# Social Capital, R&D, and Economic Performance: Theory and Evidence on Different Growth Models

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**Abstract**

Social capital, in particular levels of interpersonal trust, is known to be associated with different levels of economic performance. More recently, evidence appeared that the increase in economic performance due to higher levels trust is a causal effect. However, the mechanism through which this occurs is still unclear. This paper gauges the effect of trust on economic performance through research and development. I build a baseline model of endogenous growth that allows in its particular cases for different relationships between interpersonal trust, human capital employed in the R&D sector, and economic growth. Then, I test these results by exploiting the exogenous variation in culture caused by differences in past literacy rates and institutions within European countries. Social capital is found to have a positive and sizable causal effect on innovation output (patent applications), but not on human capital in the R&D sector. Given the theories presented, this is interpreted as evidence in favor of lab-equipment models of endogenous growth.

**Keywords:** social capital, interpersonal trust, economic growth, endogenous growth.

**JEL Codes:** A13, O30, O41, O47, Z13.

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# 1 Introduction

Culture does affect economic performance. Since the 1990s, numerous studies have shown that broad measures of cultural traits and social values, social capital as economists call them, are associated with the economic outcomes of individuals, firms, and countries. More recently, some of these effects were shown to be more than simple correlations. Differences in culture *cause* differences in economic performance, especially when measured by GDP per capita and GDP per capita growth. Nevertheless, the exact mechanisms that drive these differences are not clear yet. This paper contributes to this topic by tackling these mechanisms. In sum, it tries to answer *how* does culture affect economic performance?

In particular, this paper investigates the effects of social capital on economic performance through research and development, first theoretically and then empirically. Since Solow (1956), technological progress is known to be the main factor that sustains economic growth in the long run. The literature on endogenous growth attempts to better understand this phenomenon by explicitly modeling the R&D sector, the sector that generates technological progress. Therefore, it seems reasonable verify whether social capital affects economic performance through its effects in the R&D sector, if there are any.

Naturally, such an explanation does not prevent social capital from causing differences in economic outcomes through different mechanisms, such as the organization of firms economy-wide. However, determining the R&D effects of culture are a first step in gauging how big they are relative to the effects on other sectors and, if no effects are found, are evidence that economists should look elsewhere for the effects of culture on economic outcomes. Moreover, as will be seen, such an exercise may shed light on the adherence of different growth models on data.

The main finding of the paper is that culture does have an impact on research and development. For European regions, narrow measures of cultural traits (interpersonal trust) as well as broader measures (the first principal component of several cultural variables) have a positive and economically sizable effect on R&D output, as measured by the number of patent applications to the European Patent Office (EPO) per million inhabitants in the active population. On average, a one standard-deviation increase in the share of the population that believes that most people can be trusted increases patent applications by 210 per million inhabitants, which amounts to the average number of patent applications across regions. However, social capital is unrelated with inputs employed by the research and development sector, as measured the number of scientists and engineers as a percentage of the active population. From a theoretical standpoint, this is evidence in favor of lab-equipment specifications of endogenous growth models.

This theoretical interpretation of the data analyzed comes from incorporating social capital into an endogenous growth model. To achieve this, I first build a model of individual civility choices, firm production decision choices, and societal economic regulation choices. Individuals can choose to be civic (trusting) or not, and also to employ a decentralized or centralized production technology. Decentralized production increases the marginal productivity of individuals, but due to a negative externality, this only occurs at high levels of civility. Then, given the potential externality, society chooses whether or not to regulate the use of the decentralized production organization. In equilibrium, individuals are either civic and exhibit high marginal productivities, or individuals are uncivic and exhibit low marginal productivities.

Given this civic equilibrium, I augment a baseline endogenous growth model by allowing the marginal productivity the results from different levels of civility to augment inputs (human capital and labor) throughout the economy. In a specification close to the one in Romer (1990), higher levels of trust are associated with faster output growth and technological progress, as well as a higher allocation of human capital on the R&D sector. In a lab-equipment specification of the model, the effects of civility are restricted to output growth and technological progress, and not the human capital allocation. These are the two different predictions that the empirics of the paper test.

The empirics are based on the work of Tabellini (2010), that establishes a causal effect of culture on economic performance, mainly GDP per capita in European regions. Since culture is endogenous to the process of economic development, an exogenous source of variation in culture is necessary. Moreover, the endogeneity of culture implies that variables that affect economic development also affect culture. One of such variables is the quality of early institutions, as in Acemoglu et al. (2001). But how to distinguish the effect of these early institutions on present institutions from the effect on present culture?

European history, sprovided some conditions are verified, make such distinction. Formal institutions have been constant in European countries for at least the past 150 years. However, there is political variation *within* these countries. Then, by controlling for country fixed effects, the effect of early institutions on present institutions is removed, remaining only the effect on culture. Naturally, for this strategy to work, variation within countries is needed, and this is what motives an analysis on the regional level. Concretely, I use the quality of early institutions (1600 -1850) and literacy rates in circa 1880 as instrumental variables for culture, and then estimate the causal effects of culture on innovation.

The research presented here has connections with many strands of the literature. The first one is the literature on the economic effects of social capital. A first contribution is Putnam et al. (1994), that establishes how the different histories of northern and southern Italy had effects on culture and economic outcomes. This idea, however, can be traced back to the seminal work of Banfield (1958). In economics, La Porta et al. (1997) and Knack and Keefer (1997) started a series of empirical papers on the topic, in particular papers that use the interpersonal trust variable in the World Values Survey and related datasets as a measure of cultural traits. The focus on interpersonal trust is studied in an experimental setting in Glaeser et al. (2000). In this general topic, Guiso et al. (2006) provides an interesting review.

More recently, however, empirical work has been done to establish whether or not culture has a causal effect on economic outcomes. Besides Tabellini (2010), cited above, Algan and Cahuc (2010) and Guiso et al. (2016) try to establish such results. The first paper controls for country-fixed effects with a first-difference estimation strategy. This strategy, however, requires measured of trust that are sufficiently lagged. These are obtained by using the trust that the descendants of immigrants to the United States inherited. In such a setting, trust is causally associated with higher GDP per capita. Guiso et al. (2016), using exogenous variations on the history of Italian cities, on the other hand, establish that historical shocks have persistent effects on culture.

This paper also connects to a literature that studies the effects of trust on firm organization. Bloom et al. (2012), using data on interviews with managers, shows that in high trusting environments, firms are more likely to decentralize production and achieve bigger sizes, echoing the effects of trust on the size of organizations studied by La Porta et al. (1997). Finally, Cingano and Pinotti

(2016) shows how trust affects the organization of firms and how it has consequences for the pattern of comparative advantages.

Another field related to the research presented here is the microeconomics of cultural transmission and its consequences. Bisin and Verdier (2001) presents a survey on the theoretical and empirical literature on transmission, whereas Bisin and Verdier (1998) provides a first model on the transmission of culture and preferences. Bénabou and Tirole (2006) studies how beliefs evolve over time in a manner similar to cultural traits. Regarding the interplay between trust and institutions, Aghion et al. (2010) study how trust and regulation are connected, while Carlin et al. (2009) argue that trust and regulation are substitutes in financial markets.

Finally, this paper contributes to the literature on endogenous growth theory. On the theoretical side, it expands the work of Romer (1990) and Rivera-Batiz and Romer (1991). On the empirical side, it serves as a test for competing endogenous growth models and, in general, for endogenous growth theory, like Jones (1995) and Bloom et al. (2017).

Following this introduction, the next section presents theoretical results that include social capital in an economic growth framework, generating two different predictions. The following section, tests these predictions empirically. Finally, a conclusion summarizes the main results, discussing their shortcomings, and presenting perspectives for new research.

## 2 Theory

To analyze the effects of social capital on the research and development sector and economic performance, I present a theory of economic growth in which the level of social capital has consequences to the rate of technological progress and, thus, output and consumption growth. The model consists of two parts: a model in which civility decisions, i.e. whether or not to be trusting, are taken together with decisions on firm organization and economic regulation, and a model of economic growth with endogenous technological change.

In the first part of the model, I use the interplay between distrust and regulation to study the choice of individuals to behave or not in a civic, i.e. trusting, way and how these choices affect production decisions. In general, two types of equilibria arise. In the first, good, equilibrium, high levels of trust are be associated with low regulation and, thus, inputs are more productive, since they benefit from decentralized production. In the second, bad equilibrium, low levels of trust lead to high regulation, which prevents the economy to reap the benefits of decentralized production. The original idea for this part is from Aghion et al. (2010).

The economic growth part of the model is an adaptation of Romer (1990). This is due to the fact that since the main purpose here is to study how interpersonal trust affects economic performance through research and development. Endogenous growth models treat the R&D sector explicitly, and so are a suitable choice for this part. The model, in addition, is modified to allow for the level of interpersonal trust to affect the productivity of human capital both in the R&D sector and the final goods sector. This feature is simply a macroeconomic consequence of the first part of the model.

In addition, the growth model is built to allow for different specifications. A first specification is a baseline model. This baseline model is used to derive a balanced growth equilibrium and to later develop two different specifications of the model. The first one can be understood as an extension of Romer (1990). However, the second one modifies the main assumption of the model regarding the evolution of the stock of knowledge in the economy to obtain different results. This modification is based on the lab-equipment model first presented in Rivera-Batiz and Romer (1991). These different specifications are important because they allow for different relationships between social capital, human capital employed in the R&D sector, and improvements in knowledge to arise. These different relationships are then taken to the data and tested in setion 3

As a basic setup, consider an economy populated by a continuum of mass 1 of individuals, living in a continuous-time environment. Suppose that each individual chooses to behave in a trusting (civic) or untrusting (uncivic) way. In the aggregate, then, let $\theta$ denote the share of trusting individuals. Finally, to organize the notation, let upper-case letters denote aggregate variables and lower-case letters denote individual choices.

## 2.1 Trust, Regulation, and Decentralization Choices

I start by describing the interplay between civility choices, the organization of production, and regulatory decisions, in a simple extension of the model in Aghion et al. (2010). As described above, the starting point is an economy populated by a continuum of mass 1 of individuals. At every moment, individuals have a choice between behaving in a civic, trusting way and behaving in a uncivic, untrusting way. They are, at any given instant, risk neutral, and also have a choice regarding how to organize production. In particular, production can happen in a centralized or a decentralized way.

Consider then the choice between producing in a centralized or in a decentralized way. Bloom et al. (2012) build a model in which greater levels of social capital, i.e., trust, lead to greater decentralization and greater productivity. Their argument, which builds upon Garicano (2000), is that in every period, a firm employee draws a problem with random difficulty of solution. A given problem is solved if its random difficulty is below the worker's skill. Otherwise, the worker directs the problem to be solved at the managerial level, incurring a communication cost in terms of the time of managers. Production occurs if all problems are solved. Trust is introduced in this context as a probability that managers attach to the workers behaving in a correct way. In contexts of higher trust, managers are able to oversee more workers and, thus, productivity is higher.

In the model that I present here, I assume that firms have a choice between producing in a centralized or decentralized way. In production is centralized, productivity is at a constant level regardless of civic choices. If production is decentralized, productivity increases, possibly due to an argument similar to the one described in the previous paragraph. However, decentralized production in contexts of low trust generate an externality, possibly motivated by managers spending more time supervising production when trust is low. This externality generate the possibility of regulation.

To formalize these ideas, first recall that $\theta$ denotes the share of individuals who choose to behave civically. Then, let $\delta$ denote a baseline level of productivity. This level is invariant in the share of trusting individuals $\theta$ and is the productivity level that firms attain when production is centralized.

If production is decentralized, productivity increases. In particular, it becomes $\delta + \gamma + \iota$ if the individual is civic, and $\delta + \gamma$ if the individual is uncivic. Here, $\gamma$ is a random variable uniformly distributed on the interval $[0, 1]$. Also, $\iota$ is taken to be small, so as to serve only to break ties. It captures a small increase in productivity that happens when individuals behave in a civic way. However, as described above, uncivic individuals producing in a decentralized manner also generate a negative externality. Let $e$ denote this externality, and assume that $e > 1$ for every individual.

The timing of events is as follows:

1. Individuals choose whether or not to behave civically. This choice is costless. Following that, they choose to produce in the centralized or decentralized way.

2. Society decides whether or not to regulate production. This choice is made in such a way that social welfare, given by productivity, is maximized. If regulation is chosen, officials can either allow or ban decentralized production. They cannot, however, observe $\gamma$ or civility choices. Officials here are the same individuals that produce, "working at night".

3. Production occurs. Civic officials, due to the possibility of externalities, always ban decentralized production. Uncivic officials, however, may ask for a bribe to authorize decentralized production regardless of civicness. Civic producers always refuse to pay bribes, but uncivic ones may pay it it is worthy. Whenever decentralized production is banned, productivity reverts to the baseline $\delta$.

Given this context, an equilibrium can be defined as follows.

**Definition 1.** An **equilibrium** is a share of civic individuals $\theta$, the corresponding choice to regulate or not production, and the resulting productivity levels.

Solving the model by backwards induction, suppose that regulation is chosen and start by considering the choice of how big of a bribe to ask. Uncivic individuals will choose a bribe that maximizes the rent extracted, which has three components. The first one is the bribe itself, denoted by $b$. However, producers only pay the bribe if it the payoff from decentralized production relative to the baseline $\delta + \gamma - \delta = \gamma$ is greater than the bribe. Finally, only uncivic individuals, represented by the share $1 - \theta$ may pay the bribe. Then, unicivic officials set $b$ to maximize

$$bProb(\gamma \geqslant b)(1-\theta) = b(1-b)(1-\theta), \tag{1}$$

which is maximized at $b = 1/2$.

Given the bribe, consider now the decision whether or not to regulate decentralized production. First, notice that if there is no regulation, all individuals choose decentralized production, and the expected productivity is given by

$$
\begin{aligned}
a(\theta) &= \mathbb{E}[\theta(\delta+\gamma+\iota)+(1-\theta)(\delta+\gamma-e)] \\
&= \delta+\frac{1}{2}+\theta\iota-(1-\theta)e.
\end{aligned} \tag{2}
$$

On the other hand, if there is regulation, output will be given by the baseline $\delta$ whenever civic producers meet civic officials, which happens with a probability $\theta^2$, civic producers meet uncivic officials, which happens with probability $\theta(1-\theta)$, or uncivic producers meet civic officials, which happens with probability $(1-\theta)\theta$. If uncivic individuals meet uncivic individuals, which happens with probability $(1-\theta)^2$, the bribe is paid if $\gamma > b$, and productivity is $\delta+\gamma-e$ due to decentralized production, and is unpaid otherwise with the associated productivity at the baseline level. Then, the expected productivity with regulation is

$$
\begin{aligned}
r(\theta) &= [\theta^2+\theta(1-\theta)+(1-\theta)\theta]\delta+(1-\theta)^2[Prob(\gamma<1/2)\delta+Prob(\gamma\geqslant 1/2)(\delta+\gamma-e)] \\
&= \delta+(1-\theta)^2\int_{1/2}^{1}(y-e)\mathrm{d}y \\
&= \delta+\frac{(1-\theta)^2}{2}\left(\frac{3}{4}-e\right).
\end{aligned} \tag{3}
$$

In order to rule out negative levels of productivity, assume that $\delta > e-1/2$. The intuition for this can be seen in figure 1, which shows how the expected productivities for different shares of civic individuals $\theta$ compare under regulation and no regulation. It also motivates the following result.

**Proposition 1.** *There exists a threshold share of civic individuals $\theta^*$, such that if $\theta > \theta^*$, $a(\theta) > r(\theta)$ and there is no regulation, and that if $\theta \leqslant \theta^*$, $a(\theta) \leqslant r(\theta)$ and there is regulation.*

**Proof:** See Appendix A. $\square$

Finally, to complete the model, it remains to determine civility choices. At the first stage, the expected payoff of a civic individual is given by

$$
\begin{aligned}
\delta+\frac{1}{2}+\iota+(1-\theta)e &\quad \text{if there is no regulation} \\
\delta-(1-\theta)^2\frac{e}{2} &\quad \text{if there is regulation.}
\end{aligned}
$$

The top expression is given by the expected productivity of a civic individual engaged in decentralized production, $\delta+1/2+\iota$, together with externality losses $(1-\theta)e$, since the lack of regulation

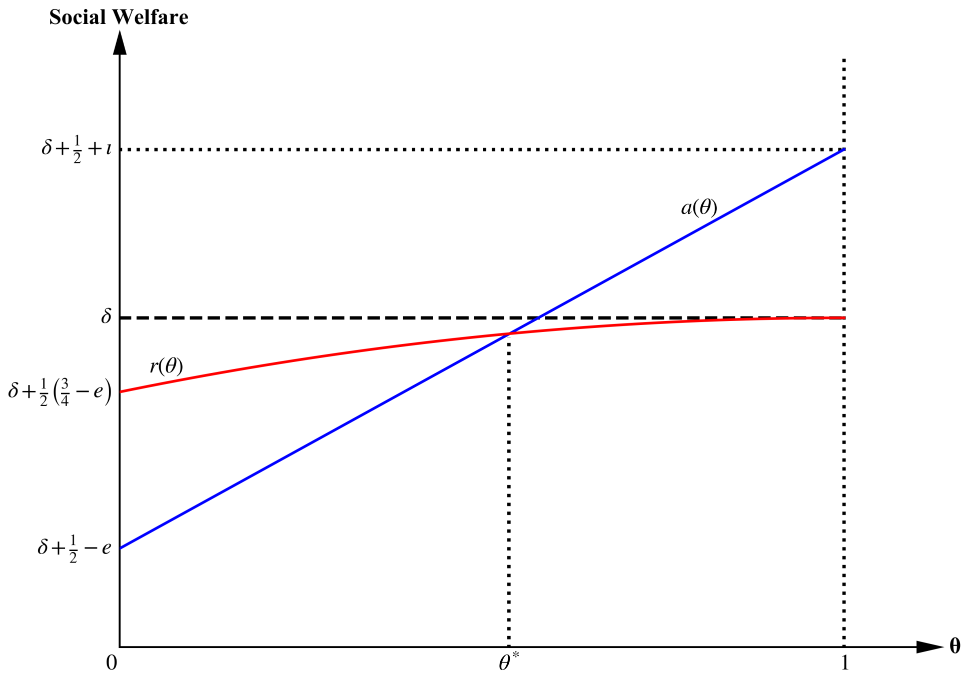


Figure 1: The Threshold Value of $\theta^*$ below which Regulation is Welfare Optimal

implies that uncivic individuals are also engaged in decentralized production. The bottom expression comes from the fact that with regulation, civic individuals engage in centralized production, achieving a productivity $\delta$, but a fraction $(1-\theta)^2$ of individuals are uncivic producers matched with uncivic officials, and with a probability of $1/2$, end up finding that the bribe is profitable and exerting the externality $e$.

Similarly, for uncivic individuals, expected payoffs are

$$\begin{aligned} \delta + \frac{1}{2} + (1-\theta)e & \quad \text{if there is no regulation} \\ \delta + \frac{1}{8}(1-\theta) + \frac{1}{4}(1-\theta) - (1-\theta)^2\frac{e}{2} & \quad \text{if there is regulation,} \end{aligned}$$

where the top expression is akin to the one for civic individuals, but without the $\iota$ term. The bottom expression is more complicated. The first term is the expected productivity after the bribe, given by $\mathbb{E}[\delta+\gamma-1/2] = \int_{1/2}^{1} \delta+\gamma-1/2dy = \delta+1/8$, the second term is the expected income from bribes $bProb(\gamma \geqslant 1/2)$, and the last term is the externality term akin to the one for civic individuals.

Notice, then, that if $\theta$ is above $\theta^*$, society will opt for no regulation. Comparing the top lines of the expected payoffs above, we can see that in this case, all individuals will choose to behave civically. On the other hand, for $\theta$ below $\theta^*$, society will opt for regulation, and the bottom lines must be compared. In this case, individuals will choose not to behave civically.

Therefore, two equilibria arise from this model. In the first one, individuals will behave civically, there will be no regulation, production will be decentralized and productivities high. In the second one, individuals will not behave civically, and there will be regulation. Production, however, will still be decentralized, since individuals ignore the effects of externalities. Productivity will be lower than in the first equilibrium. Notice, moreover, that society would be even worse off without regulation, since then all uncivic individuals would engage in decentralized production.

In the following subsection, I will build an endogenous growth model in which these two different equilibria have consequences for growth rates in a balanced growth equilibrium.

## 2.2 Interpersonal Trust in a Baseline Endogenous Growth Model

As in Romer (1990), consider an economy with four inputs and three sectors. Inputs are capital ($K$), labor ($L$), human capital ($H$) and a level of technology ($A$). Capital takes the form of a durable intermediate good, and is measured in terms of units of the final consumption good. Labor is interpreted as the service of unskilled workers, whereas human capital is interpreted as the services of skilled workers. Human capital also serves in the model to distinguish between the rival and non-rival components of the stock of knowledge. In this sense, while human capital $H$ represents the rival component of the stock of knowledge imbedded in the skills and domain knowledge of workers, the technology level $A$ represents the non-rival component, thought of as ideas, designs and blueprints. As usual, the key insight here is that applying a particular idea to produce one good does not prevent a further application of the same idea to produce a different good, and, therefore, this non-rivalry allows for increasing returns and unbounded growth. Concretely, $A$ can represent the number of designs being used the economy.

The four inputs above are used in three sectors. The research and development sector uses the level of technology and human capital to produce new designs. In particular, a new design is a new durable intermediate good. Intermediate goods are produced by the intermediate good sector, which uses designs from the R&D sector and foregone consumption of the final consumption good as inputs. Finally, the final goods sector uses labor, human capital, and intermediate goods to produce a final good that can be either consumed or saved as new capital.

Since the purpose here is to focus on how social capital expands economic possibilities through new ideas, the variables of interest are mostly related to the research sector, its inputs and output. In particular, the model will try to gauge the effects of social capital on the amount of human capital allocated to R&D and on the number of new ideas generated. Then, to keep dynamics simple, I assume that the endowment of human capita is fixed at $H$, so that only allocative decisions matter. Similarly, since the labor-leisure tradeoff is not of interest here, the endowment of labor is assumed to be constant at $L$ and inelastically supplied.

Another assumption is that capital in this economy is comprised of an infinite amount of distinct producer durables (intermediate goods). To simplify matters, I assume that instead of discrete, indivisible objects, these intermediate durables take place on a continuum and are indexed by $i$. In particular, let the level used of the intermediate good $i$ be denoted by $X(i)$. If intermediate $i$ is not used, then $X(i) = 0$. Moreover, without loss of generality, order these indices in a such a way that $X(i) = 0$ for all $i \geqslant A$.Then, the total amount of capital used in this economy is given by

$$K = \eta \int_0^\infty X(i)\mathrm{d}i = \eta \int_0^A X(i)\mathrm{d}i, \tag{4}$$

where the parameter $\eta > 0$ is the the amount of the final good necessary to produce one unit of intermediate goods. Therefore, in the equation above, $K$ is measured in terms of the final good, which leads to the following law of motion for capital:

$$\dot{K}(t) = Y(t) - C(t), \tag{5}$$

where $C(t)$ denotes aggregate consumption and $Y(t)$ denotes the output of the final good, both at time $t$.

Given the fixed endowment of labor $L$ and the amount of intermediate goods described above, an allocation of human capital employed in the final goods sector is what is left for output of the final good to be determined. Let this allocation be denoted by $H_Y$. Then, output in the final goods sector, denoted by $Y$, is given by

$$Y(H_Y, L, A, x) = (S_Y(\theta)H_Y)^{\alpha}(S_L(\theta)L)^{\beta}\int_0^A X(i)^{1-\alpha-\beta}\mathrm{d}i, \tag{6}$$

where, $\alpha, \beta < 1$, and $S_Y(\theta)$ and $S_L(\theta)$ are increasing functions of the share of trusting individuals $\theta$ in the economy that capture how different levels of social capital affect the marginal productivity of human capital and labor. As equation 6 makes clear, higher levels of interpersonal trust serve in this economy to augment the amount of human capital or labor employed in the production of final goods. These functions are best interpreted as resulting from the equilibria presented in subsection 2.1. For example, the good equilibrium with the economy populated by only civic agents and exhibiting no regulation can be interpreted as $S_Y(1) = S_L(1) = S^H$, whereas the bad equilibrium with uncivic agents and regulation can be interpreted as $S_Y(0) = S_L(0) = S^L$, with $S^L < S^H$.

Notice that equation 6 can be rewritten as

$$Y(H_Y, L, A, \tilde{X}) = (S_Y(\theta)H_Y)^{\alpha}(S_L(\theta)L)^{\beta}\tilde{X}^{1-\alpha-\beta},$$

where

$$\tilde{X} = \left(\int_0^A X(i)^{(\varepsilon\,-\,1)/\varepsilon}\mathrm{d}i\right)^{\varepsilon/\varepsilon\,-\,1},$$

and $\varepsilon$ in the elasticity of substitution between intermediate goods. This makes clear that, for a given $A$, production of the final good exhibits constant returns to scale. Therefore, this sector can be thought of as being populated by a single representative firm.

It remains to specify how the production of new technology takes place. The research sector uses human capital and the technology level to produce new designs. Since it is assumed that the current level of technology is freely available to all researchers, $A$ enters linearly in the the production of new designs. Then, the evolution of the stock of technology is

$$\dot{A} = (S_A(\theta)H_A)^{\phi}A, \tag{7}$$

where $\phi < 1$, $A$ is the level of technology, and $H_A$ is the human capital allocated to the R&D sector. Once again, human capital is augmented by a function that is increasing in the share of trusting individuals in the economy $\theta$.

Equation 7 uses two different assumptions than the standard model in Romer (1990). The first one is related to $S_A(\cdot)$. In the original model, production of new designs is determined by a constant $\delta$, taking the form $\dot{A} = \delta H_A A$. Here, this constant is substituted by a function of the level of trust. As in the case of $S_Y(\cdot)$, subsection 2.1 provides a theory behind $S_A(\cdot)$.

The second difference is related to the marginal returns of human capital in the production of designs. In the original model, $H_A$ enters the production of designs linearly, exhibiting constant marginal productivity. Here, due to the parameter $\phi < 1$, human capital exhibits diminishing marginal productivity. This assumptions does not have big effects on the growth implications of the model, but it does allow for a more interesting allocation decision for human capital and, most importantly, for richer consequences for different levels of trust on this allocation and economic growth. The key insight from Romer (1990), namely, that the level of technology enters equation 7 linearly, is unchanged. Thus, unbounded growth at a constant rate is still a feasible outcome.

In sum, knowledge generates growth in the same two ways as it does in Romer (1990). First, it enables the production of new intermediate goods through equation 4. Second, it increases the amount of new knowledge that is produced through equation 7.

Before solving the model, a note on the notation for prices is useful. Let all prices be spot prices. Then, prices will be connected intertemporally through the interest rate, denoted by $R$ and expressed in terms of the final good. Then, let the price of a new design be $P_A$, the price of the intermediate good of index $i$ be $P(i)$, and let the final good be the *numéraire*. Moreover, wages are $W_{H,A}$ for human capital employed in the R&D sector, $W_{H,Y}$ for human capital employed in the final goods sector, and simply $W$ for labor, necessarily employed in the final goods sector. Naturally, a competitive market for human capital will require in an equilibrium that wages are the same in both designs and final goods sector, $W_{H,A} = W_{H,Y} = W_H$, and that the allocation is feasible, that is, $H_A + H_Y = H$. Notice that market clearing in the labor market is simpler due to the inelastic supply of labor $L$.

To solve the model, start by considering the final goods producer problem. The producer of final goods faces wages $W_{L,Y}$ and $W_{H,Y}$, and a continuum of prices $\{P(i) : i \in \mathbb{R}_+\}$ for all intermediate durables[1]. Given these variables, it decides how much human capital, labor, and the amount of

[1] For durables not in use take $P(i) = \infty$.

each durable good to hire in order to maximize profits:

$$\max_{H_Y, L, [X(i)]_{i=0}^{A}} (S_Y(\theta)H_Y)^\alpha (S_L(\theta)L)^\beta \int_0^A X(i)^{1-\alpha-\beta}\mathrm{d}i - W_{H,Y}H_Y - W_{L,Y}L - \int_0^A P(i)X(i)\mathrm{d}i. \quad (8)$$

As usual, the first-order conditions for this problem yield the factor demands. For human capital, it is

$$W_{H,Y} = \alpha S_Y(\theta)^\alpha H_Y^{\alpha-1}(S_L(\theta)L)^\beta \int_0^A X(i)^{1-\alpha-\beta}\mathrm{d}i, \quad (9)$$

whereas for labor it is

$$W_{L,Y} = \beta(S_Y(\theta)H_Y)^\alpha S_L(\theta)^\beta L^{\beta-1} \int_0^A X(i)^{1-\alpha-\beta}\mathrm{d}i. \quad (10)$$

Finally, the first-order condition with respect to durables yields the demand for durables. This from the differentiation under each of the integrals and is

$$P(i) = (1-\alpha-\beta)(S_Y(\theta)H_Y)^\alpha (S_L(\theta)L)^\beta X(i)^{-\alpha-\beta}. \quad (11)$$

The intermediate goods sector is characterized by monopolies. Each producer of index $i$ faces the decision of purchasing a design (or patent) from the designs sector, sold at price $P_A$. If it purchases the design, it owns a perpetually enforced monopoly on the production of the intermediate good indexed by $i$. Therefore, producers in this case do not take prices as given, but act as monopolists.

Therefore, the demand function in equation 11 is of particular importance, since it is the demand curve that the producer of intermediate good $i$ faces. The problem for this producer, after it pays $P_A$ for the design, is to choose an amount of the durable $i$ that maximizes (flow) profits:

$$\begin{aligned} \pi &= \max_X P(X)X - R\eta X \\ &= \max_X (1-\alpha-\beta)(S_Y(\theta)H_Y)^\alpha L^\beta X^{-\alpha-\beta} X - R\eta X. \end{aligned} \quad (12)$$

To understand the use of $\eta$ above, notice that $P(X)$ returns the price of the durable good when an amount $X$ is demanded in terms of final output and recall that it takes $\eta$ units of the final good to produce one unit of an intermediate durable. Therefore, the cost in the equation above is the interest cost in terms of output. It is implicitly assumed that at any point in time, output can be converted into capital and vice-versa.

The first-order condition for the problem in equation 12 yields the price charged by a monopolist $i$, given by[2]

$$\overline{P} = \frac{R\eta}{1-\alpha-\beta}, \tag{13}$$

where, since the problem is symmetric for all monopolists, that is, all indices $i$, all prices will be the same and, thus, the notation becomes $\overline{P}$. Consequently, for all $i$, the amount supplied of the intermediate good will be the same, denoted by $\overline{X}$. These two quantities imply flow profits of

$$\pi = (\alpha+\beta)\overline{PX}. \tag{14}$$

With the flow profits above, it remains to consider the decision to produce or not a given intermediate good. This production will occur if the net present value of the flow profits exceed the fixed cost of starting production. To start producing an intermediate $i$, the monopolist must first pay $P_A$ for the design. Since the market for designs is competitive, the price $P_A$ will be just enough to match the discounted stream of net revenue, so

$$\int_t^\infty \mathrm{e}^{\int_t^\tau R(s)ds}\pi(\tau)\mathrm{d}\tau = P_A(t) \tag{15}$$

for all $t$. If $P_A$ is constant, as will be the case in the balanced growth equilibrium shown below[3], this can be rewritten as

$$\pi(t) + R(t)\int_t^\infty \mathrm{e}^{\int_t^\tau R(s)ds}\pi(\tau)\mathrm{d}\tau = 0,$$

which yields

$$\pi(t) = R(t)P_A. \tag{16}$$

Therefore, at any point in time, flow profits will be just sufficient to cover the interest cost on the initial investment.

The research and development sector faces the price of a design given above and hires human capital up to the point that

$$W_A = \phi P_A S_A(\theta)^\phi H_A^{\phi-1}A. \tag{17}$$

[2]Notice that the problem is the problem of a monopolist facing a constant-elasticity demand curve, so that the optimal price is a markup over the marginal cost.

[3]Notice that a constant price across inputs, $\overline{P}$, does not amount to a constant price over time.

Finally, to close the model, it remains to specify preferences. Assume, then, the existence of a representative household that discounts utility at an instantaneous rate of $\rho$ and exhibits constant relative risk aversion, so that preferences are

$$\int_0^\infty \mathrm{e}^{-\rho t} \frac{C^{1-\sigma} - 1}{1 - \sigma} \mathrm{d}t, \tag{18}$$

with $\sigma \in [0, \infty)$. The household is endowed with one unit of labor $L$ and one unit of human capital $H$. Every period, it also earns the flow profits from intermediate monopolists and interest on the capital it owns. Given this context, the representative household decides how much to consume and how much to save. Its problem, then, is

$$\begin{aligned} &\max_{\{C(t), \dot{K}(t)\}_{t=0}^\infty} \int_0^\infty \mathrm{e}^{-\rho t} \frac{C(t)^{1-\sigma} - 1}{1 - \sigma} \mathrm{d}t \\ &s.t.\; C(t) + \dot{K}t \leqslant W_H(t)H + W_L(t)L + R(t)K(t) \int_0^A \pi(i)\mathrm{d}i \; \forall t. \end{aligned} \tag{19}$$

The associated Euler equation is

$$\frac{\dot{C}(t)}{C(t)} = \frac{1}{\sigma}(R(t) - \rho) \tag{20}$$

Given the model so far, an equilibrium for this economy can be defined as follows. Notice that it is defined as a *decentralized* equilibrium instead of a *competitive* one because of the presence of intermediate goods monopolists.

**Definition 2.** A **decentralized equilibrium** for this economy consists of time paths of consumption $[C(t)]_{t=0}^\infty$, capital $[K(t)]_{t=0}^\infty$, human capital employed in research and development $[H_A(t)]_{t=0}^\infty$, human capital employed in the production of final goods $[H_Y(t)]_{t=0}^\infty$, labor employed in the production of final goods $[L_Y]_{t=0}^\infty$, time paths of available intermediate goods $[A(t)]_{t=0}^\infty$, time paths of amounts and prices of particular intermediate goods $[X(i,t), P(i,t)]_{i \in [0, A(t), t=0}^\infty$, and time paths of interest rates, prices and wages $[R(t), P_A(t), W_H(t), W_Y(t)]]_{t=0}^\infty$ such that

i. Given interest rates, prices and wages $[R(t), P_A(t), W_H(t), W_Y(t)]_{t=0}^\infty$, consumption and capital time paths $[C(t), K(t)]_{t=0}^\infty$ solve the household problem in equation 19.

ii. Given wages $[W_H(t), W_Y(t)]]_{t=0}^\infty$ and intermediate goods prices $[P(i,t)]_{i \in [0, A(t)], t=0}^\infty$, final goods producers choose time paths for human capital, labor, and intermediate goods $[H_Y(t), L_Y(t), X(i,t)]_{i \in [0, A(t), t=0}^\infty$ to maximize profits.

iii. Monopolists choose prices and quantities $[X(i,t), P(i,t)]_{i\in[0,A(t)],t=0}^{\infty}$ to maximize profits.

iv. Given prices for designs $P_A(t)]_{t=0}^{\infty}$, firms in the research and development sector maximize profits.

v. Markets clear.

Just like in Romer (1990) there is an equilibrium in this model in which knowledge, the stock of capital, and output of final goods grow at the same exponential and constant rate. Denote this equilibrium as a balanced growth equilibrium. To characterize this equilibrium, I make an assumption regarding the evolution of the interest rate and show that this assumption is compatible with equilibrium behavior in this economy.

Assume, then, than interest rates are constant over time, so $R(t) = R \ \forall t$. Then, since in any given moment all durables have the same price, from equation 13, the prices of *all* intermediate durables $i$ are constant over time. Consequently, from the demand for durables in equation 11, the quantity of *all* durables is constant over time. In sum $\overline{P}(t) = \overline{P} \ \forall t$ and $\overline{X}(t) = \overline{X} \ \forall t$. Then, from equation 14, flow profits are, thus, constant over time at $\pi = (\alpha+\beta)\overline{PX}$. Then, since the price of a design must equal the discounted stream of flow profits (from 16),

$$P_A = \frac{1}{R}\pi = \frac{\alpha+\beta}{R}\overline{PX} = \frac{\alpha+\beta}{R}(1-\alpha-\beta)(S_Y(\theta)H_Y)^{\alpha}(S_L(\theta)L)^{\beta}\overline{X}^{1-\alpha-\beta}, \tag{21}$$

where the last equality follows from equation 11.

Market clearing for the human capital market requires the same wage for human capital in both sectors, so

$$\begin{aligned} W_A &= W_{H,Y} \\ \phi P_A S_A(\theta)^{\phi} H_A^{\phi-1} A &= \alpha S_Y(\theta)^{\alpha} H_Y(t)^{\alpha-1}(S_L(\theta)L)^{\beta}\int_0^A X(i)^{1-\alpha-\beta}\mathrm{d}i, \end{aligned} \tag{22}$$

which after substituting for $P_A$ from equation 21 reduces to

$$\frac{H_Y}{H_A^{\phi-1}} = \frac{1}{\phi S_A(\theta)^{\phi}}\frac{\alpha}{(\alpha+\beta)(1-\alpha-\beta)}R. \tag{23}$$

Notice that the right-hand side above, for constant interest rates, is constant. Then, the ratio in the left-hand side must also be constant, and since the endowment of human capital is fixed, $H_Y + H_A = H$, the allocations of human capital are constant.

Then, from $H_A(t) = H_A \ \forall t$ and equation 7 the rate of technological progress is constant, since

$$\frac{\dot{A}}{A} = (S_A(\theta)H_A)^{\phi}.$$

Therefore, since $\overline{X}$ is constant, the stock of capital, given by output can be expressed as

$$Y = (S_Y(\theta)H_Y)^{\alpha}(S_L(\theta)L)^{\beta}A\overline{X}^{1-\alpha-\beta},$$

which implies that output grows at the same rate as knowledge, $\dot{Y}/Y = \dot{A}/A$.

Now, to find that the rate of consumption growth matches the rate of output and knowledge growth, notice that the stock of capital $K$ can be written as $K = \eta A\overline{X}$, and, thus, $\dot{K}/K = \dot{A}/A$. Then, the ratio $K/Y$ must be constant, and from the law of motion for capital

$$\frac{C}{Y} = \frac{Y - \dot{K}}{Y} = 1 - \frac{\dot{K}}{K}\frac{K}{Y}$$

must yield a constant ratio $C/Y$. Thus, let the common growth rate be denoted by $g$:

$$g = \frac{\dot{C}}{C} = \frac{\dot{Y}}{Y} = \frac{\dot{K}}{K} = \frac{\dot{A}}{A} = (S_A(\theta)H_A)^{\phi}. \tag{24}$$

Finally, the Euler equation becomes

$$g = \frac{\dot{C}}{C} = \frac{1}{\sigma}(R - \rho),$$

which implies a constant interest rate, the initial assumption. The discussion above, therefore establishes the following result.

**Proposition 2.** *In the baseline model of endogenous growth with interpersonal trust, there exists a balanced growth equilibrium, in which output, consumption, the capital stock, and the stock of knowledge all grow at the same exponential rate $g$.*

**Proof:** See Appendix A. □

Given the result above, changes in the balanced growth equilibrium caused by changes in interpersonal trust can by analyzed by equations 23 and 24. Start by considering the allocation of human capital between R&D and final good production. Recalling that $S_A(\theta)$ is increasing in $\theta$ and that in a balanced growth equilibrium $R$ is constant over time, an increase in interpersonal trust $\theta$

will decrease the ratio $H_Y/H_A$, and, since the endowment of human capital is fixed, more human capital will be allocated towards the R&D sector.

Moreover, from equation 24, a higher level of interpersonal trust will increase the growth rate of knowledge, consumption and output, establishing the following result.

**Proposition 3.** *In the baseline model of endogenous growth with interpersonal trust, an higher share $\theta$ of individuals who are trusting will increase the amount of human capital employed in the R&D sector, increase the rate of knowledge growth, and increase the rate of output growth in the balanced growth equilibrium.*

**Proof:** See Appendix A. □

One interesting feature of this model is that it embeds a formulation very close to the one in Romer (1990). Recall that in Romer (1990), the production of new designs is determined by a constant $\delta$, taking the form $\dot{A} = \delta H_A A$. Then, the model here reverts to the one in Romer (1990) for $\phi = 1$ and $\delta = S_A(\theta)^{\phi}$. One advantage of this approach is that it simplifies the allocation of human capital and allows for closed form solutions.

Under the two assumptions above, then, in a balanced growth equilibrium, the relationship between human capital allocation and the interest rate becomes

$$\begin{aligned} H_Y &= \frac{1}{S_A(\theta)} \frac{\alpha}{(\alpha+\beta)(1-\alpha-\beta)} R \\ &= \frac{1}{S_A(\theta)} \Lambda R, \end{aligned} \tag{25}$$

where $\Lambda = \alpha/[(\alpha+\beta)(1-\alpha-\beta)]$.

Then, since now $g = S_A(\theta)H_A$ and $H_Y + H_A = H$,

$$g = S_A(\theta)H - \Lambda R, \tag{26}$$

which, together with the Euler equation, implies

$$g = \frac{S_A(\theta)H - \Lambda\rho}{\sigma\Lambda + 1}. \tag{27}$$

Notice that, as expected, equations 26 and 27, again together with the fact that $S_A(\theta)$ is increasing in $\theta$, make clear that the results in Proposition 3 still hold.

One interesting feature of the model is that, as equations 23 and 26 show, the allocation of human capital does not depend of how trust affects the production of final goods, as represented by the functions $S_Y(\theta)$ and $S_L(\theta)$. In other words, even though trust may augment the amount of human capital and labor employed in the production of the final good, is has no effect on how human capital is allocated. This is due to the fact that free entry in the R&D sector implies, zero profits in this sector, and, thus, that the price of designs $P_A$ will change in the same proportion as the price of the intermediate good $\overline{P}$. But $\overline{P}$, from the production function for final goods, changes in the same proportion as $S_Y(\theta)$ and $S_L(\theta)$. Then, since $P_A$ enters the human capital wage in the $R\&D$ sector linearly, the market clearing condition for human capital $W_A = W_{H,Y}$ remains the same whenever $S_Y(\theta)$ and $S_L(\theta)$ change. Therefore, only changes in $S_A(\theta)$ will affect the allocation of human capital.

Alternatively, one can think of the demand for human capital in each sector as consisting of the price sold together with the marginal productivity of human capital. An increase in trust will increase the demand for human capital in both the R&D sector and the final goods sector. However, in the R&D sector, this increase occurs in two different ways. The first one is through the price $P_A$, whereas the second one is through the marginal productivity, a function of $S_A(\theta)$. The increase through $P_A$, however is of the same proportion as the increase in the marginal productivity of human capital in the final good sector, so these two offset each other. Only the increase caused through $S_A(\theta)$ remains.

One consequence of the argument above is that whenever trust has no isolated effect on the marginal productivity in the R&D sector, increases in trust will completely offset increases in the demand for human capital in the R&D and final goods sector, and, therefore, trust will have no effects on the allocation of human capital. This point is further explored in the next subsection, that presents a lab-equipment version of the model.

### 2.3 Interpersonal Trust in a Lab-Equipment Growth Model

Suppose that the model follows a lab-equipment specification, as introduced by Rivera-Batiz and Romer (1991). The model is the same as the one in the previous subsection, with an important change in the evolution of knowledge, given now by

$$\dot{A} = \mu Z, \tag{28}$$

where $\mu > 0$, and $Z$ is an amount of the final good. The formulation above makes clear that in this economy all that is required to produce new knowledge is final goods, that is, investment in equipment or laboratories. Hence, the "lab-equipment" appellation. However, this can also be understood as an economy where both the final goods sector and the designs sector employ the same inputs at the same proportions, so that

$$\dot{A} = \mu(S_Y(\theta)H_A)^{\alpha}(S_L(\theta)L_A)^{\beta}\int_0^A X_A(i)^{1-\alpha-\beta}\mathrm{d}i, \tag{29}$$

where $H_A$, $L_A$, $X_A(i)$ are, respectively, the amounts of human capital, labor, and intermediate durable $I$ employed by the R&D sector.

In this context, the resource constraint for the economy changes. Now, final output is used to consume, to increase the capital stock, and to produce new knowledge. Then, now

$$C + \dot{K} + \frac{\dot{A}}{\mu} = Y.$$

The final difference is related to profit maximization in the R&D sector. Now, since one unit of final output produces and amount $\mu$ of designs, one design will requires an amount $1/\mu$ of final output and free entry in the design sector will require

$$P_A = \frac{1}{\mu}. \tag{30}$$

This lab-equipment specification also allows for a balanced growth equilibrium. To characterize this equilibrium, notice that from equation 28, $\dot{A}/A = \dot{Y}/Y$. The condition $\dot{C}/C = \dot{K}/K = \dot{A}/A$ can be obtained like in the previous case.

In addition, equation 14, $\pi = (\alpha+\beta)\overline{PX}$, and equation 13, $\overline{P} = R\eta/(1-\alpha-\beta)$, imply that

$$\frac{\pi}{R} = \frac{\alpha+\beta}{1-\alpha-\beta}\eta\overline{X},$$

and, since $P_A = \pi/R$,

$$P_A = \frac{(\alpha+\beta)\eta}{1-\alpha-\beta}\overline{X},$$

which substituting into equation 30 yields

$$\overline{X} = \frac{(1-\alpha-\beta)}{(\alpha+\beta)\eta\mu}.$$

Then, after substituting the expression above into the first order condition for intermediate durables producers, the interest rate is

$$R = \Upsilon(S_Y(\theta)H_Y)^{\alpha}(S_L(\theta)L_Y)^{\beta}, \tag{31}$$

where

$$\Upsilon = (1-\alpha-\beta)^{2-\alpha-\beta}(\alpha+\beta)^{\alpha+\beta}\eta^{\alpha+\beta-1}\mu^{\alpha+\beta}. \tag{32}$$

Then, substituting the interest rate above into the Euler equation yields the following result.

**Proposition 4.** *In the lab-equipment model of endogenous growth with interpersonal trust, there exists a balanced growth equilibrium, in which output, consumption, the capital stock, and the stock of knowledge all grow at the same exponential rate*

$$g' = \frac{1}{\sigma}[\Upsilon(S_Y(\theta)H_Y)^{\alpha}(S_L(\theta)L_Y)^{\beta} - \rho],$$

*where* $\Upsilon$ *is defined as in equation 32.*

**Proof:** See the discussion above. □

From proposition 4 it is clear, given that $S_Y(\theta)$ and $S_L(\theta)$ are increasing in $\theta$ that a higher level of interpersonal trust will increase the growth rate in the balanced growth equilibrium. Therefore, in this model, like in the baseline model in the previous subsection, greater social capital will lead to greater economic performance. However, unlike the previous model, now, due to the fact that the R&D sector uses only output to generate new knowledge, greater levels of trust will not increase the amount of human capital employed by the research and development sector.

**Proposition 5.** *In the lab-equipment model of endogenous growth with interpersonal trust, an increase in the share of individuals who are trusting* $\theta$ *will not increase the amount of human capital employed in the R&D sector, but it will increase the rate of knowledge growth, and increase the rate of output growth.*

**Proof:** See Appendix A. □

In the next section, I take propositions 3 and 5 to the data, and check the empirical support for each model.

# 3 Evidence

Both models above establish three results regarding the effects of trust in an economy. The first result is that greater levels of trust will lead to faster economic growth and improved economic performance. The second result is that greater levels of trust will increase the growth rate of knowledge, or, concretely, will increase the number of patents in an economy. Finally, the third result regards greater levels of trust and the amount of human capital employed by the research and development sector. While the baseline model predicts that trust will lead to higher employment of human capital in R&D, in the lab-equipment model there is no relationship between these two variables. In this section, I aim to empirically test the last two results. The result relating trust and economic performance is already considered in the literature on the topic, and, therefore, is not of primary interest here.

The objective of empirical analysis, then, is twofold. First, testing whether greater levels of trust lead to a higher output of patents is a first effort into determining what is the mechanism behind the positive, and likely causal, relationship between social capital and economic performance. Of course, establishing that trust increases the production of knowledge does not imply that that is the only mechanism through which culture can affect economics. However, the lack of such result does imply that economists should look somewhere else. This test, therefore, is a worthy one.

Second, as the theories above explicit, testing whether trust is associated with the employment of human capital in the R&D sector is a way to empirically distinguish between a standard endogenous growth model and its lab-equipment counterpart. This distinction, by itself, is an interesting question, but it may have even more important repercussions. For instance, Bloom et al. (2017) present evidence that human capital exhibits diminishing returns in the creation of new ideas, and that sustained exponential growth can only occur with large increases in research effort that offset its declining productivity. Empirical evidence in favor of the lab-equipment specification tend to go against these findings.

The key issue in estimating a causal effect of culture on economic development and related variables is that culture is endogenous to the development phenomenon. Economic development is a process that has effects on cultural and social traits, and these traits generate a bias on estimates of the effect of culture. Therefore, to identify a causal effect from culture to innovation and R&D behavior, exogenous variations in culture must be exploited.

The idea here is to apply the methodology of Tabellini (2010). The methodology, that follows from Acemoglu et al. (2001), uses the fact that countries in Europe have been subject to the same formal and legal institutions for the past century and a half, but within several of these countries different political histories are observed. Therefore, controlling for country fixed effects removes from cultural measures the effects of common national institutions. What remains, then, is just the effect of historical variables. Then, historical variables that serve as exogenous variation for culture and institutional features, once country fixed-effects are added, become a source of exogenous variation on culture only and, hence, can be exploited as instrumental variables. Naturally, such an approach requires the level of analysis to be more disaggregated than the country level, so I use regions in Europe.

## 3.1 Estimation Strategy

The goal is to identify the causal effect of trust, and culture in general, on innovation activities, either the number of patents generated or a measure of human capital employed by the R&D sector. Consider, then, the following regression model:

$$I = \alpha + \beta C + \delta I_0 + \gamma X + \varepsilon, \tag{33}$$

where $I$ denotes a regional innovation variable, $C$ is a measurement of culture, $I_0$ is an indicator of past innovation, $X$ denotes other regressors, $\varepsilon$ is a unobserved error term, and $\beta$ is the parameter of interest. The model above suffers from the common endogeneity issue: culture and the unobserved error term in 33 are likely to be correlated. This may be due to reverse causality, since innovation and development are closely linked, and development affects cultural traits. Moreover, omitted variable may also contribute to this problem.

To tackle the issue of endogeneity, it is necessary to understand the determinants of trust and culture. One possibility is to follow the theoretical work of Bisin and Verdier (2001) , Bénabou and Tirole (2006), and Boyd and Richerson (1985) and assume that culture is shaped by two forces: horizontal and vertical transmission. Horizontal transmission is the diffusion and evolution of cultural traits through social and economic interactions among peers, that is, contemporaneously. Vertical transmission, on the other hand, occurs across generations, mainly from parents to children. Evidence that vertical transmission does indeed influence the evolution of cultural traits is available. One example are immigrants, who carry with themselves values close to those seen in their ancestors' countries of origin. In fact, the second part of the empirical analysis here exploits this fact.

Then, a plausible model of culture can be

$$C = a + bC_0 + dI_0 + cX + u, \tag{34}$$

where $C_0$ denotes the cultural traits of earlier generations, and $u$ is an error term capturing all other determinants of culture. These earlier traits, if observable, would be a natural instrumental variable. Unfortunately, they are not available. However, since current cultural variables depend on, besides earlier culture, on other regressors denoted by $X$, earlier cultural traits will depend on earlier regressors, denoted by $X_0$ and so we can write

$$C = \phi_0 + \phi_1 X_0 + \phi_2 I_0 + \phi_3 X + \nu, \tag{35}$$

where the $\phi_i$ are the parameters, and $\nu$ is an unobserved error term. The variables in $X_0$, then, are the instrumental variables in this approach. They separate the variation in culture that is exogenous, that is, due to the historical variables, from the possibly endogenous variation in culture due to $\nu$.

However, for this estimation strategy to yield unbiased and causal estimates of $\beta$ in 33, two hypotheses must be true. The first one is that culture is transmitted over time, but that it also reflects contemporaneous conditions. This amounts to $X_0$ being included in 35. In concrete terms, history must affect culture, so that past values of institutional features explain cultural differences today. This assumption is plausible. On one hand, children tend to share cultural traits with parents and evidence from immigrants does show that culture transmits vertically; on the other, environmental variables may very well shape the behavior of agents and cause changes in cultural traits. Moreover, if culture is completely independent of contemporaneous factors, endogeneity is not an issue. As usual, this assumption, although central, is not the problematic one, since it can be tested, albeit indirectly.

The second assumption is that the historical variables used as instruments in $H_0$ are valid instruments, and, thus, excluded from 33. This restriction is not satisfied in a general way, it requires controlling for contemporaneous regressors denoted by $X$. In practice, for every past feature that affects culture, a contemporaneous measure of the same variable must be included in the regressions.

I now describe in detail all the variables that will be used.

## 3.2 Data

I use data on 60 regions in 8 European countries: Belgium, France, West Germany, Italy, the Netherlands, Portugal, Spain, and the United Kingdom. Regions are defined according to the Nomenclature of Territorial Units for Statistics (NUTS), a standard for geocoding and dividing European countries into smaller subdivisions. Most of the regions in the sample amount to the coarsest subdivision, called NUTS1. NUTS1 regions are, generally, regions or states, and range from 3 to 7 million inhabitants. In some cases, however, a region is a merged set of NUTS1 areas. A table containing the regions used is in Appendix B. Given these regions, the data span four broad categories: innovation and R&D, culture, institutions and economics, and the instruments.

The source for R&D data is Eurostat, the main office for statistics relative to the European Union. I use two variables. The first one is the number of patent applications to the European Patent Office per million inhabitants in the active population. This variable aims to be a measure of growth of the knowledge stock, that in the theory is denoted by $\dot{A}$. The other variables aims to capture the allocation of human capital in the R&D sector. It is the number of scientists and engineers as a percentage of the active population. Both variables are averaged for 2005 - 2010 for each region. For regions that are merged, the numbers of patents for each region are added together, whereas the percentages of scientists and engineers are averaged.

The spatial distribution of the patent applications, and the scientists and engineers variables are shown in figures 2 and 3. The variables are divided into five intervals of equal size. A point of note is that the distribution patent applications is more concentrated in some regions relative to

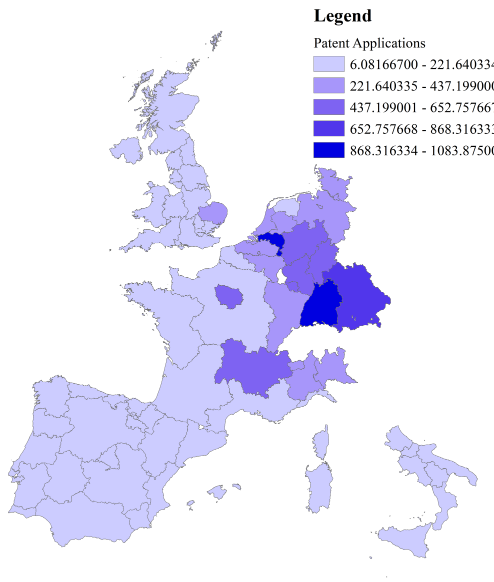


Figure 2: Distribution of patent applications over European regions

the distribution of scientists and engineers.

Data on culture is obtained from the European Values Study (EVS). The EVS is a large-scale survey on values and beliefs related to many issues. It covers many different European countries and consists of multiple cross-sections. The issues are also varied: work, family, politics and society, morality and religion, etc. In particular, I use the latest wave of the EVS, collected between 2008 and 2010. The raw data from the EVS is available at the individual level. The mean number of observations per region is 180, but ranges from 50 to 700. To reduce problems associated with this issue, many regressions are weighted by the inverse of a measure of cultural variability in each region. In total, I use the observations from 12,564 individuals.

The main cultural variable is interpersonal trust. For each region, I compute the share of individuals who believe that most people can be trusted, that is, that responded "Most people can be trusted" to the question "Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people." The other options are "Can't be too careful" and "Don't know."

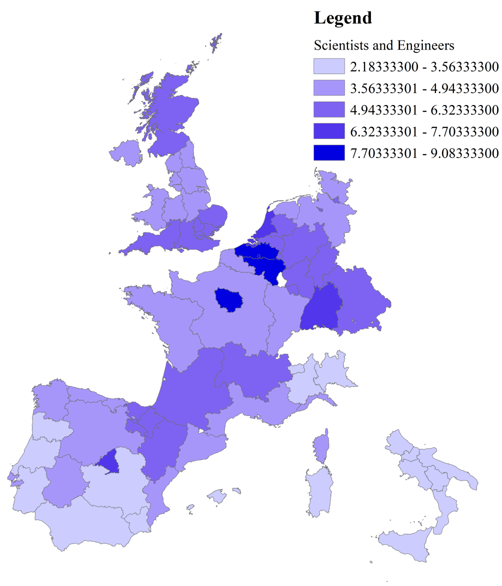


Figure 3: Distribution of scientists and engineers (%) over European regions

Besides trust, I also use variables that summarize cultural attitudes more generally. In particular, I consider, together with trust, the fraction of individuals who believe that tolerance and respect are good values to impart on children, the fraction of individuals who believe that obedience is a good value to impart on children, and the average of how much people believe they have control over the outcomes of their lives. Then, I compute the first principal components of all four variables, and of the variables that are expected to have a positive effect on innovation, namely trust, control over the outcomes of your life, and the importance of tolerance and respect. The correlation between all cultural variables and the principal components is presented in Table 1. One feature that the table shows is that while the cultural traits are not correlated with each other (last three columns), the principal components are indeed correlated with the individual cultural traits (first two columns), suggesting that the summary measures capture a common cultural pattern besides the noise in individual responses.

Figure 4 shows how trust varies across European regions, whereas 5 does the same for the first principal component of culture. As before, the data is displayed in intervals of equal size. Notice

Table 1: Correlations among cultural variables

| | *PC Culture* | *PC Culture Pos.* | *Trust* | *Control* | *Respect* |
|---|---|---|---|---|---|
| *PC Culture Pos.* | 0.92 | | | | |
| *Trust* | 0.66 | 0.69 | | | |
| *Control* | 0.54 | 0.67 | 0.12 | | |
| *Respect* | 0.51 | 0.50 | 0.07 | 0.06 | |
| *Obedience* | -0.48 | -0.09 | -0.09 | -0.02 | -0.07 |

Note: 12,564 observations.

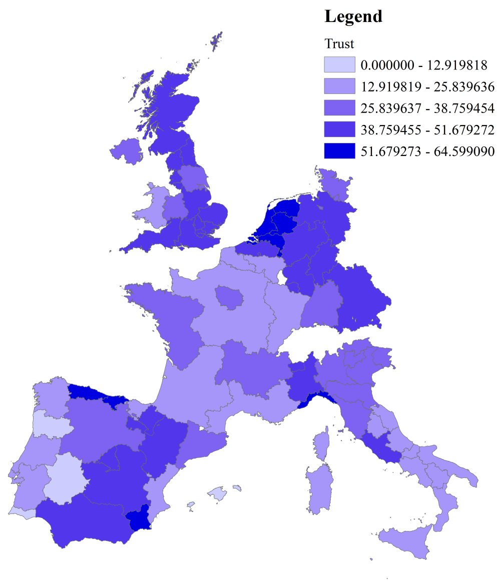


Figure 4: Distribution of trust over European regions

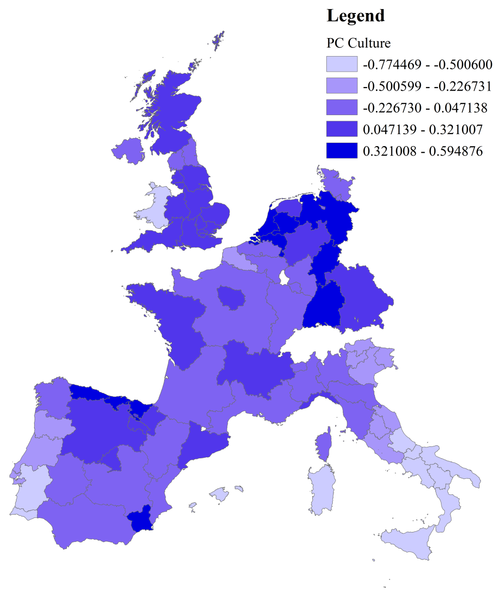


Figure 5: Distribution of the first principal component of culture over European regions

first that the two figures show the correlation between both variables. Additionally, while some correlation exists between the cultural variables and the innovation variables, the picture is far from obvious. Finally, there is a great deal of variation in culture for Europe, not only between countries, but also within them.

This variation, however, also occurs within each region. To control for a part of the regional variation in culture, I followed Tabellini (2010) and created a *conditional* measure of trust. This conditional trust variable is the regional average of trust after controlling for several characteristics of each individual respondent. Concretely, it is the regional dummy coefficient of a regression of the trust variable on, besides the regional dummy variables, marital status, gender, age group, and self-reported categorical variables for health and education. The natural way to interpret this variable is to interpret it as the regional trust average after controlling for the regressors just mentioned. The same approach was taken for the other cultural variables and principal components. Importantly, whenever these conditional measures are used in regressions, I weigh observations by the inverse of the standard error of these dummy coefficients.

From equation 33 data on past innovation and data on other regressors are needed, specially to reduce the risk of invalid instruments. Data of past innovation is not available in the disaggregated level needed. However, given the relationship between innovation and economic development, variables for past values of development serve as proxies. The first variable used is the gross enrollment rate of primary and secondary schools in the 1960s. Education is known to be a determinant of economic development, so it should also be correlated with innovation. Moreover, adding a measure of education avoids using culture as a proxy for human capital. Finally, the choice of using values for the 1960s is motivated by two facts: it minimizes the risk of reverse causation, and it increases variability. The source is Tabellini (2010), which collected the data from national statistics institutes.

The second variable is the fraction of the population living in cities with more than 30,000 inhabitants circa 1850, an urbanization rate. The motivation here is that urbanization is closely associated with economic performance, so this variable serves as a good proxy for innovation as well. Once again, the source is Tabellini (2010), obtained through Bairoch et al. (1988).

It remains to discuss the variables used as instruments. Equation 35 implies that good instruments are past values of the regressors included in $X$. Then, good instruments would be measures of past education attainment and economic performance across European regions. Tabellini (2010) uses as past values of education literacy data for circa 1880. As figure 6 shows (with the data divided in five equal-length intervals), there is a good deal of variability in this data. It also is positively correlated with current economic outcomes and varies within countries.

Finally, the second instrumental variable attempts to capture innovation behavior even further in the past. From Acemoglu et al. (2001), Acemoglu et al. (2005), and Tabellini (2010) the quality of early institutions is a proper instrument. An interesting and important feature of European history that motivates this choice is the fact that regions that today belong to the same countries were parts of different countries in the past. For instance, Germany and Italy were only unified and became, each, a single country in the 1871, whereas regions that belong to northern France today were part of Belgium and Germany in the past. Therefore, there is variation in past institutions within European countries today, and this variation can be exploited.

Data on early political institutions can be obtained from the POLITY IV dataset. Following

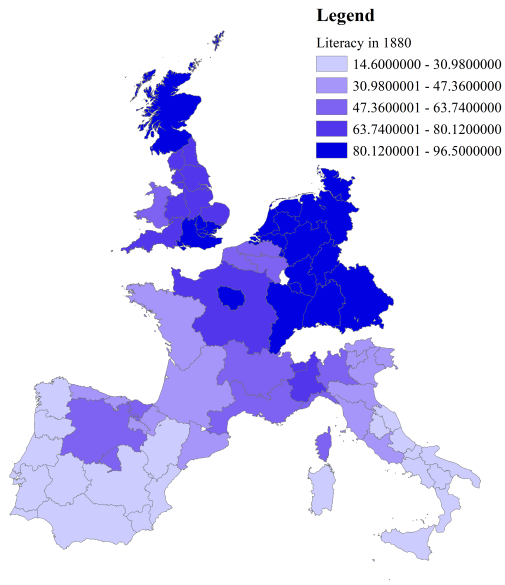


Figure 6: Distribution of the literacy rates (%) around 1880

the existing literature, the variable *Constraints on the Executive* is the variable used. It is designed to capture "institutionalized constraints on the decision making powers of chief executives," so that better institutional quality amounts to areas where the holder of executive power is either accountable to other political and social bodies or its powers are constrained by checks and balances or the rule of law. The variable ranges from 1 to 7, where 1 denotes unlimited authority and 7 an accountable executive, constrained by checks and balances. Following Tabellini (2010) and Acemoglu et al. (2005), five time spans are used: forty-year intervals between 1600, 1700, 1750, 1800, and 1850. From a geographic perspective, the variable exhibits the same values for all regions in a given country whenever the boundaries of the country are roughly the same today. There are two exceptions: Northern Ireland, coded as having the same institutions as Ireland, and the Spanish regions of Aragon, Catalonia, and Valencia, coded as having a higher score due to period between 1600 and 1700 when they had their own Parliaments. Finally, the cases of Germany and Italy remain. In these cases I use the values of Tabellini (2010), who tracked the institutional quality of subregions in each of these countries. To summarize the five periods used, I calculated the first

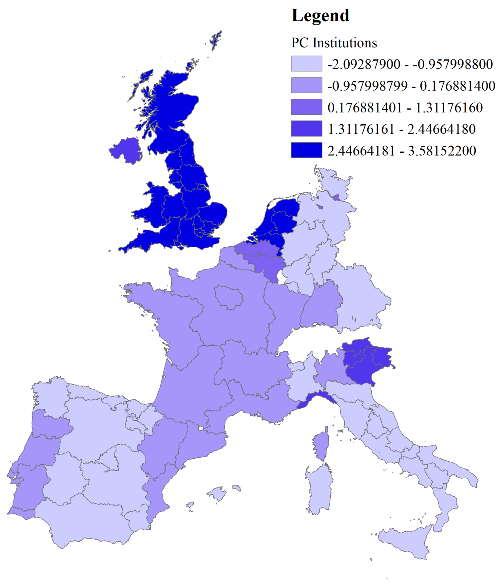


Figure 7: Distribution of the first component of early institutions

principal component.

Figure 7 shows the geographic pattern of the first principal component of past institutions. Great Britain, the Netherlands, and northern Italy exhibit the best institutional quality. It is worthwhile to note that there is not a big correlation between this instrument and the literacy rates in 1880, indicating that the two instrumental variables capture different features of the history of these regions.

## 3.3 Results

Table 2 presents the simple ordinary least squares estimates of the regression patent applications and percentage of scientists and engineers on trust, or other culture variables, and controls, following the model in equation 33. Standard errors are estimated robustly and by using clusters on countries, and presented in parenthesis, respectively, on the first and second lines below the point estimates. Clustering on countries allows for arbitrary correlations between regions within a country.

In general, the table reflects the correlations observed in the figures of the preceding subsection.

Table 2: Innovation and Trust, OLS estimates, unconditional variables

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Patent Applications | | | Scientists and Engineers | | |
| Schooling 1960 | 0.80 | -0.04 | 1.19 | 0.01 | -0.00 | 0.01 |
| | (1.04) | (0.96) | (0.86) | (0.02) | (0.02) | (0.02) |
| | (0.76) | (0.79) | (0.84) | (0.01) | (0.01) | (0.01) |
| Urbanization 1850 | -2.02 | -2.11 | -1.69 | 0.03 | 0.02 | 0.03 |
| | (1.26) | (1.33) | (1.39) | (0.01)* | (0.01)* | (0.01)** |
| | (1.40) | (1.43) | (1.53) | (0.01)* | (0.01)* | (0.01)** |
| Trust | 4.13 | | | 0.03 | | |
| | (1.25)*** | | | (0.01)** | | |
| | (2.51) | | | (0.02)* | | |
| PC Culture | | 2.27 | | | 0.02 | |
| | | (0.89)** | | | (0.01)*** | |
| | | (0.83)** | | | (0.01)* | |
| PC Cult. Pos. | | | 3.09 | | | 0.03 |
| | | | (1.14)*** | | | (0.01)*** |
| | | | (0.96)** | | | (0.01)* |
| N | 62 | 62 | 62 | 61 | 61 | 61 |
| Adj. $R^2$ | 0.56 | 0.55 | 0.56 | 0.59 | 0.59 | 0.61 |

In parentheses: robust standard errors (above), clustered on countries (below). Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation method: OLS. Country fixed effects always included.

Trust is associated with higher levels of patent applications, and since the principal components of culture contain trust, these are also correlated with patent applications. Moreover, the effect also exists for the share of scientists and engineers in the active population. The effects are also sizable, an increase in trust of 20 percentage points, which amounts to roughly the difference in trust between Sicily and Lombardy, in the south and north of Italy, respectively, is associated with 82 more patent applications per one million inhabitants in the active population, almost 40% of the 209.95 patent average. Relative to scientists, the increase in trust is associated with an increase of 0.6 percentage points in the share of scientists and engineers, from an average of 4.67%. Estimates are similar for the conditional measures of trust and culture, presented in table 3. Finally, an interesting feature of the tables is the lack of correlation between innovation and schooling in the 1960s and urbanization in circa 1950.

Of course, there is no reason to assume that culture is independent of innovation. In fact, as argued above, there are good reasons to believe that the results in the two tables are plagued by endogeneity problems, and cannot be interpreted in a causal way. Therefore, I proceed to present estimates from the use of the instrumental variables.

Table 4 presents the reduced form that connects the instrumental variables to the innovation variables of interest. If past literary and early institutions are correlated with trust, and if trust affects innovation, some correlation between the instruments and the innovation variables is expected. This is broadly confirmed. From the table, literacy rates and early institutions are indeed correlated with patent applications. However, this correlation is weaker for the share of scientists and engineers. This lack of association, however, is not necessarily an indication that the estimation strategy is flawed, since it may be caused by a lack of correlation between culture and the share of scientists and engineers, and not by a lack of correlation between the instruments and culture. In any case, the first-stage results should settle this matter.

The first-stage results are reported in tables 5, 6, and 10[4]. The first of these tables shows the effects of the instruments on trust. Literacy exhibits a strong effect on both the unconditional and conditional measures of trust, which is not seen with early institutions. This restricts the number of instruments in the second-stage estimation. Moreover, it prevents the use of an over-identification test. However, by restricting the instrument set to just the literacy variable, the risk of weak instruments vanishes.

For the broader measures of culture, as table 5 shows, both instruments are significant for

[4]Table 10 can be found in Appendix B.

Table 3: Innovation and Trust, OLS estimates, conditional variables

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Patent Applications | | | Scientists and Engineers | | |
| Schooling 1960 | 0.97 | 0.87 | 1.78 | 0.02 | 0.02 | 0.03 |
| | (1.69) | (1.59) | (1.65) | (0.02) | (0.02) | (0.02) |
| | (1.57) | (1.40) | (1.44) | (0.01) | (0.01)** | (0.01)** |
| Urbanization 1850 | -1.86 | -1.57 | -1.71 | 0.03 | 0.03 | 0.03 |
| | (1.40) | (1.39) | (1.36) | (0.01)** | (0.01)** | (0.01)** |
| | (1.56) | (1.48) | (1.47) | (0.02) | (0.01)* | (0.01)* |
| Trust | 5.05 | | | 0.03 | | |
| | (1.93)** | | | (0.01)* | | |
| | (3.27) | | | (0.02) | | |
| PC Culture | | 249.74 | | | 1.50 | |
| | | (84.23)*** | | | (0.53)*** | |
| | | (98.03)** | | | (0.54)** | |
| PC Cult. Pos. | | | 222.32 | | | 1.61 |
| | | | (73.57)*** | | | (0.58)*** |
| | | | (102.63)* | | | (0.63)* |
| N | 62 | 62 | 62 | 61 | 61 | 61 |
| Adj. $R^2$ | 0.55 | 0.55 | 0.54 | 0.64 | 0.65 | 0.65 |

In parentheses: robust standard errors (above), clustered on countries (below). Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation method: weighted least squares. Weights: Inverse of standard errors of conditional culture indicators. Country fixed effects always included.

the unconditional measure of trust, whereas for the conditional measure, once again, only literacy is significant. As before, weak instruments are not a concern: the F-test statistics for excluded

Table 4: The influence of literacy and early institutions on innovation, reduced form estimates

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Patent Applications | | | Scientists and Engineers | | |
| Schooling 1960 | -0.24 | -0.04 | -0.91 | 0.03 | 0.00 | 0.03 |
| | (2.36) | (1.08) | (2.66) | (0.02)* | (0.02) | (0.02)* |
| | (2.47) | (0.90) | (2.82) | (0.01)** | (0.01) | (0.02)* |
| Urbanization 1850 | -2.76 | -2.45 | -3.14 | 0.02* | 0.02 | 0.02 |
| | (1.23)** | (1.73) | (1.45)** | (0.01) | (0.02) | (0.01) |
| | (1.23)* | (2.08) | (1.74) | (0.01) | (0.01) | (0.01) |
| Literacy | 4.85 | | 4.27 | 0.03 | | 0.03 |
| | (0.98)*** | | (1.14)*** | (0.02)* | | (0.02)* |
| | (0.90)*** | | (0.43)*** | (0.02) | | (0.02) |
| PC Institutions | | 62.63 | 39.66 | | 0.24 | -0.01 |
| | | (37.15)* | (39.95) | | (0.13)* | (0.14) |
| | | (16.58)*** | (31.79)*** | | (0.08)** | (0.14) |
| N | 62 | 62 | 62 | 61 | 61 | 61 |
| Adj. $R^2$ | 0.56 | 0.55 | 0.56 | 0.59 | 0.59 | 0.61 |

In parentheses: robust standard errors (above), clustered on countries (below). Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation method: OLS. Country fixed effects always included.

instruments are 11.51 and 10.52 for the unconditional and conditional variables, respectively. Note, however, that both instruments are used in the first case, but only literacy is used in the second. Results for the positive components of culture are similar and reported in the appendix. It is of note, however, that the F-test statistic is even higher, at 34.90.

Table 7 presents the second-stage results for the effect of culture on patent applications. Culture in all of its measures has a significant effect on patents. The effects are economically relevant as well. Recall that the difference in trust between Sicily and Lombardy is roughly 20 percentage

Table 5: Early literacy and political institutions, and trust, first stage results

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | | Trust | | | Conditional Trust | |
| Schooling 1960 | 0.26 | -0.11 | 0.25 | -0.10 | -0.16 | -0.10 |
| | (0.28) | (0.28) | (0.28) | (0.21) | (0.16) | (0.21) |
| | (0.20) | (0.12) | (0.19) | (0.17) | (0.14) | (0.17) |
| Urbanization 1850 | 0.05 | 0.10 | 0.04 | 0.05 | 0.11** | 0.05 |
| | (0.10) | (0.09) | (0.09) | (0.07) | (0.05)** | (0.07) |
| | (0.06) | (0.07) | (0.06) | (0.06) | (0.05)** | (0.06) |
| Literacy | 0.31 | | 0.30 | 0.25 | | 0.26 |
| | (0.10)*** | | (0.11)*** | (0.07)*** | | (0.08)*** |
| | (0.12)** | | (0.11)** | (0.10)** | | (0.10)** |
| PC Institutions | | 2.65 | 0.76 | | 1.18 | -0.23 |
| | | (2.28) | (1.98) | | (1.53) | (1.38) |
| | | (2.66) | (1.84) | | (2.34) | (1.69) |
| N | 65 | 67 | 65 | 65 | 67 | 65 |
| Adj. $R^2$ | 0.49 | 0.39 | 0.49 | 0.63 | 0.57 | 0.62 |

In parentheses: robust standard errors (above), clustered on countries (below). Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation method: OLS in columns (1)-(3), weighted OLS in columns (4)-(6) with inverse of standard errors of conditional culture (principal component) as weights. Country fixed effects always included.

points. Then, the point estimate of 15.47 implies that if Sicily were to have the same level of trust of Lombardy, it would, per million inhabitants in the active population, increase patent applications by 310 patents. This amounts to more than the average patent applications per million inhabitants (209.95) and to ten times the patent applications in Sicily (32.09). Effects are similar for the other measures of culture. The difference in the first principal component of culture between Sicily and Lombardy is of roughly 50 points, so an estimate that is roughly half of the one attached to trust

Table 6: Early literacy and political institutions, and cultural traits, first stage results

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | | PC Culture | | | Conditional PC Culture | |
| Schooling 1960 | 0.38 | 0.10 | 0.32 | 0.00 | -0.00 | 0.00 |
| | (0.35) | (0.26) | (0.30) | (0.00) | (0.00) | (0.00) |
| | (0.28) | (0.10) | (0.30) | (0.00) | (0.00) | (0.00) |
| Urbanization 1850 | 0.11 | 0.09 | 0.03 | -0.00 | 0.00 | -0.00 |
| | (0.15) | (0.20) | (0.16) | (0.00) | (0.00) | (0.00) |
| | (0.14) | (0.17) | (0.14) | (0.00) | (0.00) | (0.00) |
| Literacy | 0.67 | | 0.48 | 0.01 | | 0.01 |
| | (0.17)*** | | (0.15)*** | (0.00)*** | | (0.00)*** |
| | (0.32)* | | (0.18)** | (0.00)* | | (0.00)* |
| PC Institutions | | 12.34 | 10.16 | | 0.06 | 0.03 |
| | | (2.86)*** | (3.06)*** | | (0.03)* | (0.03) |
| | | (3.40)*** | (2.24)*** | | (0.05) | (0.03) |
| N | 65 | 69 | 67 | 65 | 67 | 65 |
| Adj. $R^2$ | 0.70 | 0.72 | 0.76 | 0.65 | 0.60 | 0.65 |

In parentheses: robust standard errors (above), clustered on countries (below). Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation method: OLS in columns (1)-(3), weighted OLS in columns (4)-(6) with inverse of standard errors of conditional culture (principal component) as weights. Country fixed effects always included.

produces an effect on patent applications that is approximately of the same size.

Columns (3) and (5) in table 7, use both instruments in the first stage. Therefore, the assumption of valid instruments can be tested through overidentification tests. The Hansen J statistics for columns (3) and (5), respectively, are 0.173 and 0.553, with associated p-values of 0.6774 and 0.4570. Therefore, the null hypothesis of valid overidentifying restrictions cannot be rejected, which is evidence that the instruments are valid.

Table 7: Culture and patent applications, second stage results

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | | | Patent Applications | | | |
| Schooling 1960 | -3.93 | 2.48 | -4.07 | 0.00 | -0.27 | 3.70 |
| | (4.34) | (4.24) | (2.79) | (3.63) | (2.35) | (3.75) |
| | (4.79) | (4.97) | (2.66) | (3.55) | (2.46) | (4.50) |
| Urbanization 1850 | -3.36 | -3.62 | -3.65 | -2.35 | -2.45 | -3.28 |
| | (1.46)** | (1.62)** | (1.75)** | (1.60) | (1.65) | (1.45)** |
| | (0.91)** | (1.74)* | (1.88) | (1.83) | (1.91) | (1.69) |
| Trust | 15.47 | 19.92 | | | | |
| | (4.64)*** | (5.21)*** | | | | |
| | (4.67)** | (7.52)*** | | | | |
| PC Culture | | | 7.88 | 907.52 | | |
| | | | (2.17)*** | (293.64)*** | | |
| | | | (3.15)** | (426.84)* | | |
| PC Culture Pos. | | | | | 8.74 | 824.94 |
| | | | | | (2.13)*** | (274.49)** |
| | | | | | (3.29)** | (306.76)** |
| Conditional? | No | Yes | No | Yes | No | Yes |
| N | 60 | 60 | 60 | 60 | 60 | 60 |
| Adj. $R^2$ | 0.61 | 0.62 | 0.66 | 0.65 | 0.71 | 0.69 |

In parentheses: robust standard errors (above), clustered on countries (below). Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation method: 2SLS, weighted by the inverse of the conditional cultural variable in columns (4) and (6). Country fixed effects always included. Instruments: literacy in columns (1),(2),(4), and (6), literacy and PC institutions in columns (3) and (5).

Table 8: Culture and scientists and engineers, second stage results

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | | | Scientists and Engineers | | | |
| Schooling 1960 | 0.01 | 0.05 | 0.01 | 0.03 | 0.03 | 0.06 |
| | (0.03) | (0.04) | (0.03) | (0.03) | (0.02)** | (0.03)** |
| | (0.03) | (0.03) | (0.03) | (0.01)** | (0.01)*** | (0.04) |
| Urbanization 1850 | 0.02 | 0.02 | 0.01 | 0.03 | 0.02 | 0.02 |
| | (0.01) | (0.02) | (0.01) | (0.01)* | (0.01)* | (0.01) |
| | (0.01) | (0.02) | (0.02) | (0.02) | (0.01) | (0.02) |
| Trust | 0.10 | 0.14 | | | | |
| | (0.05)* | (0.08)* | | | | |
| | (0.09) | (0.14) | | | | |
| PC Culture | | | 0.05 | 6.38 | | |
| | | | (0.03)* | (4.12) | | |
| | | | (0.05) | (6.78) | | |
| PC Culture Pos. | | | | | 0.06 | 5.79 |
| | | | | | (0.03)* | (3.68) |
| | | | | | (0.06) | (5.26) |
| Conditional? | No | Yes | No | Yes | No | Yes |
| N | 59 | 59 | 60 | 59 | 59 | 59 |
| Adj. $R^2$ | 0.93 | 0.93 | 0.95 | 0.94 | 0.96 | 0.95 |

In parentheses: robust standard errors (above), clustered on countries (below). Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation method: 2SLS, weighted by the inverse of the conditional cultural variable in columns (4) and (6). Country fixed effects always included. Instruments: literacy in columns (1),(2),(4), and (6), literacy and PC institutions in columns (3) and (5).

Finally, table 8 presents results for the second stage relative to the number of scientists and engineers as a percentage of the active population. In this case, culture, particularly in its conditional variables, does not seem to have a large effect on the dependent variable: many estimates are not significant at the usual levels, and those that are are only at the 10% level. Moreover, even when the effects are statistically distinguishable from zero, the are not large enough to be economically relevant. For instance, the aforementioned 20 percentage-point difference between trust in Sicily and Lombardy amounts to an increase in the percentage of scientists and engineers of 2 percentage points.

Once again, in columns (3) and (5) two instrumental variables are used and, thus, overidentifying restrictions can be tested. The Hansen J statistic is now 1.785 with a p-value of 0.1815 for column (3), and 2.127 with a p-value of 0.1447 for column (5). Once again, there is evidence that the instruments are valid.

In general, then, trust in particular, and culture in general is causally associated with innovation, but not with all measures of it. Whereas regions in Europe with greater trust do exhibit higher levels of innovation, measured through patent applications, they do not exhibit a greater number of scientists and engineers as a percentage of the active population. Before revising these facts and discussing its consequences, it is useful to go through some robustness checks.

## 3.4 Robustness Checks

Given that early institutions were not used as an instrumental variables in all regressions, it is worthwhile to check if it has by itself an effect on innovation. This should allow for smaller standard errors and tighter estimates, as well as controlling for a potentially important variable.

Moreover, the identification strategy used relies on the assumption that the instruments, once the effect of culture on innovation is controlled for, do not have a direct effect on either patent applications or the percentage of scientists and engineers. This assumption cannot be tested for all instruments. However, as a check it is possible to include instruments as regressors in the second stage. If the instruments are valid, the instrument included as a regressor should have no effect on the dependent variable, exhibiting coefficients close to zero. In addition, the causal effect estimated with the included instrument should not change much relative to the other models. Therefore, including early institutions as a regressor in the second stages provides evidence of how good the estimates from the use of literacy as an instrument are.

Tables 11 and 12 (in the appendix) show the estimates from such regressions. As expected, early institutions do not have any effect on either patent applications or the percentage of scientists and engineers on any of the specifications. Moreover, the coefficients associated with culture are roughly of the same magnitude as the ones reported in previous tables. As an example, the effect of unconditional trust on patent application changes from 15.47 to 14.71, whereas on scientists and engineers changes from 0.10 to 0.11.

In general, then, the results from the previous subsection remain unchanged.

# 4 Conclusion

It is reasonably established that culture plays a role in economic development. The interaction between social capital, political institutions, and economic performance has been recurring in the literature since, at least, the work of Putnam et al. (1994). More recently, the effects of culture on economic performance were shown to be *causal*. However, the exact mechanisms that operate to make countries with higher levels of social capital more prosperous is still unknown. This paper posits and confirms that the R&D sector may be part of this effect.

First, it builds a theory to incorporate an equilibrium relationship between interpersonal trust, regulation, and production decisions into a macroeconomic endogenous growth model. In particular, higher levels of trust augment the human capital and labor employed in the economy, both in the production of final goods and in the production of new designs. Two balanced growth equilibria arise: in a baseline model, higher levels of trust increase the production of knowledge and output, and shift human capital towards the R&D sector; in a lab-equipment specification, higher levels of trust just increase the production of knowledge and output, but keeps the allocation of human capital unchanged.

The theory presented can surely be improved. One issue is the fact that even though trust is an equilibrium outcome, it has no dynamics associated with it. Whether these dynamics can be incorporated into the model in a tractable way that still allow for testable predictions to be derived is a matter for future work. Also, a more explicit model for the productivity of human capital in the different sectors is a welcome addition. As it is, it is just assumed that in high trust environments firms may produce in a decentralized way at a higher productivity. One possibility is to incorporate into the model a Garicano (2000) type model. However, such types of models, like in Bloom et al. (2012) treat trust as an exogenous, parametric feature, which may not be desirable. Studying these implications is also a potential avenue of future research.

Then, I use data on European regions to test the implications of each model. In general, social capital is associated with higher levels of innovation output, as measured by patent applications to the EPO per million inhabitants in the active population, but not with innovation inputs, as measured by the number of scientists and engineers as a percentage of the active population. This is evidence in favor of the lab-equipment specification.

There are also good arguments to believe that the estimates presented here are causal. The estimation strategy exploits institutional variations that occur within European countries. This is possible due to accidents in European history, mainly the unification of regions that two centuries ago were independent polities and changing European borders. Then, once country fixed effects are used, variation in early variables become an exogenous source of variation in culture only, and can be used in an instrumental variables framework. Overidentifying restriction tests present evidence that these instruments are valid.

There are, however, caveats in the empirics here presented. Besides the usual issues when historical variables are used as instrumental variables, a first main concern is data availability and the resulting sample size. The identification strategy relies on particular occurrences in European history, restricting the number of observations available. As a consequence, standard errors get inflated, and some effects may not be distinguishable from zero. While this is not a concern regarding estimates related to patents, it may have been the case for the scientists and engineers estimates. A lack of data and small sample size also compromises the empirics by restricting the possibility of robustness checks.

Besides the suggestions above, some paths of future research also arise on empirics. A feature mentioned in Bloom et al. (2012) is the effect of trust in the size of firms. This feature is not contemplated in any part of the analysis here. Augmenting the model to include firm size is an interesting perspective, and it allows the use of firm-level data, which is promising.

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# Appendix

## Appendix A: Derivations and Proofs

**Proof of Proposition 1.** Both $a(\theta)$ and $r(\theta)$ are continuous functions defined on $[0,1]$. Then, since $a(0) < r(0)$ and $a(1) > r(1)$, by the intermediate value theorem there exists $\theta^*$ such that $a(\theta^*) = r(\theta^*)$. Moreover, since both functions are strictly increasing on $\theta$, it follows that $a(\theta) > r(\theta)\ \forall \theta > \theta^*$ and vice versa. $\square$

**Proof of Proposition 2.** Suppose that a constant interest rate $R$ exists. Then, the right-hand side in equation 23 in constant, impyling

$$\frac{\dot{H}_Y}{H_Y} - (\phi - 1)\frac{\dot{H}_A}{H_A} = 0.$$

However, from $H_Y + H_A = H$,

$$\frac{\dot{H}_Y}{H_Y} + \frac{\dot{H}_A}{H_A} = 0 \iff \frac{\dot{H}_Y}{H_Y} = -\frac{\dot{H}_A}{H_A},$$

and so, given that $\phi > 0$, $\dot{H}_A/H_A = 0$ and $\dot{H}_Y/H_Y = 0$. Therefore, since $S_A(\theta)$ is constant, equation 24 implies that $g$ is constant, and from the Euler equation, $R$ must be constant, as assumed. $\square$

**Proof of Proposition 3.** To establish that a higher $\theta$ increases the shifts the allocation of human capital towards the R&D sector, simply notice $S_A(\theta)$ increasing in $\theta$ implies that $H_Y/H_A$ is decreasing in $\theta$ in equation 23. Then, by equation 24, $g$ increases. $\square$

**Proof of Proposition 5.** The growth rate of output $Y$ and of the stock of knowledge $A$ are the same and given by

$$g' = \frac{1}{\sigma}[\Upsilon(S_Y(\theta)H_Y)^{\alpha}(S_L(\theta)L_Y)^{\beta} - \rho],$$

and, therefore, since both $S_Y(\theta)$ and $S_L(\theta)$ are increasing in $\theta$, $g'$ is increasing in $\theta$. It remains to establish that the amount of human capital employed in the R&D sector does not respond to $\theta$. This can be done just by recalling that the R&D does not directly employ human capital. Furthermore, even if it did, since it produces new knowledge using the same function as the final good sector, the human allocation would remain invariable to $\theta$. To see that, notice first that the R&D sector would hire human capital its marginal product matched its remuneration:

$$W_{H,A} = P_A \alpha \mu S_Y(\theta)^\alpha H_A^{\alpha-1} (S_L(\theta) L_A)^\beta \int_0^A X_A(i)^{1-\alpha-\beta} \mathrm{d}i.$$

Then, notice that the same argument would apply to the final goods sector, and

$$W_{H,Y} = \alpha S_Y(\theta)^\alpha H_A^{\alpha-1} (S_L(\theta) L_A)^\beta \int_0^A X_A(i)^{1-\alpha-\beta} \mathrm{d}i.$$

Since in equilibrium $W_{H,A} = W_{H,Y}$, the ratio $H_A/H_Y$ is constant at $P_A \mu = 1$ and independent of $\theta$. $\square$

## Appendix B: Additional Figures and Tables

Table 9: Regions and Conditional Variables

| Region Name | Country | NUTS Regions | Cond. Trust | Cond. PC Culture | Cond. PC Culture Pos. |
|---|---|---|---|---|---|
| Reg.Bruxelles-Cap./Br | Belgium | BE1 | 16.56 | -0.7342 | -0.6145 |
| Vlaams Gewest | Belgium | BE2 | 20.91 | -0.6303 | -0.3863 |
| Region Wallonne | Belgium | BE3 | 3.74 | -0.7980 | -0.6677 |
| Ile De FRance | France | FR1 | 12.34 | -0.6047 | -0.5194 |
| Paris Basin East/West | France | FR2 | 4.26 | -0.7197 | -0.6398 |
| North FR | France | FR3 | 4.24 | -0.8135 | -0.6747 |
| East FR | France | FR4 | 3.72 | -0.6532 | -0.4516 |
| West FR | France | FR5 | 8.58 | -0.4821 | -0.4118 |
| South West FR | France | FR6 | 6.09 | -0.6271 | -0.5499 |
| South East FR | France | FR7 | 10.18 | -0.5617 | -0.4692 |
| Mediterrean FR | France | FR8 | 1.50 | -0.7982 | -0.6964 |
| Baden-Wuerttemberg | Germany | DE1 | 18.00 | -0.2466 | -0.2496 |
| Bayern | Germany | DE2 | 22.95 | -0.4294 | -0.4118 |
| Bremen Hamburg | Germany | DE5 DE6 | 12.12 | -0.6612 | -0.4955 |
| Hessen | Germany | DE7 | 24.89 | -0.0746 | -0.1458 |
| Niedersachsen | Germany | DE9 | 20.76 | -0.1404 | -0.2350 |
| Nordrhein-Westfalen | Germany | DEA | 30.49 | -0.2641 | -0.2890 |
| Rheinland-Pfalz Saarl | Germany | DEB DEC | 36.02 | -0.4919 | -0.4102 |
| Schleswig-Holstein | Germany | DEF | 12.90 | -0.5146 | -0.5482 |
| Piemonte - Vallle D'Aosta | Italy | ITC1 ITC2 | 22.71 | -0.7414 | -0.6010 |
| Liguria | Italy | ITC3 | 30.92 | -0.5155 | -0.4495 |
| Lombardia | Italy | ITC4 | 23.18 | -0.7456 | -0.7011 |

Regions and Conditional Variables (continued)

| Region Name | Country | NUTS Regions | Cond. Trust | Cond. PC Culture | Cond. PC Culture Pos. |
|---|---|---|---|---|---|
| Trentino Alto Adige - Veneto - Friuli Venezia Giulia | Italy | ITD1 ITD2 ITD3 ITD4 | 13.40 | -0.7639 | -0.7160 |
| Emilia-Romagna | Italy | ITD5 | 23.29 | -0.5502 | -0.4247 |
| Toscana | Italy | ITE1 | 18.63 | -0.7221 | -0.7620 |
| Umbria - Marche | Italy | ITE2 ITE3 | 5.68 | -0.8122 | -0.6194 |
| Lazio | Italy | ITE4 | 21.87 | -0.7908 | -0.7164 |
| Campania | Italy | ITF3 | 4.31 | -1.1487 | -1.0722 |
| Abruzzi - Molise - Basilicata | Italy | ITF1 ITF2 ITF5 | 7.2177 | -1.0404 | -0.8367 |
| Puglia | Italy | ITF4 | 3.1292 | -1.1654 | -1.0142 |
| Calabria | Italy | ITF6 | 7.4496 | -1.0503 | -0.8175 |
| Sicilia - Sardegna | Italy | ITG1 ITG2 | 2.6180 | -1.3056 | -1.2805 |
| Noord Nederland - Groningen | Netherlands | NL1 | 40.05 | -0.2807 | -0.0618 |
| Oost Nederland | Netherlands | NL2 | 38.75 | -0.2864 | -0.1085 |
| West Nederland | Netherlands | NL3 | 42.08 | -0.1788 | -0.0476 |
| Zuid Nederland | Netherlands | NL4 | 40.70 | -0.2530 | -0.1061 |
| Galicia | Spain | ES11 | 4.8747 | -0.6140 | -0.3728 |
| Asturias-Cantabria | Spain | ES12 ES13 | 42.8146 | 0.0962 | 0.1049 |
| Pais Vasco | Spain | ES21 | 10.6075 | -0.1508 | -0.0579 |
| Navarra - Rioja | Spain | ES22 ES23 | 32.6523 | -0.1842 | 0.0100 |
| Aragon | Spain | ES24 | 24.6047 | -0.6439 | -0.5792 |
| Madrid | Spain | ES30 | 21.9695 | -0.3416 | -0.0404 |

Regions and Conditional Variables (continued)

| Region Name | Country | NUTS Regions | Cond. Trust | Cond. PC Culture | Cond. PC Culture Pos. |
|---|---|---|---|---|---|
| Castilla-Leon | Spain | ES41 | 21.3850 | -0.2744 | -0.1457 |
| Castilla-La Mancha | Spain | ES42 | 29.1067 | -0.6069 | -0.4003 |
| Extremadura | Spain | ES43 | -6.5258 | -0.5028 | -0.2509 |
| Cataluna | Spain | ES51 | 15.6759 | -0.2763 | -0.3634 |
| Comunidad Valenciana | Spain | ES52 | 8.6441 | -0.5597 | -0.4747 |
| Baleares | Spain | ES53 | 0.4941 | -0.9667 | -1.1511 |
| Andalucia | Spain | ES61 | 24.6120 | -0.4398 | -0.2327 |
| Murcia | Spain | ES62 | 35.0445 | -0.1766 | -0.0727 |
| Canarias | Spain | ES70 | 6.9644 | -0.1412 | 0.0754 |
| North UK | UK | UKC UKD1 | 18.79 | -0.6011 | -0.2172 |
| Yorkshire And Humbers | UK | UKE | 16.2143 | -0.4556 | -0.1642 |
| East Midlands | UK | UKF | 23.80 | -0.3565 | -0.2053 |
| West Midlands | UK | UKG | 13.26 | -0.4061 | -0.2613 |
| East Anglia | UK | UKH1 | 24.36 | -0.3451 | -0.1705 |
| South East UK | UK | UKJ UKI UKH2 UKH3 | 25.92 | -0.5067 | -0.1631 |
| South West UK | UK | UKK | 18.65 | -0.4008 | -0.1869 |
| North West UK | UK | UKD3 UKD4 UKD6 UKD7 | 26.45 | -0.4176 | -0.1328 |
| Wales | UK | UKL | 6.95 | -1.0548 | -0.6419 |
| Scotland | UK | UKM | 25.83 | -0.3978 | -0.0656 |
| Northern Ireland | UK | UKN | 14.5057 | -0.5278 | -0.1510 |

Table 10: Early literacy and political institutions, and positive cultural traits, first stage results

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | | PC Culture | | Cond. PC Culture Positive. | | |
| Schooling 1960 | -0.10 | -0.34 | -0.16 | -0.00 | -0.01 | -0.00 |
| | (0.30) | (0.24) | (0.23) | (0.00) | (0.01) | (0.00) |
| | (0.21) | (0.09)*** | (0.22) | (0.00) | (0.00) | (0.00) |
| Urbanization 1850 | -0.03 | -0.08 | -0.11 | 0.00 | 0.00 | 0.00 |
| | (0.14) | (0.17) | (0.13) | (0.00) | (0.00) | (0.00) |
| | (0.13) | (0.12) | (0.09) | (0.00) | (0.00) | (0.00) |
| Literacy | 0.61 | | 0.42 | 0.01 | | 0.01 |
| | (0.14)*** | | (0.10)*** | (0.00)*** | | (0.00)*** |
| | (0.27)* | | (0.14)** | (0.00)** | | (0.00)** |
| PC Institutions | | 11.71 | 10.48 | | 0.03 | 0.01 |
| | | (2.56)*** | (2.64)*** | | (0.04) | (0.03) |
| | | (3.26)*** | (1.63)*** | | (0.06) | (0.04) |
| N | 65 | 69 | 67 | 65 | 67 | 65 |
| Adj. $R^2$ | 0.70 | 0.74 | 0.79 | 0.74 | 0.67 | 0.73 |

In parentheses: robust standard errors (above), clustered on countries (below). Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation method: OLS in columns (1)-(3), weighted OLS in columns (4)-(6) with inverse of standard errors of conditional culture (principal component) as weights. Country fixed effects always included.

Table 11: Robustness of patent estimates, including PC institutions as a regressor

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | | | Patent Applications | | | |
| Schooling 1960 | -4.03 | 1.41 | -3.97 | -0.40 | 0.39 | 2.48 |
| | (4.22) | (4.02) | (2.85) | (3.50) | (2.50) | (3.53) |
| | (4.79) | (4.97) | (2.66) | (3.55) | (2.46) | (4.50) |
| Urbanization 1850 | -3.49 | -3.51 | -3.52 | -2.41 | -2.05 | -3.23 |
| | (1.53)** | (1.59)** | (1.65)** | (1.57) | (1.50) | (1.44)** |
| | (0.91)** | (1.74)* | (1.88) | (1.83) | (1.91) | (1.69) |
| PC Institutions | 16.36 | 64.46 | -19.11 | 37.20 | -38.91 | 62.24 |
| | (53.40) | (66.31) | (45.02) | (64.23) | (49.86) | (60.05) |
| | (78.00) | (100.80) | (44.68) | (95.05) | (44.71) | (82.92) |
| Trust | 14.71 | 16.85 | | | | |
| | (4.88)*** | (5.78)*** | | | | |
| | (4.23)** | (7.28)* | | | | |
| PC Culture | | | 8.34 | 827.72 | | |
| | | | (2.79)*** | (338.16)** | | |
| | | | (3.56)* | (445.14) | | |
| PC Culture Pos. | | | | | 9.76 | 703.59 |
| | | | | | (2.87)*** | (277.77)** |
| | | | | | (3.61)** | (311.42)* |
| Conditional? | No | Yes | No | Yes | No | Yes |
| N | 60 | 60 | 60 | 60 | 60 | 60 |
| Adj. $R^2$ | 0.63 | 0.68 | 0.64 | 0.67 | 0.68 | 0.72 |

In parentheses: robust standard errors (above), clustered on countries (below). Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation method: 2SLS, weighted by the inverse of the conditional cultural variable in columns (4) and (6). Country fixed effects always included. Instruments: literacy.

Table 12: Robustness of scientists and engineers estimates, including PC institutions as a regressor

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | | | Scientists and Engineers | | | |
| Schooling 1960 | 0.01 | 0.05 | 0.01 | 0.04 | 0.05 | 0.06 |
| | (0.03) | (0.04) | (0.03) | (0.03) | (0.01)*** | (0.03)* |
| | (0.03) | (0.03) | (0.03) | (0.01)** | (0.01)*** | (0.03) |
| Urbanization 1850 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 |
| | (0.01) | (0.02) | (0.01) | (0.01)* | (0.01)*** | (0.01) |
| | (0.01) | (0.02) | (0.02) | (0.02) | (0.01) | (0.02) |
| PC Institutions | -0.20 | -0.11 | -0.46 | -0.34 | -0.61 | -0.13 |
| | (0.32) | (0.37) | (0.35) | (0.47) | (0.40) | (0.32) |
| | (0.43) | (0.69) | (0.44) | (0.66) | (0.51) | (0.54) |
| Trust | 0.11 | 0.14 | | | | |
| | (0.06)* | (0.08)* | | | | |
| | (0.09) | (0.12) | | | | |
| PC Culture | | | 0.06 | 7.11 | | |
| | | | (0.04) | (4.76) | | |
| | | | (0.06) | (6,67) | | |
| PC Culture Pos. | | | | | 0.08 | 6.03 |
| | | | | | (0.04) | (3.95) |
| | | | | | (0.04) | (4.91) |
| Conditional? | No | Yes | No | Yes | No | Yes |
| N | 59 | 59 | 59 | 59 | 59 | 59 |
| Adj. $R^2$ | 0.93 | 0.93 | 0.94 | 0.93 | 0.95 | 0.94 |

In parentheses: robust standard errors (above), clustered on countries (below). Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimation method: 2SLS, weighted by the inverse of the conditional cultural variable in columns (4) and (6). Country fixed effects always included. Instruments: literacy.