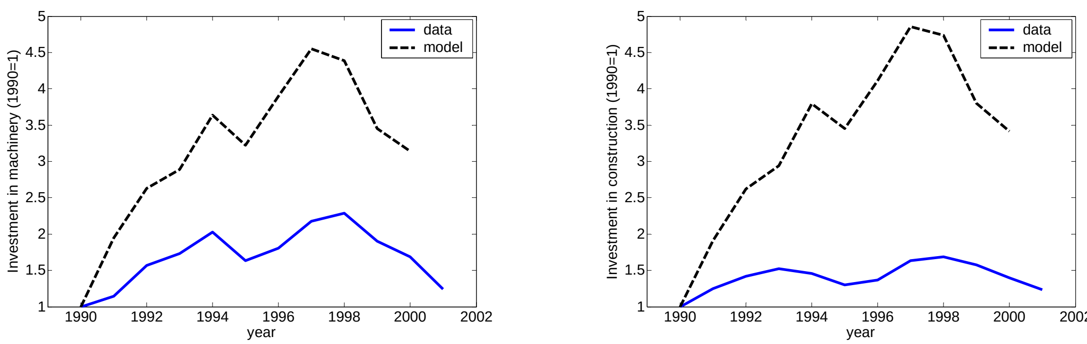


Figure 3.7: Comparison of model and data. Investment (1986=1). Left panel: machinery. Right panel: construction.

In terms of the possibilities I suggested in the introduction, I found the following. (i) Non-tradable output is less intensive in capital (relative to labor) than tradable output but the differences are small (recall that $\theta^N = 0.38$ and $\theta^T = 0.43$), and therefore this fact does not account for much of the overestimation of aggregate capital in a one-sector model. (ii) Investment in each sector is composed by a large share of both types of goods, tradable and non-tradable, and therefore it is not possible to close the gap between model and data through this channel. I will consider now the simulation of the relative price of non-tradables, which will possibly shed light on the "capital shallowing" anomaly.

The relative price puzzle

Figure 3.8 presents the simulated behavior of the relative price of non-tradables, calculated with equation (3.17): it moves in opposite direction to the data. The simulated behavior is determined mainly by the change in relative sectoral productivity. In the model, why does an increase in non-tradable productivity with respect to tradable productivity depreciate the relative price of non-tradables? We can gain some intuition about this relationship by working an impulse-response exercise: a 5% increase in the level of non-tradable productivity. The results are shown in figure 3.9. Supply of non-tradables will increase due to the increase of its productivity. This will induce the increase of the demand of the two types of investment. With no change in price, there will be an excess supply of non-tradables and an excess demand of tradables. Therefore, the price of non-tradables to tradables will have to diminish to clear markets.

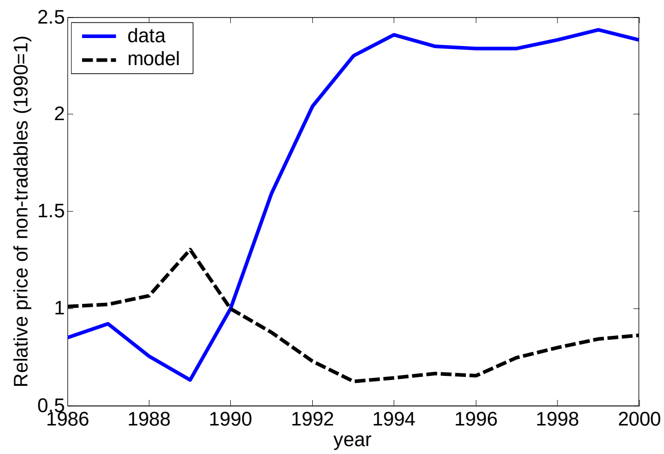


Figure 3.8: Comparison of model and data. The relative price of non-tradables (1990=1).

In Argentina in the 90s, the opposite to the impulse-response exercise happened. In the period 1990-1994 the relative productivity of non-tradable increased drastically but the price of non-tradables increased drastically too! In the period 1996-2001, by contrast, the productivity of the non-tradable sector lost gradually some terrain, and the price of non-tradables remained roughly constant.

In a general exercise in business cycles analysis, Stockman and Tesar (1995) found that the correlation between relative consumption $\frac{c^N}{c^T}$ and relative prices $\frac{p^N}{p^T}$ was -1 in their model and between 0.39 (Japan) and -0.86 (US) in the data, which they consider an anomaly. In the present exercise the striking result is that the correlation in the model is -1 while the correlation in the data is 0.91!

Given the difference between the observed and the simulated relative price of non-tradables, we can measure the misalignment by computing

$$\tau = \frac{p^o}{p^s} - 1, \tag{3.28}$$

where p^o is the observed price, p^s is the simulated price, and τ is the misaligment. I assumed that in 1990 the observed price was the equilibrium price; that is, I set

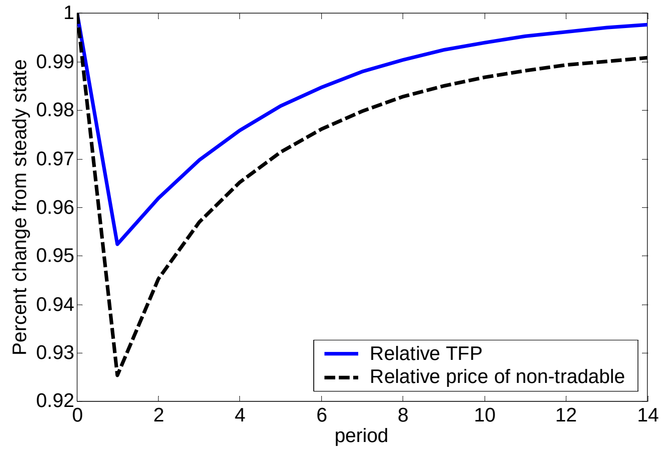


Figure 3.9: Two sector model. Response to a 5% increase in the non-tradable sector productivity. Relative TFP is the ratio of the tradable to the non-tradable sector productivity.

$\tau_{1990} = 0$. According to figure 3.10, overvaluation was very high, up to 250%, in the years following the launch of the convertibility plan in 1991 and declined gradually from 1993 onwards.

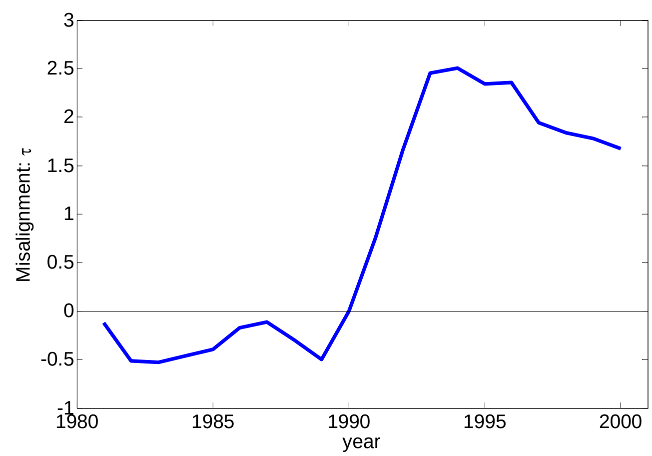


Figure 3.10: Misalignment of the relative price of non-tradables (τ), as defined in the text (1990=0).

The income effect story

The appreciation of the relative price of non-tradables in the early years of the decade came along with an increase in income. It has been noticed that tradable and non-tradable desired consumption change differently with income growth. An increase in income will increase the share of non-tradable consumption in total consumption. In other words, c^N is a superior good. This fact, other things equal, will increase the price of non-tradables as a response to an increase in income, which can lead to the argument that the appreciation of the relative price of non-tradables was due to the increase in income, *despite* the increase in the relative productivity of non-tradables.

To test this hypothesis, I postulate a new momentary utility function with non-homothetic preferences

$$U(c^T, c^N, l) = [(a{c^T}^{\eta} + (1-a){c^N}^{\eta+\lambda})^{\alpha/\eta} l^{1-\alpha}]^{1-\sigma}/(1-\sigma), \tag{3.29}$$

where λ measures the degree of nonhomotheticity. I calibrate λ in the following way. I calculated different output per capita annual growth rates in each sector, γ^T and γ^N (1.4% and 5.5% respectively for the 90s). For the utility to be stationary given these rates, I have to detrend tradable and non-tradable consumption by their respective growth rates, *and* λ must be such that

$$(1+\gamma^T)^{\eta} = (1+\gamma^N)^{\eta+\lambda} \tag{3.30}$$

which implies a value of λ equal to 0.89.[11] I adjust accordingly the value of a to 0.16.

Now I get the path for the equilibrium price by using equation (3.17) modified

$$p = \frac{(1-a)}{a} \frac{(\eta+\lambda)}{\eta} \frac{{c^N}^{\eta+\lambda-1}}{{c^T}^{\eta-1}}, \tag{3.31}$$

and plugging in actual data on consumption.

I show the result in figure 3.11: the relative price of non-tradables should still have depreciated, though, reasonably, less than with homotheticity. Thus, we can not attribute the appreciation of the relative price of non-tradables to the combination of growing income and the superior character of non-tradable goods.

This exercise also clarifies the puzzle: even if the model can precisely replicate the consumption profiles, it will badly miss the price. In other words, we need a model where equation (3.17), or (3.31), is broken down, and the price of the non-tradable good increases *despite* the increase in its relative productivity and consumption.

[11] González-Rozada and Neumeyer (2003) obtained a value near 1.4 for this parameter. The results are similar using this alternative value.

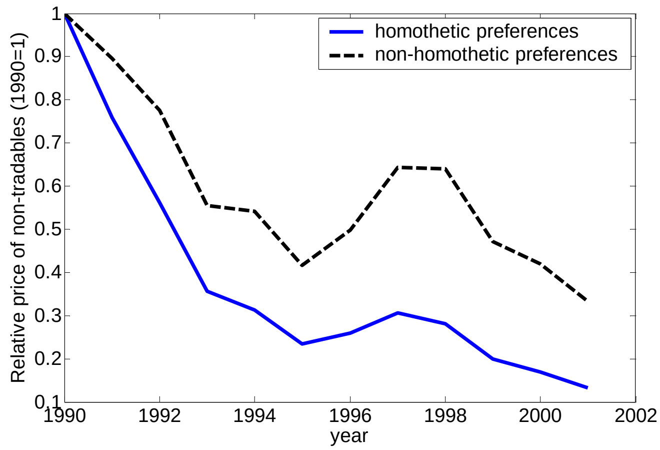


Figure 3.11: Effects of non-homotheticity of preferences on the equilibrium relative price of non-tradables, calculated inputting actual consumption on equations 3.17 and 3.31 respectively.

Open economy

How well these results would hold if we were considering a small open economy model? First, note that, as KZ(2002b) contend, the overestimation of physical capital would have been even higher in an open economy model (at least for the period between 1991 and 1996). As productivity increased drastically in the non-tradable sector (and in the aggregate), capital should have flowed into the country. Second, what would have been the effects on the relative price of non-tradables? An increase in non-tradable productivity coupled with a stronger increase in capital in the non-tradable sector would have depreciated even more the relative price of non-tradables (relative to the closed economy model, see equation (3.24)). The conclusion is that the misalignment would be even more severe in an open economy model.

Another way of concluding that the prediction of an open economy model with respect to the relative price of non-tradables would not be very different from the close economy model presented here is the following. Argentina is a relatively close economy. The openness share (the ratio of imports plus exports over output) during all the period considered was around 20%, somewhat similar to the United States during the same period. Under reasonable parameters, changes in quantities of net exports can not influence prices by much. To see this, consider equation (3.17) which will hold also in an open economy if we consider c^T to include net imports. As net imports are such a small share of total consumption, it is clear that the prediction for the price, given *observed* consumption, would be very similar to the close economy case. I conclude therefore that opening the model economy would not diminish the two anomalies. It may worsen them.

Price floor

The essential puzzle is now clear: from the production side, how can there have been an *increase* in the relative productivity of non-tradables with an *increase* in the relative price of non-tradables? From the consumption side, how can there have been an *increase* in the relative consumption of non-tradables with an *increase* in its relative price? By all logic, the relative price should have evolved in the opposite direction.

One way out of this "conundrum" is to consider that the relative price was not at its free-market equilibrium level, because the government was intervening in the markets for goods, by setting a price floor for the relative price of non-tradables, buying the excess supply of non-tradable goods, and supplying the excess demand of tradables.

In what follows I will consider the following experiment. First, assume that each period the government was setting the relative price of non-tradables at the observed price. Second, assume that each period the government was buying the excess supply of non-tradables. Third, assume that the government was buying tradables outside the country and selling them inside the country to cover the excess demand of tradables. Fourth, assume that the government did not have a financing constraint: it could always borrow abroad to pay for these transactions; and that individuals in the economy assume it too. Given these assumptions, I ask the question: taking as exogenous the observed relative price and the sectoral productivity, can the model replicate better the sectoral and aggregate capital time series?

I want to compute a model with the relative price of non-tradable good fixed exogenously. One problem is that with a fixed price the previous model is overdetermined. To see this, observe that the five equations (3.20) to (3.24) are defined on five unknowns, the ratios $\frac{k^T}{n^T}$, $\frac{k^N}{n^N}$, $\frac{x^{TT}}{x^{NT}}$, $\frac{x^{NN}}{x^{TN}}$, and p. If I make p exogenous, I will have five equations in four unknowns. I decided then to simplify the model by fixing the labor supply: the labor-leisure decision and the decision to switch labor between sectors are eliminated (equation 3.24 does not need to hold anymore). For the purpose of our exercise this is an innocuous decision: after solving this simplified model with fixed labor and flexible relative price, both the aggregate capital and the relative price anomalies persist (see figure 3.12). Consequently I fix the labor inputs to their steady state values, $n^N = 0.21$ in the non-tradable sector, and $n^T = 0.09$ in the tradable sector.

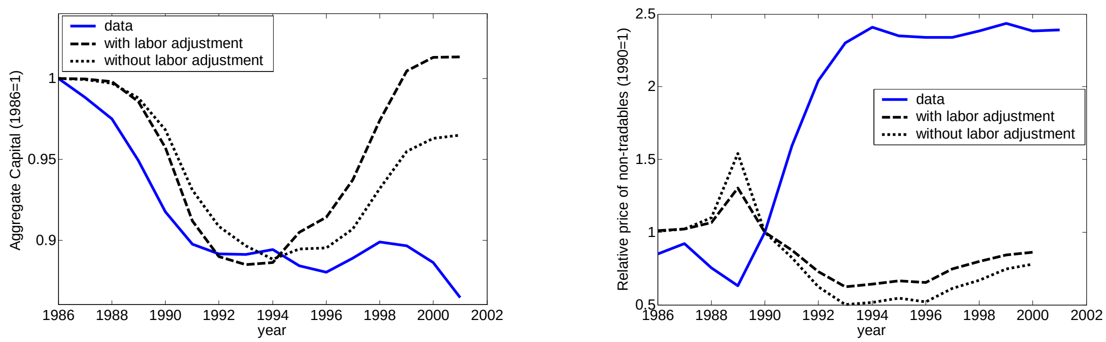


Figure 3.12: Model with fix labor supply. Left panel: capital per capita (1986=1). Right panel: relative price of non-tradables (1990=1).

Computationally, the only essential difference with the previous simulation is that I estimate a stochastic process for the relative price of non-tradables, and include this price as a third exogenous state variable in the *decentralized* version of the benchmark model. The coefficient of the first order autoregressive process for the price is 0.79. The results are presented in figure 3.13. As expected, there is a decrease of the capital in the tradable sector (top left panel), at least for the period of strong appreciation of the relative price, and a strong increase of the capital in the non-tradable sector (top right panel).[12] The aggregate capital is still overestimated (bottom panel). In fact, more than ever. This is due, of course, to the overestimation of capital in the non-tradable sector. And this, in turn, is due to the "high profitability" of the non-tradable sector when its price is fixed too high. An increase in the relative price of non-tradables increases the incentive to invest in that sector, and therefore, under the present calibration, increases aggregate capital *even more* than a model without government intervention.

The effect of a fix exogenous price on the individuals' decisions with respect to investment and consumption is too strong. I consider however that a model with an explicit government sector fixing the relative price of non-tradables, might account better for the time series involved. In particular, as fixing a real price implies a periodical cost for the government (it has to buy the excess supply of non-tradables each period), agents might forecast that the policy of a high relative price is not sustainable, predict wild fluctuations in the price, and therefore not invest as much as they would under

[12]The decrease of the simulated capital in the tradable sector would have been bigger if not for the zero constraint on investment. In fact, I obtained that for the period between 1990 and 1994 there was no investment in the tradable sector. Firms in this sector just let their capital depreciate.

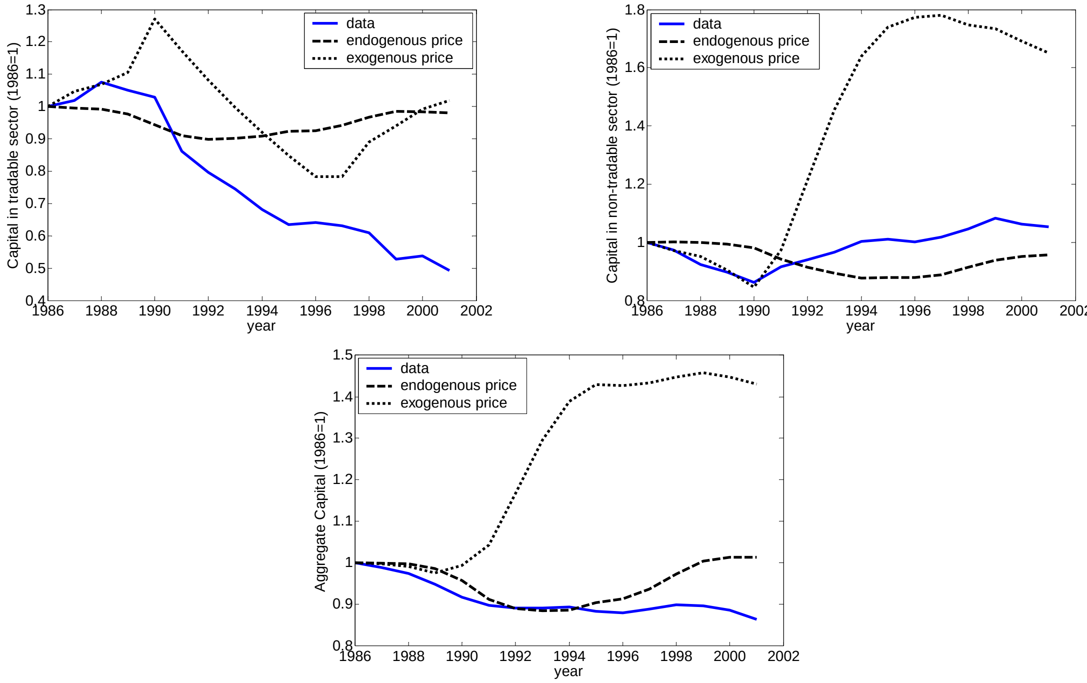


Figure 3.13: The effects of an exogenous relative price of non-tradables. Capital per capita (1986=1). Fix labor supply. Top left panel: tradable sector. Top right panel: non-tradable sector. Bottom: aggregate.

stable conditions. I leave the full development of this possibility for further research. That investigation should include an understanding of both, the government objectives that led to fixing a high relative price of non-tradables, and the instruments used. With respect to the former, I will say that, in a first instance, it could be related to the inflation stabilization policies of the early 90s, and later to a policy of distribution of income between tradable and non-tradable factors of production. With respect to the latter, I consider that the instrument used was a combination of a monetary policy that fixed the price of tradables (by pegging the nominal exchange rate) with a fiscal policy that increased spending on non-tradables (mainly state workers) financed with debt. I would like to mention that this scenario is consistent with the main macroeconomic facts of Argentina in the 90s: fiscal deficit, current account deficit, increase in debt, fix nominal exchange rate, and high wages in the public sector. This scenario is also consistent with the fact that when lending to the government dried out in the early 2000s, the government was not able to maintain the relative price high, and therefore it dropped, as can be seen in the last observation of figure 3.2. It kept falling in the following years.

3.6 Concluding comments

In this paper I have studied the macro-economic case of Argentina in the 90s. Given the disparity in the performance of the tradable and non-tradable sectors, I disaggregate the economy into those two sectors. I found the following results.

1. There was huge disparity in total factor productivity in each sector. The non-tradable sector accounts for all of the gains in aggregate productivity in the decade. The tradable sector presented slight decreases in productivity.

2. There was a large concomitant increase in the relative price of non-tradables, early in the decade. From the perspective of the model, this increase is inconsistent with the productivity changes mentioned in 1.

3. The two-sector model can not solve the anomaly uncovered by KZ(2002b), in which aggregate capital is underestimated, but it can close the gap some 5%. The model also identifies that underinvestment was mainly in the tradable sector, and in the non-tradable component (that is, construction).

4. The calibrated model highlights the importance of considering investment as a composite of tradable (machinery) and non-tradable goods (construction).

5. The relative price anomaly (point 2) is not solved by considering non-tradable consumption as a superior good (non-homothetic preferences).

6. Both anomalies would be larger if we had considered an open economy model.

In the last subsection I showed that many aspects of Argentina's experience in the 90s are consistent with the government fixing the relative price of non-tradables at a higher value than the equilibrium level. This hypothesis should be tested by constructing a model with an explicit government.

Finally, I consider that it is also important to address the causes of the extraordinary changes (by international standards) in measured productivity at the sectoral level, which is taken as exogenous throughout this paper.

3.A Appendix

3.A.1 Data sources and procedures

I thank Carlos Zarazaga for generously providing KZ(2002b) dataset, to Oscar Meloni for referencing me to the MN(2001) dataset, and Beatriz Anchorena and Ezequiel Caviglia for helping in the collection of additional data.
The main dataset is the one constructed by Maia and Nicholson (MN(2001)). It can be retrieved from http://www.mecon.gov.ar/peconomica/ basehome/evolucion_productividad.html.
The MN dataset contains aggregate data on output, labor, investment and capital from 1960 to 2001. It also contains the investment disaggregated into machinery and construction. The series of machinery that I used includes national and imported machinery. The series of construction that I used excludes residential construction, consistent with the capital series, that does not include residential capital, and with KZ(2001) series.
I used series of shares of tradable and nontradable to disaggregate GDP, labor and capital. For GDP, between 1965 and 2001, I used the shares informed in Worldbank Development Indicators: I sum the shares of agriculture and manufacturing for tradable share and consider the rest nontradable. For labor, between 1960 and 1991, I used data in the Censuses of Argentina for 1960, 1970 and 1991. Again, I calculate the share of tradable employment by summing the employment in agriculture, mining and manufacturing and dividing by total employment. I interpolate the values of these shares between censuses to obtain annual shares. Between 1994 and 2001, I used data of employment by sector informed by the AFIP through the Ministry of Economy (http://www.mecon.gov.ar/peconomica/basehome/infoeco.html). Again, I interpolated for years 1992 and 1993. For capital, I used data on electrical energy between 1976 and 2001 obtained by private email from the Secretary of Energy (http://energia.mecon.gov.ar). The total energy data is disaggregated into energy for "commerce" and energy for "industry". I used that data to calculate shares identifying "industry" with tradable sector and "commerce" with nontradable. I thank Ana Maria Duco of the Secretary of Energy for providing this information.
I calculate the data on consumption (used in the "income effect story section") by substracting investment from output in each sector. I obtained the data on the price of nontradables goods in terms of tradables between 1981 and 2002 from ECLAC, Buenos Aires (http://www.eclac.cl/argentina/noticias/paginas/9/9839/Cuadro13.xls). I obtained data on construction permits by sector at INDEC (http://www.indec.mecon.ar), section Industry and Construction. I obtained data on imported machinery by sector from Ministry of Economy (http://www.mecon.gov.ar).
I obtained data for US from the following sources. Total and sectoral GDP and labor from the Bureau of Economic Analysis as well as total capital. Electricity shares were obtained from the Energy Information Administration (http://www.eia.doe.gov/ fuelelectric.html).

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