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Neo-Schumpeterian Growth: Political and Religious Stability Matter★

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Abstract

The purpose of this paper is to re-investigate one of the most prominent predictions of Neo-Schumpeterian growth theory—namely, that economic development is augmented by investments in R&D—by stressing that such a prediction applies only when conditional on institutional and socio-cultural stability. To achieve this aim, an unbalanced panel data set of 23 OECD members and accession candidate countries from 1998 to 2018 is employed to estimate a Type III growth equation extended by interaction terms between R&D intensity and government/religious stability. Using a full set of macro controls and a full set of country-specific fixed effects, it is found that the marginal association of R&D and economic development strictly increases with institutional stability. Quantitatively, a 1-standard-deviation increase in R&D intensity is found to have a negligible association with GDP per capita when government stability is low but raises GDP per capita by up to 13.3% when government stability is high. Moreover, a symmetric relation is found such that a 1-standard-deviation increase in R&D intensity raises GDP per capita by up to 12.9% when religious stability is high. In contrast, the unconditional association between R&D and economic development is found to be small and statistically indistinguishable from 0 when religious stability is low.

Keywords:
R&D intensity; economic development; neo-Schumpeterian growth; institutions; government stability; religious stability; technology diffusion; OECD members and candidates panel.

JEL:
O30; O40; O43; P16; Z12; C23.

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1. Introduction

The history of capitalism from the Industrial Revolution onwards is one of increasing differences in productivity and living conditions across different parts of the globe. For more than 50 years, researchers and economists are still trying to find an answer to question of different levels of successful economic growth and prosperity (Baltgailis 2019). One of the major contributions to this issue has been made by the neo-Schumpeterian theory of endogenous economic growth, which demonstrates the central role of innovation in productivity differences. Unfortunately, we know from the work of Andrés Rodríguez-Pose (1998, 2013), that the mechanism linking R&D to growth is not straightforward and depends on many factors, foremost among which is institutional quality.

But history teaches us that in many periods and many countries, institutions and religious powers were – and sometimes still are – closely linked, which obviously impacts growth (Bisin et al., 2023). Countries like Finland and the United States show that high R&D and stable governments lead to productivity gains. In contrast, nations with political or religious instability, such as France and Turkey, see less growth from R&D investment. The relationship between innovation, institutions, and religion is complex and longstanding.

In the fifteenth century, the invention of printing enabled the rapid spread of Protestantism, with supporters translating Martin Luther’s works and distributing them widely, despite Catholic repression. The widespread dissemination of Protestantism can be attributed to the early support of printers and booksellers who converted to evangelical ideas decided to translate Luther's writings into the vernacular, which illustrates the sometimes close links between innovation and religion. Gutenberg’s movable type press, developed in Mainz around 1450, quickly expanded across Europe due to skilled workers, trade routes, and rising demand from institutions, lowering production costs compared to manuscripts. This expansion occurred in successive waves: first across Germany and neighboring regions, then into Italy, and finally into France, the Low Countries, and the Iberian Peninsula from the 1470s onward. However, although France adopted printing relatively early (Paris in 1470), its diffusion there remained slower (c.f. Appendix A1) and far more tightly regulated than in the German or Italian regions.

Strict intellectual and religious control by the Sorbonne - the leading theological authority in Western Europe - as well as by the monarchy supported by the Parlement of Paris - the institutional authority in France - led to censorship, bans on Protestant Bibles, and required publishing authorization, making France highly restrictive for printers. Political centralization further enforced these controls, unlike the decentralized cities of Germany and Italy. Economic resistance from established guilds and less favorable commercial conditions also limited the growth of printing in France, which lacked investment and major international trade hubs except for Lyon.

Thus, although printing reached France only 15 to 20 years after Germany and Italy, its development there was restrained by a combination of religious, political, economic, and institutional factors. Strict regulation by the Sorbonne, centralized royal authority, resistant guilds, and less active commercial networks led to higher book production costs and slower growth in the sector[1]. This example highlights how political and religious institutions can significantly influence economic development and innovation.

The paper is structured as follows: in Section 2, we present the main literature. In Section 3, we provide detail on the data and variables. In Section 4, we present our methodology while section 5 is dedicated to descriptive statistics and preliminary analysis. Our empircal results and their interpretation are in section 6. Finally, in the conclusion, we summarise our main contributions.

2. Literature

In the neo-Schumpeterian theory of endogenous economic growth, innovation has a critical role to play as a catalyst for cross-country differences in productivity and income levels. R&D inputs are the drivers for the supply of new ideas and technology, which in turn increase TFP through sustained growth in 'strong' endogenous economic growth theory with semi-endogenous technical change or level effects with semi-endogenous growth rate of research productivity (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992; Jones, 1995a,b). The empirical studies thus emphasize the critical role played by R&D intensity in determining economic performance in the long run, yet simultaneously emphasize the fact that the R&D payoff varies across different institutional settings. The very premise our research, however, lies in the fact that the macroeconomic payoff to R&D investments does not mechanically depend on R&D investments, but on whether the political and socio-cultural environment provides scope for financing, protecting, and diffusing inventions on a larger scale.

The first strand of the literature provides a rationale for the fact that why political instability would matter for the R&D-growth relationship. R&D investments are irreversible, forward-looking, and are subject to appropriation risk and policy risk, and hence would reduce the incentives for R&D even in the presence of underlying scientific potential. Moreover, political instability would reduce economic growth and investments, partly because it would create uncertainty, which in turn would reduce long-term projects and commitment power (Alesina et al., 1996). In a broader sense, the literature on institutions and growth has stressed the importance of property rights, predictability of policies, and law enforcement for the return

[1] A table detailing the main factors affecting the spread of printing in Germany, Italy and France is available in Appendix A2.

on investment in production (Knack & Keefer, 1995; Acemoglu et al., 2001; Rodrik et al., 2004). If this literature is applied to the R&D investment function, it becomes clear that as a consequence of the decrease in political stability, the return on investment in R&D decreases as a consequence of the increase in the probability of expropriation. Moreover, as a consequence of the increase in political stability, investment in R&D will lead to aggregate productivity growth as a consequence of the existence of complementary institutions to diffuse knowledge.

A second literature strand deals with the topics of religion, cultural conflicts, and the diffusion of knowledge. The literature on the role of religion in economic development is broad. The most important part of the literature dealing with the role of religion in economic development is the literature arguing that the relation between Protestantism and economic development can be explained by human capital formation in the form of increased literacy and schooling instead of the 'work ethic' hypothesis (Becker & Woessmann, 2009). The literature is important for the neo-Schumpeterian framework as a consequence of the crucial complementarity between the two topics: the return on investment in R&D increases as a consequence of human capital formation, and religion plays a role in human capital formation.

More relevant to the results of these innovations, the political economy approach developed by Bénabou et al. (2013) incorporates a conflict between scientific progress and religious authority in a formal model. Some of these innovations are those which are perceived to be threatening religious beliefs and authority. The political response to a situation of this type can be accommodation, laissez-faire secularization, or blocking diffusion, depending on the incentives faced by political and religious authorities (Bénabou et al., 2013). An important feature of the political economy approach is that, unlike the standard macroeconomic approach, religious conflict is not just a critical cultural background factor but can also be a constraint to the diffusion of innovations. In other words, "religious stability" is a theoretically channel that can affect the growth effect of R&D. When levels of religious stability are low, it can be thought of as a reflection of high levels of religious tension, polarization, or conflict. In such a situation, it can be expected that the political costs of diffusion will be naturally higher, implying that the macroeconomic payoff to a given unit of R&D expenditure will be lower. When levels of religious stability are high, it can be expected that there will not be any political costs of diffusion, implying a stronger R&D-growth linkage. There is historical evidence for this approach in a somewhat more direct fashion. There is a large literature on religious tolerance in Prussia in the 19th century. The basic hypothesis of the study is that, for a given level of scientific knowledge, levels of religious tolerance and pluralism are associated with higher levels of technological creativity and innovations, as it facilitates interaction among groups and attracts talent. Cities with greater levels of religious diversity/tolerance had more valuable patents

(Cinnirella and Streb, 2017).

This perspective is immediately relevant to the 'religious stability' mechanism in our research, in the sense that low levels of stability could be seen as equivalent to a 'tax' on diffusion/inflow of skilled people, whilst higher levels of stability could be seen as equivalent to a 'social infrastructure' that enhances the productivity of inventive effort.

Another historical micro-setting that could be of potential relevance is the historical city of Berlin in the early modern period, which was a major center of refuge for persecuted minorities, and in which the rulers actively encouraged settlement by various groups (including Huguenots, Jews, and Bohemians). Using within-city-district panel data, the evidence suggests that there is a positive relationship between increased ethnic diversity and measures of textile production, consistent with the presence of complementarity effects between groups, and the idea that the co-location of several groups in a tolerant environment will boost economic activity more than any of the groups could have achieved in isolation (Hornung, 2019).

This historical episode is of potential relevance to the macro mechanism highlighted here, in the sense that it is an episode in a setting in which religious/ethnic tensions are under control, and in which supportive institutions for coexistence are in place, both of which will boost productivity via complementarity effects, etc., and hence boost the growth impact of innovative effort.

Lastly, the macro results indicate the possible negative effect between religiosity and productivity growth, which is mediated through the scientific attitude, cognitive style, and productivity of R&D efforts. A decline in church attendance will lead to an increase in total factor productivity growth, which is connected to our results through religiosity, innovation, and the diffusion of scientific ideas, as per the panel study on developed economies by Herzer and Strulik (2020).

This is not equivalent to our definition of religious stability; however, it is connected to the overall idea that religious environments have an impact on the macro environment, which then translates into R&D and then into science and productivity growth.

The overall implication from these studies is an interaction-based model for R&D efforts as a requirement for driving growth through an innovation-based mechanism; however, this is dependent upon the macro environment as defined by political and religious stability. When political stability is low, the diffusion process is much more uncertain. Therefore, the R&D and growth relationship is much weaker. When religious stability is low, the diffusion process is much more costly. Therefore, the R&D and growth relationship is much weaker as well. When both are high, the overall macro environment is much more conducive for driving R&D efforts and its diffusion. Therefore, this overall relationship is much stronger.

This is consistent with the overall neo-Schumpeterian mechanism for R&D efforts driving overall growth through an innovation mechanism as per Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992), Bénabou et al. (2013), Cinnirella and Streb (2017), and Hornung (2019).

3. Data

We use an unbalanced panel of 23 economies over 1998-2018, consisting mainly of OECD members and including 3 OECD accession candidate countries (Argentina, Bulgaria, and Romania).[2] In theory, this represents 483 observations; however, due to missing values for R&D intensity, the final sample includes 468 observations. The countries in the sample are Argentina, Austria, Belgium, Bulgaria, Canada, South Korea, Denmark, Spain, the United States, Finland, France, Hungary, Ireland, Italy, Japan, the Netherlands, Poland, Portugal, Romania, the United Kingdom, Slovenia, the Slovak Republic, and Turkey.

The dependent variable corresponds to the logarithm of GDP per capita in constant 2015 US dollars. Data are taken from the World Bank's World Development Indicators (WDI). Using the logarithm of real GDP per capita allows for measuring economic growth while controlling for inflation and differences in price levels across countries.

The growth rate of the population also comes from the World Bank and represents the annual percentage change in total population. This variable captures demographic effects that may influence long-run growth dynamics.

R&D intensity is measured using two complementary indicators. The first is the number of researchers in R&D per 100 inhabitants. This ratio reflects the human effort devoted to research. The second measure corresponds to R&D expenditures as a percentage of GDP, obtained from the World Bank. This variable captures the financial resources invested in research and innovation within each economy.

Institutional quality is proxied by two variables drawn from the International Country Risk Guide (ICRG):

- Government stability assesses the ability of a country to maintain a coherent and durable executive. The indicator is based on three components: government unity, legislative strength, and popular support. Each component is scored from 0 to 4, giving a total possible score of 12. Higher scores indicate stronger political stability.
- Religious stability measures the extent to which a country faces religious tensions or risks of religiously driven conflict. The index ranges from 0 to 6, with 6 representing full stability. It captures factors such as the dominance of a single religious group over governance, restrictions on

[2] Argentina, Bulgaria, and Romania are not OECD members; accession discussions were opened in 2022.

religious freedom, or the presence of interreligious tensions.

Finally, a set of macroeconomic control variables is obtained from the Global Macroeconomic Database. These controls include:

- trade openness (exports and imports as a percentage of GDP),
- final consumption and investment (as percentages of GDP),
- government expenditures, revenues, tax revenues, public deficit, and public debt (all expressed as percentages of GDP),
- inflation rate, and unemployment rate.

Together, these data cover a wide range of economic and institutional dimensions. This allows for a comprehensive analysis of how institutional quality influences the relationship between R&D intensity and economic growth across OECD countries.

4. Methodology

We use a Type III approach to test the relevance of either the Schumpeterian or the semi-endogenous growth model, following the framework described by Herzer (2022), although he does not apply it himself. We include an interaction term between institutional quality and R&D intensity, which represents a novelty relative to the existing literature. Only individual fixed effects are considered; time fixed effects are not included, as justified by Herzer (2022).[3] In the Appendix B, we demonstrate how this econometric model is derived from the theoretical framework and show the theoretical values of the coefficients under both the semi-endogenous and Schumpeterian growth models. The model to be estimated can therefore be written as follows:

$$g_{y,it} = \mu_i + \beta_1 g_{L,it} + \beta_2 \frac{X_{it}}{Q_{it}} + \beta_3 \text{Instit}_{it} + \beta_4 \left(\frac{X_{it}}{Q_{it}} \times \text{Instit}_{it}\right) + \gamma' Z_{it} + \varepsilon_{it} \quad (1)$$

In our model, $g_{y,it}$ denotes the logarithm of per capita output in country i at time t. The term $g_{L,it}$ represents the growth rate of the labor force, while X_{it} corresponds to an R&D input and Q_{it} is the stock of product varieties. The ratio X_{it}/Q_{it} therefore captures R&D intensity. Instit_{it} measures the quality

[3] Year fixed effects absorb all shocks common to the sample in a given year. In the Herzer (2022) testing framework used here, we do not include year dummies in the baseline because they would, by construction, remove common time variation that may be part of the long-run component relevant for discriminating between Schumpeterian and semi-endogenous predictions. Instead, we include a selective set of macroeconomic controls—fiscal variables, inflation, and unemployment—that proxy cyclical conditions in a targeted way, including crisis-related dynamics, while remaining aligned with the theoretical restrictions underlying the specification.

of institutions in each country at time t , and the product of X_{it}/Q_{it} and Instit_{it} represents the interaction between R&D intensity and institutional quality. Z_{it} is a vector of additional control variables that may influence growth. Finally, μ_i captures country-specific fixed effects, accounting for unobserved characteristics that are constant over time, and ε_{it} is the idiosyncratic error term, capturing shocks or factors not included in the model.

Estimating the empirical specification allows us to assess how different factors contribute to economic growth. If the coefficient β_1 is positive and significant, while β_2 and β_4 are not, this suggests that growth is primarily driven by the accumulation of exogenous factors, such as labor force expansion, rather than by R&D intensity. In this case, the growth pattern corresponds to the standard semi-endogenous mechanism.

Conversely, if β_2 is positive and significant while β_1 is not, growth appears to depend mainly on R&D intensity, in line with the neo-Schumpeterian framework. Importantly, if β_4 is positive and significant, even when β_1 and β_2 are not, this implies that the neo-Schumpeterian mechanism becomes relevant only in countries with high-quality institutions. In such contexts, R&D efforts are associated with larger income differences, highlighting the crucial role of institutional quality, such as government stability or cultural and religious stability. This finding suggests that before implementing R&D policies, a stable institutional environment may matter, as the effectiveness of innovation efforts could depend on it.

We interpret the estimates as reduced-form associations implied by the theoretical framework, focusing on whether the marginal relationship between R&D intensity and GDP per capita varies systematically with political and religious stability. Overall, this interpretation extends the existing literature by emphasizing that institutional quality moderates the impact of R&D on growth, and that strong institutions are a prerequisite for realizing the full potential of research and innovation.

5. Descriptive Statistics and Preliminary Analysis

This section provides a descriptive overview of the main variables used in the analysis, covering economic development, R&D intensity, and institutional stability across 23 OECD countries between 1998 and 2018. Descriptive statistics and graphical illustrations are used to highlight the variability across countries and over time, setting the stage for understanding how institutional and scientific capacities may interact to influence economic performance.

Table 1 presents descriptive statistics for the main variables used in the analysis, providing an overview of their central tendency, dispersion, and range across the 23 OECD countries over the period 1998–2018.

The descriptive analysis reveals substantial heterogeneity across countries in economic development, R&D intensity, and institutional and religious stability. The dependent variable, the logarithm of GDP per capita in constant 2015 US dollars, has a mean of 10.06[4] with a standard deviation of 0.706, reflecting the variation in economic development across countries. R&D intensity, measured by the number of researchers per 100 inhabitants, averages 0.318, which corresponds to roughly 0.3 researchers per 100 inhabitants. Turkey shows minimal scientific investment with only 0.03 researchers per 100 inhabitants, whereas Denmark reaches 0.801. R&D expenditure averages 1.66% of GDP with a standard deviation of 0.932, showing that countries do not invest equally in R&D. Working-age population growth has a mean of 0.004 with a standard deviation of 0.006. Government stability has a mean of 7.96, with Hungary in 2009 reaching a minimum of 4.042 amid a financial and political crisis, GDP contraction, €20 billion in international assistance, and a technocratic government led by Gordon Bajnai. Religious stability has a mean of 5.236, with the Netherlands from 2005 to 2008 recording a low of 2.5 following the assassinations of Pim Fortuyn and Theo van Gogh, which exacerbated Islamophobia, fueled anti-immigration demonstrations, and strengthened populist parties like Geert Wilders' PVV. Overall, these statistics highlight the variation across countries and the influence of historical, political, and policy contexts on scientific capacity and governance.

Table 1. Descriptive Statistics of Main Variables

	N	Mean	Std. Dev.	P10	Median	P90	Min	Max
Log of GDP per capita	483	10.060	0.706	8.993	10.355	10.775	8.172	11.191
Number of researchers per 100 inhabitants	468	0.318	0.176	0.109	0.295	0.531	0.030	0.801
R&D expenditure (% of GDP)	483	1.663	0.932	0.495	1.575	3.010	0.362	4.516
Growth rate of the working-age population	483	0.004	0.006	-0.003	0.004	0.011	-0.022	0.029
Growth rate of R&D researchers	442	0.040	0.067	-0.025	0.034	0.100	-0.187	0.465
Government stability	483	7.962	1.467	6.167	7.792	10.000	4.042	11.083
Religious stability	483	5.236	0.727	4.000	5.500	6.000	2.500	6.000

This table reports summary statistics for the main variables used in the empirical analysis. P10 and P90 refer to the 10th and 90th percentiles, respectively.

The descriptive statistics are complemented by graphical representations, which illustrate the distributions, trends, and relationships among the main variables over time.

[4] The mean of log GDP corresponds to a GDP per capita of approximately 23,500 USD when exponentiated (exp (10.06)), in constant 2015 US dollars.

In the Appendix C, Figures C.1 and C.2 present temporal trends in GDP per capita and R&D intensity. GDP per capita shows a general upward trend, interrupted by the 2008 financial crisis. Western European and North American countries maintain high levels throughout the period, whereas Eastern and Southern European countries display significant catch-up growth. R&D intensity increases in most countries, led by Denmark, Finland, and Ireland. Some countries, such as Bulgaria, remain consistently low, while others including Ireland, Slovenia, and South Korea show strong growth trajectories, reflecting successful national policies and investment in research.

Figures C.3 and C.4 illustrate government and religious stability over time. Government stability declines modestly after 2008, with Northern and Western European countries generally maintaining high stability and several Southern and Eastern European countries exhibiting volatility. Religious stability remains relatively high overall, with occasional fluctuations linked to social or political events. These figures highlight that institutional conditions vary both across countries and over time, suggesting that the capacity of R&D to translate into economic growth may depend on these institutional environments. The rest of Appendix C present the maps for the variable involved in the analysis. Appendix D provides extensive definition of the ICRG variables that we will use in the rest of the analysis.

Overall, the descriptive evidence highlights strong heterogeneity across OECD countries in terms of economic development, R&D intensity, and institutional stability. These patterns suggest that the growth effects of R&D may depend on the surrounding institutional environment.

The next section presents the results of the empirical analysis. Building on the Type III growth model proposed by Herzer (2022), we estimate a set of panel regressions with country fixed effects to examine whether the relationship between R&D intensity and economic performance is conditional on institutional stability. This approach allows us to move beyond descriptive patterns and to identify the interaction mechanisms through which scientific intensity and institutional environments jointly influence economic growth.

6. Results

This section presents the empirical results, beginning with the baseline estimates of the Type III model and then examining how the association between R&D intensity and economic performance varies with government and religious stability.

Table 2 presents the baseline estimates of the Type III model proposed by Herzer (2022), without including institutional quality or its interaction with R&D intensity. The results show that R&D intensity is positively and significantly associated with income levels, while the estimated relationship with growth of the working-age population is not robust. These baseline estimates thus support the neo-Schumpeterian framework, in which growth depends primarily on R&D intensity rather than demographic dynamics.

We then extend this baseline model to examine whether the impact of R&D intensity on economic performance depends on institutional stability, particularly governmental and religious stability. As noted by Tebaldi (2008), well-functioning institutions are necessary for R&D policies to have a positive association with growth. Accordingly, the influence of R&D intensity may only materialize in countries with sufficiently stable institutions, implying a direct policy-relevant conclusion: R&D policies have a positive influence only when the institutional environment is stable.

Table 2. Baseline Estimates

	GDP per capita in log (1)	GDP per capita in log (2)
Growth of working-age population	5.8079**	-1.0328
	(2.5687)	(2.9437)
Number of researchers per 100 inhabitants	1.0487***	0.6213***
	(0.1848)	(0.1823)
Trade openness (% of GDP)		0.2131**
		(0.0980)
Final consumption (% of GDP)		-0.8896**
		(0.3448)
Investment (% of GDP)		-0.2751
		(0.3649)
Government revenues (% of GDP)		-0.4989
		(0.3805)
Government expenditures (% of GDP)		0.3999*
		(0.2320)
Tax revenues (% of GDP)		-0.9395**
		(0.4293)
Government deficit (% of GDP)		-0.2127
		(0.2908)
Government debt (% of GDP)		0.0145
		(0.0515)
Inflation rate (%)		-0.8777***
		(0.1678)
Unemployment rate (%)		-2.5488***
		(0.3258)
Intercept	9.6884***	10.9649***
	(0.0638)	(0.3143)
R-squared	0.32	0.79

Number of observations	468	468
F-statistic	16.12	80.00

Notes. robust standard errors clustered at the country level in parentheses. Country fixed effects included. *, **, *** denote significance at 10%, 5%, and 1% levels.

The following tables present the estimates of our core econometric specification, where we examine whether the impact of R&D intensity on growth depends on institutional stability, starting with the model without control variables.

The results reported in Table 3 highlight the differentiated role of growth determinants depending on institutional context. The growth of the working-age population is positive and statistically significant across all models, consistent with the semi-endogenous growth framework: an increase in the labor force directly contributes to per capita GDP growth.

In contrast, the estimated relationship between R&D intensity and growth is strongly conditional on government stability. In a simple specification, the number of researchers per capita (as a measure of R&D intensity) is positive and highly significant, consistent with the neo-Schumpeterian model, where greater scientific intensity drives productivity gains. However, once the interaction term between R&D intensity and government stability is included, the direct association of R&D intensity becomes non-significant, while the interaction term is positive and statistically significant. This indicates that the neo-Schumpeterian model becomes valid only when government stability is sufficiently high.

The marginal association plot vividly illustrates this pattern: the influence of R&D intensity on growth increases progressively with government stability. In countries with low government stability, the influence of R&D intensity remains small and statistically insignificant, but it becomes positive and significant only beyond a certain threshold of stability. In other words, intensifying R&D only contributes meaningfully to economic growth in countries with high government stability.

This finding has important policy implications. Promoting higher R&D intensity in countries with weak government stability is unlikely to be associated with substantial growth returns. Innovation policies should be analyzed by considering government stability, with strong governance as a potential mediator for higher scientific intensity to influence significantly the income level.

Finally, religious stability and its interaction with R&D intensity are not significant, suggesting that in this framework, government stability is the central channel through which scientific intensity affects growth.

In summary, the core result is clear: the effectiveness of policies aiming to increase R&D intensity depends on government stability, and the interaction term demonstrates that the growth impact of scientific intensity becomes stronger as government stability increases, reaching statistical and economic significance only at high levels of stability.

Table 3. Influence of government and religious stability (growth equation)

	GDP per capita in log (1)	GDP per capita in log (2)
Growth of working-age population	6.8586**	5.9295**
	(2.4362)	(2.6131)
Number of researchers per 100 inhabitants	-0.3102	1.7334
	(0.4926)	(1.0894)
Government stability	-0.0698***	
	(0.0227)	
Number of researchers per 100 inhabitants × Government Stability	0.1480**	
	(0.0598)	
Religious Stability		0.0267
		(0.0637)
Number of researchers per 100 inhabitants × Religious Stability		-0.1293
		(0.1928)
Intercept	10.3029***	9.5497***
	(0.1997)	(0.3524)
R-squared	0.43	0.32
Number of observations	468	468
F-statistic	11.87	7.51

Notes. robust standard errors clustered at the country level in parentheses. Country fixed effects included. *, **, *** denote significance at 10%, 5%, and 1% levels.

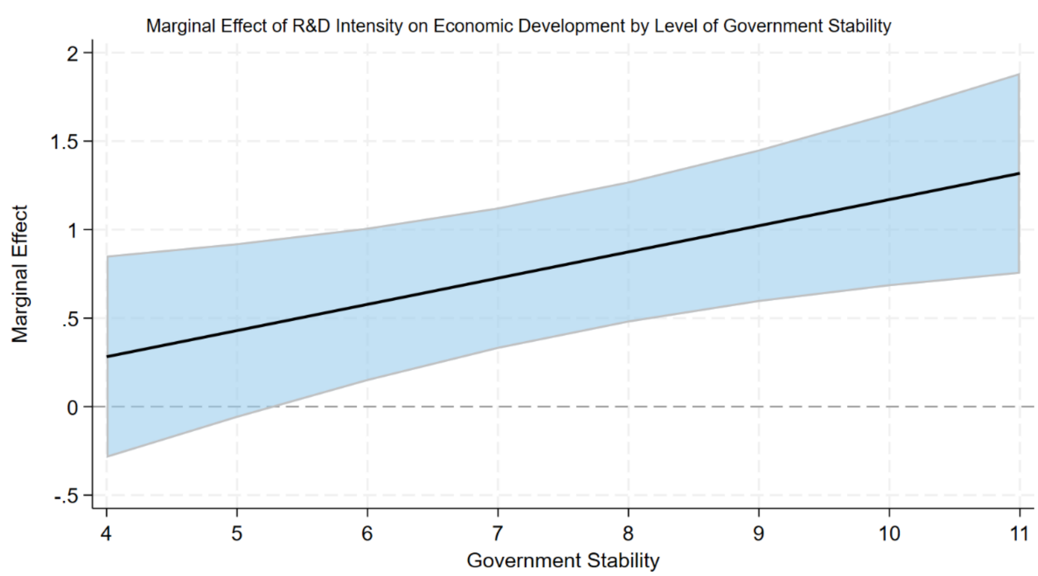

Figure 1. Marginal effect of R&D intensity on economic development by government stability.

Notes. The solid line reports the estimated marginal effect of R&D intensity on economic development evaluated at each value of the government stability index, computed from the interaction specification between R&D intensity and government stability. The shaded area represents the corresponding confidence interval around the marginal effect. The horizontal dashed line denotes a zero marginal effect; values above it indicate that higher R&D intensity is associated with higher economic development at the given level of government stability.

Table 4. Influence of government and religious stability with controls (growth equation)

	GDP per capita in log (1)	GDP per capita in log (2)
Growth of working-age population	-1.3974	-0.5821
	(2.7058)	(2.7977)
Number of researchers per 100 inhabitants	-0.0544	-0.9196*
	(0.3091)	(0.5299)
Government stability	-0.0440***	
	(0.0098)	
Number of researchers per 100 inhabitants × Government stability	0.0737**	
	(0.0329)	
Religious Stability		-0.1039***
		(0.0337)
Number of researchers per 100 inhabitants × Religious stability		0.2754**
		(0.1031)
Trade openness (% of GDP)	0.1707**	0.2266**
	(0.0704)	(0.1012)
Final consumption (% of GDP)	-0.6950**	-0.9715***
	(0.2683)	(0.2979)
Investment (% of GDP)	-0.2367	-0.1893
	(0.3337)	(0.3592)
Government revenues (% of GDP)	-0.7191**	-0.4887
	(0.2974)	(0.3683)
Government expenditures (% of GDP)	0.2507	0.4527**
	(0.2156)	(0.1959)
Tax revenues (% of GDP)	-0.7299**	-0.8055*
	(0.3469)	(0.3906)
Government deficit (% of GDP)	-0.1372	-0.1595
	(0.2206)	(0.2210)
Government debt (% of GDP)	0.0054	0.0214
	(0.0520)	(0.0489)
Inflation rate (%)	-0.8184***	-0.9591***
	(0.1211)	(0.1298)
Unemployment rate (%)	-2.6894***	-2.4463***
	(0.2981)	(0.3310)
Intercept	11.3297***	11.5036***
	(0.2806)	(0.2723)
R-squared	0.83	0.80
Number of observations	468	468
F-statistic	64.95	183.29

Notes. robust standard errors clustered at the country level in parentheses. Country fixed effects included. *, **, *** denote significance at 10%, 5%, and 1% levels.

Table 4 introduces a comprehensive set of control variables to assess the robustness of these results. Once controls are included, the semi-endogenous channel via the working-age population is no longer significant. Importantly, the conditional association of R&D remains robust: the interaction with government stability continues to be positive and significant, confirming that the neo-Schumpeterian effect materializes only when government stability is high. Additionally, the interaction with religious stability becomes positive and significant, indicating that R&D intensity also promotes growth in contexts with strong religious institutional stability. Overall, a one-standard-deviation increase in R&D intensity has no significant impact on economic performance when political stability is low, but raises GDP per capita by up to 13.3% under strong government stability[5] and by 12.9% under high religious stability[6]. Marginal association plots confirm that the growth-enhancing influence of scientific intensity manifests only under high levels of both government and religious stability. These results may have some policy implication: R&D-driven growth has a positive influence only in contexts with a stable government and strong religious stability.

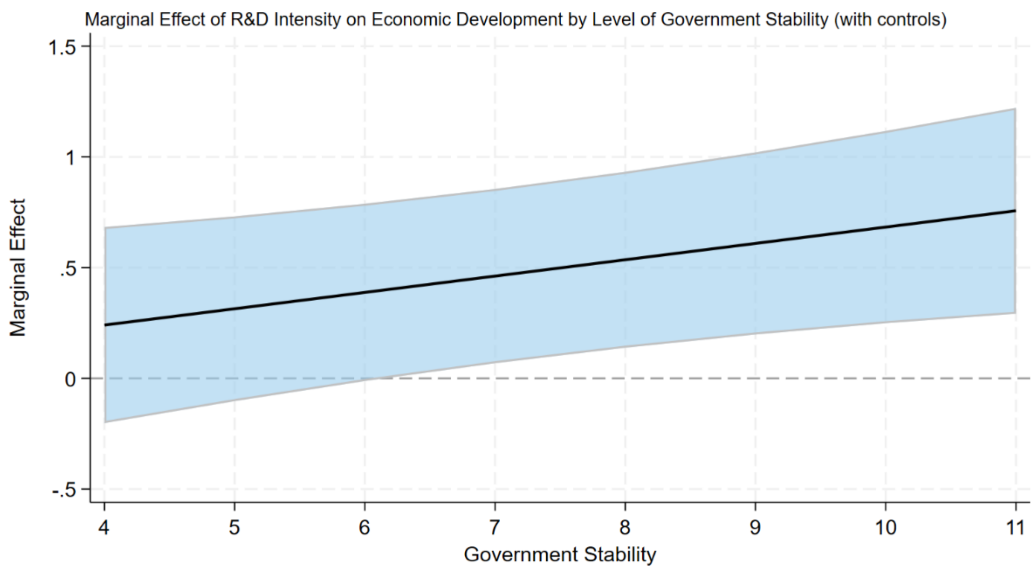

Figure 2. Marginal effect of R&D intensity on economic development by government stability (with controls).

Notes. The solid line plots the estimated marginal effect of R&D intensity on economic development evaluated at each value of the government stability index, implied by the interaction between R&D intensity and government stability in the baseline specification that includes the full set of controls. The shaded area reports the corresponding confidence interval. The horizontal dashed line indicates a zero marginal effect; effects above this line imply that higher R&D intensity is associated

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[5] Marginal effects are computed from the partial derivative $\frac{\partial g_{y,it}}{\partial X_{it}/Q_{it}} = \beta_2 + \beta_4 \times$ Government Stability.
Government Stability is fixed at 11. Effects are evaluated for a one–standard-deviation increase in the number of researchers per 100 inhabitants (SD = 0.176). Using the estimated coefficients from the regression table ($\beta_2 = -0.0544$, $\beta_4 = 0.0737$), the marginal effect is given by $(-0.0544 + 0.0737 \times 11) \times 0.176 = 0{,}133$.

[6] Marginal effects are computed from the partial derivative $\frac{\partial g_{y,it}}{\partial X_{it}/Q_{it}} = \beta_2 + \beta_4 \times$ Religious Stability.
Religious Stability is fixed at 6. Effects are evaluated for a one–standard-deviation increase in the number of researchers per 100 inhabitants (SD = 0.176). Using the estimated coefficients from the regression table ($\beta_2 = -0.9196$, $\beta_4 = 0.2754$), the marginal effect is given by $(-0.9196 + 0.2754 \times 6) \times 0.176 = 0{,}129$.

with higher economic development at that level of government stability.

In specifications that include interaction terms between R&D intensity and stability, the coefficients reported in the tables are not interpreted in isolation. The relevant objects are the implied partial derivatives, which summarize the marginal association of R&D intensity with GDP per capita at a given level of political (or religious) stability, and symmetrically the marginal association of stability at a given level of R&D intensity. We therefore focus on these marginal associations rather than on the main coefficients evaluated at the reference value of the interacting variable. Figures 2-4 plot the estimated marginal associations across the observed range of stability, together with their confidence bands

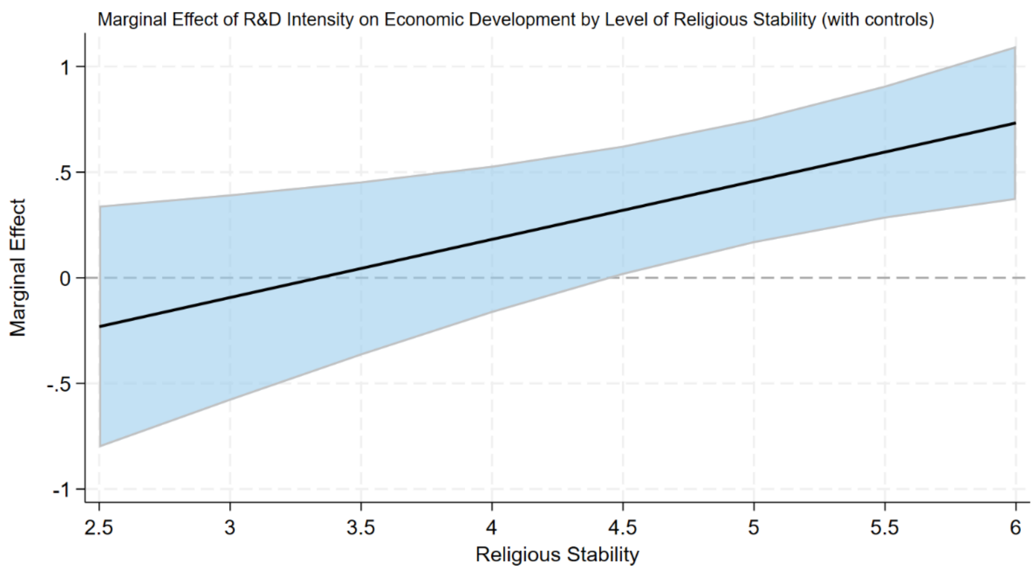

Figure 3. Marginal effect of R&D intensity on economic development by religious stability (with controls).

Notes. The solid line plots the estimated marginal effect of R&D intensity on economic development evaluated at each value of the religious stability index, implied by the interaction between R&D intensity and religious stability in the specification that includes the full set of controls. The shaded area reports the corresponding confidence interval. The horizontal dashed line indicates a zero marginal effect; when the confidence band lies above this line, the estimated return of R&D to economic development is positive and statistically distinguishable from zero at that level of religious stability.

To further validate these results, we perform an additional robustness check using an alternative measure of R&D intensity. While previous specifications relied on the number of researchers per 100 inhabitants, we re-estimate the model using R&D expenditure as a percentage of GDP. The results of this check are presented in Table 5. The growth of the working-age population is again not significant, indicating that the semi-endogenous growth channel does not play a central role in this specification. R&D intensity, measured here as R&D expenditure (% of GDP), is positive and significant in the simple model without interactions, consistent with the neo-Schumpeterian growth framework. Once the interaction terms with government stability and religious stability are included, the direct influence of R&D intensity becomes non-significant, while both interaction terms are positive and statistically significant. This confirms that the neo-Schumpeterian model only becomes valid when government stability and religious stability are sufficiently high, just as observed in Table 4.

Table 5. Robustness with an alternative measure of R&D intensity

	GDP per capita in log (1)	GDP per capita in log (2)	GDP per capita in log (3)
Growth of working-age population	-1.1153	-1.4398	-0.3700
	(2.9243)	(2.7795)	(2.7390)
R&D expenditure (% of GDP)	0.1492***	0.0500	-0.0987
	(0.0417)	(0.0615)	(0.1031)
Government stability		-0.0440***	
		(0.0078)	
R&D expenditure (% of GDP) × Government stability		0.0105**	
		(0.0051)	
Religious Stability			-0.1075***
			(0.0375)
R&D expenditure (% of GDP) × Religious stability			0.0427**
			(0.0190)
Trade openness (% of GDP)	0.2585**	0.1925**	0.2591**
	(0.1125)	(0.0751)	(0.1081)
Final consumption (% of GDP)	-0.9749**	-0.7502**	-1.0228***
	(0.3828)	(0.2812)	(0.3420)
Investment (% of GDP)	-0.0522	-0.0472	0.0710
	(0.4448)	(0.4036)	(0.3915)
Government revenues (% of GDP)	-0.8408*	-1.0639***	-0.7741*
	(0.4304)	(0.3122)	(0.4007)
Government expenditures (% of GDP)	0.3549	0.3264	0.4504*
	(0.2433)	(0.1918)	(0.2265)
Tax revenues (% of GDP)	-0.8861**	-0.7480**	-0.7067*
	(0.4234)	(0.3416)	(0.3731)
Government deficit (% of GDP)	-0.2232	0.0175	-0.1945
	(0.2773)	(0.2065)	(0.2505)
Government debt (% of GDP)	0.0460	0.0084	0.0537
	(0.0495)	(0.0485)	(0.0488)
Inflation rate (%)	-0.8578***	-0.7764***	-0.9411***
	(0.1606)	(0.1209)	(0.1294)
Unemployment rate (%)	-2.4833***	-2.6355***	-2.3976***
	(0.3826)	(0.3190)	(0.3355)
Intercept	11.0404***	11.3843***	11.5279***
	(0.3037)	(0.2557)	(0.2976)
R-squared	0.78	0.83	0.79
Number of observations	483.00	483.00	483.00
F-statistic	91.89	105.00	121.27

Notes. robust standard errors clustered at the country level in parentheses. Country fixed effects included. *, **, *** denote significance at 10%, 5%, and 1% levels.

Overall, the results confirm the robustness of our findings: even with an updated measure of R&D intensity, the interaction terms remain significant, and the core conclusion that the growth impact of R&D is conditional on high government and religious stability remains unchanged.

To illustrate the interaction terms identified in the econometric analysis, Appendix C presents a set of representative country maps combining R&D intensity, government stability, and religious stability.

Countries such as Finland and the United States combine high R&D intensity with strong government stability and relatively high religious stability. These institutional configurations correspond to the setting in which the econometric results show that R&D intensity has a strong and significant positive influence on economic performance. In such environments, innovation efforts are effectively transformed into productivity gains, reflecting a high degree of institutional complementarity.

By contrast, South Korea and Japan exhibit high R&D intensity but lower government stability. Consistent with the regression results, this weaker institutional environment limits the growth returns to innovation: despite substantial R&D investment, the marginal estimated influence of scientific intensity on economic performance remains more limited than in countries with stronger institutional stability.

The case of France provides a direct link with the historical discussion developed in the introduction. According to the maps, France is characterized by moderate government stability, relatively high religious tensions, and a moderate level of R&D intensity, alongside an intermediate level of economic development. This configuration is consistent with a situation of incomplete institutional complementarity, in which innovation efforts are partially constrained by the institutional environment.

This contemporary pattern echoes the historical experience of the diffusion of the printing press in France. As discussed in the introduction, strong religious control and political centralization slowed the diffusion of printing, limiting the economic impact of a major technological innovation despite its early arrival. While the contexts differ, both historical and contemporary evidence support the central conclusion of this paper: innovation-driven growth depends not only on the intensity of R&D, but crucially on the stability and interaction of political and religious institutions.

In summary, the baseline and extended estimates consistently show that the positive association between R&D intensity and economic performance is highly conditional on institutional context. While R&D alone is not sufficient to boost growth across all countries, its impact becomes statistically and economically significant when government stability is high. The inclusion of religious stability further highlights a complementary influence: scientific intensity contributes more to economic performance in countries where both government and religious stability are strong.

These findings confirm the core neo-Schumpeterian prediction that R&D drives productivity gains, but only within a conducive institutional environment. They also suggest a policy-relevant insight: promoting R&D policies without ensuring stable governance and supportive institutional conditions is unlikely to produce substantial gains in economic performance. Future research could investigate in greater depth how government and religious stability interact to shape innovation adoption and ultimately influence long-term economic performance.

7. Conclusion

This paper shows that the influence of R&D intensity on economic performance varies strongly across countries and depends on the broader institutional and religious environment. R&D investment alone is not systematically associated with superior economic performance. Its influence becomes clearly positive only when both government stability and religious stability are high. These results suggest a complementarity between government and religious stability, consistent with North's idea that culture and institutions form an institutional matrix characterized by complementarities.

From a policy perspective, the implication is straightforward: strengthening government stability and ensuring high religious stability may be important for scientific investment to have a positive influence. Simply increasing R&D intensity is unlikely to be associated with substantial gains in economic performance if these institutional dimensions are weak. Enhancing political and religious stability therefore appears to be a crucial step for maximizing the returns to innovation.

Future research could explore in greater detail how complementarities between government and religious stability shape economic performance, and more specifically how they interact to influence the adoption of innovations and their ultimate impact on long-term economic performance. Understanding these complementarities would clarify the channels through which innovation becomes an effective driver of development.

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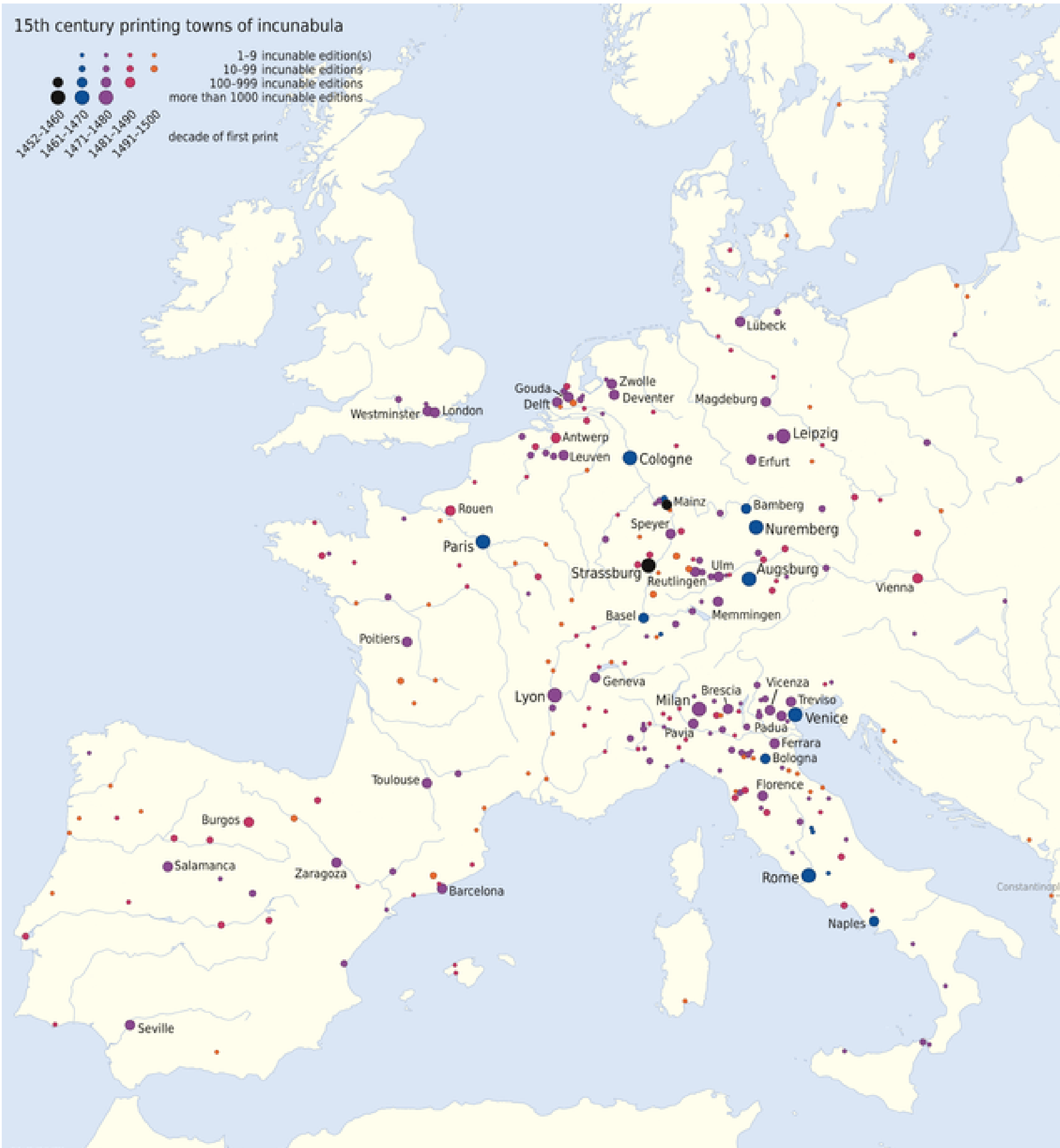
Appendix A. The diffusion of printing press

Figure Appendix A.1: Printing in Europe in the 15th century



Source: NordNordWest/Wikipedia Commons, *Printing towns incunabula.svg*.

Table Appendix A.2: Main factors affecting the spread of printing in Germany, France and Italy

Factor	Germany (early)	Italy (early)	France (slower)
Origin & innovation	Mainz: Birthplace of printing in 1450	Arrival in 1465	Arrival in 1470
Diffusion of innovation	Highly mobile craftsmen; Universities open to technical innovations.	Enthusiastic and flourishing humanists that implies high demand for books.	Low initial mobility; Very conservative Sorbonne; mistrust of new ideas.
Book economy	Numerous trading cities; Hanseatic networks	Venice = European book capital.	Resistant copyist guilds; Paris dominates the market too much.
Instituional regulation and control	Weak control at first; great freedom to print.	Little censorship in the 15th century; active patronage.	Strong royal control + Parliament + Sorbonne: strict authorisations.
Political and economical context	Autonomous cities, dynamic competition.	Rich and competitive city-states.	Centralised and cautious kingdom; tradition of mistrust of new developments.
Conflict & instability	Stable context after 1450.	Relative peace until the Italian Wars.	End of the Hundred Years' War; fragile finances.
Development between 1470 and 1500	Rapid explosion: More than 80 cities equipped.	Rapid expansion: More than 60 cities equipped.	Slow expansion : Only 25 cities equipped.

Appendix B. Theoretical Framework

Following Herzer (2022), who reviews and compares the empirical testing of semi-endogenous and Schumpeterian growth models, we build on the standard formulation of the knowledge production process:

$$\frac{\dot{A}_t}{A_t} = \delta \left(\frac{X_t}{Q_t^{\beta}}\right)^{\lambda} A_t^{\phi-1} \qquad (A.1)$$

In this framework, A_t denotes the stock of knowledge or ideas accumulated up to time t, while $\frac{\dot{A}_t}{A_t}$ represents the growth rate of this knowledge stock. The variable $\dot{A}_t$ therefore measures the flow of new ideas or technological innovations produced at time t, that is, the rate of technological progress.

δ is a constant of proportionality. The parameter ϕ characterizes the nature of returns to knowledge in the production of ideas. When $\phi < 1$, the process exhibits diminishing returns: the larger the existing stock of knowledge, the more difficult it becomes to generate new ideas.

X_t represents the R&D input, typically measured by R&D employment or total R&D expenditure. The ratio X_t/Q_t captures R&D intensity. The parameter λ, with $0 < \lambda \leq 1$, reflects the degree of duplication in research activities. A lower value of λ indicates greater duplication of research, whereas a value closer to 1 implies that R&D activities are more original and productive.

Q_t denotes the number of product varieties or sectors and, appearing in the denominator in (1), captures potential product proliferation effects that can reduce the effectiveness of R&D efforts. The parameter β measures the intensity of this product proliferation effect.

In neo-Schumpeterian growth models, it is assumed that $\beta = 1$ and $\phi = 1$, implying constant returns to knowledge and full product proliferation effects. In contrast, semi-endogenous growth models are characterized by $\beta = 0$ and $\phi < 1$.

If $\phi = 1$ and $\beta = 1$, as predicted by the neo-Schumpeterian framework (Aghion, 1998; Dinopoulos, 1998; Peretto, 1998; Young 1998) equation (A.1) simplifies to:

$$\frac{\dot{A}_t}{A_t} = \delta \left(\frac{X_t}{Q_t}\right)^{\lambda} \qquad (A.2)$$

Following Jones (1999) and Laincz and Peretto (2006), let $Y_{\text{sector},t}$[7] denote the average sectoral output,

[7] $Y_{sector,t} = \frac{Y_t}{Q_t}$

given by the production function:

$$Y_{\text{sector},t} = A_t K_t^{\alpha} (L_t h_t)^{1-\alpha} \tag{A.3}$$

Aggregating across Q_t sectors yield the aggregate production function:

$$Y_t = Q_t^{\theta} A_t K_t^{\alpha} (L_t h_t)^{1-\alpha} \tag{A.4}$$

Dividing the sectoral output by the labor force gives the average sectoral output per worker:

$$y_{\text{sector},t} = \frac{Y_{\text{sector},t}}{L_t} = A_t \left(\frac{K_t}{L_t}\right)^{\alpha} h_t^{1-\alpha} \tag{A.5}$$

Since the capital–labor ratio can be expressed as

$$\frac{K_t}{L_t} = \frac{K_t}{Y_t} \cdot \frac{Y_t}{L_t} = \frac{K_t}{Y_t} \cdot y_t \tag{A.6}$$

we can rewrite :

$$y_{\text{sector},t} = A_t \left(\frac{K_t}{Y_t} y_t\right)^{\alpha} h_t^{1-\alpha} \tag{A.7}$$

Solving for $y_{\text{sector},t}$, we obtain:

$$y_{\text{sector},t} = A_t^{\frac{1}{1-\alpha}} \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} h_t \tag{A.8}$$

Finally, since the number of sectors Q_t is assumed to be proportional to the labor force L_t, per capita output can be expressed as the product of $Q_t^{\theta-1}$ and the average sectoral output per worker:

$$y_t = Q_t^{\theta-1} A_t^{\frac{1}{1-\alpha}} \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} h_t \tag{A.9}$$

where Q_t is the number of sectors and $\theta > 1$ captures the variety effect, reflecting productivity gains from the greater availability of specialized inputs.

Along a balanced growth path, all terms on the right side of (A.9) except for $Q_t^{\theta-1}$ and $A_t^{\frac{1}{1-\alpha}}$ are constant[8]. Therefore, the steady-state growth rate of per capita output is[9]:

$$g_y = (\theta - 1)g_Q + \frac{1}{1-\alpha} g_A \qquad (A.10)$$

where g_Q is the steady-state growth rate of varieties and g_A is the steady-state growth rate of average knowledge. Assuming a sectoral knowledge production process of the form

$$\dot{A}_t = \delta A_t X_t^{\lambda} \qquad (A.11)$$

the steady-state growth rate of knowledge depends on research effort per sector:

$$g_A = \lambda\delta \frac{X}{Q} \qquad (A.12)$$

Substituting (A.12) into (A.10) yields:

$$g_y = (\theta - 1)g_Q + \frac{\lambda\delta}{1-\alpha}\frac{X}{Q} \qquad (A.13)$$

Under balanced growth, the growth rate of the labor force equals the growth rate of product varieties, $g_L = g_Q$. Hence, the steady-state growth rate of output per worker can be rewritten as:

$$g_y = (\theta - 1)g_L + \frac{\lambda\delta}{1-\alpha}\frac{X}{Q} \qquad (A.14)$$

---

8 $\frac{\partial \log\left(\frac{K_t}{Y_t}\right)}{\partial t} = 0, \frac{\partial \log(h_t)}{\partial t} = 0$

9 $\frac{\dot{y}}{y} = \frac{\partial \log(y_t)}{\partial t} = \frac{\partial}{\partial t}\left((\theta - 1)\log(Q_t) + \frac{1}{1-\alpha}\log(A_t) + \frac{\alpha}{1-\alpha}\log\left(\frac{K_t}{Y_t}\right) + \log(h_t)\right) = (\theta - 1)g_Q + \frac{1}{1-\alpha} g_A$

Equation (A.14) implies that economic growth depends positively on both the growth rate of the labor force and the intensity of R&D activity. The contribution of population growth requires $\theta > 1$; if $\theta = 1$, long-run growth depends solely on R&D intensity.

To empirically assess this relationship, we estimate the following specification:

$$g_{y,it} = \mu_i + \beta_1 g_{L,it} + \beta_2 \frac{X_{it}}{Q_{it}} + \varepsilon_{it} \tag{A.15}$$

Where $\beta_1 = (\theta - 1)$ measures the elasticity of output growth with respect to the growth rate of product variety; and $\beta_2 = \frac{\lambda\delta}{1-\alpha}$ captures the impact of R&D intensity on economic growth.

In the Schumpeterian framework outlined above, the coefficient $\beta_1 = (\theta - 1)$ governs the elasticity of output growth with respect to the growth of product variety.

In the semi-endogenous model (Jones, 1995a,b; Kortum, 1997; Segerstrom, 1998), this coefficient is different, taking the form

$$\beta_1 = \frac{\lambda}{(1-\alpha)(1-\phi)} \tag{A.16}$$

We can demonstrate the result as follows.

If $\phi < 1$ and $\beta = 0$, then equation (A.1) reduces to

$$\frac{\dot{A}_t}{A_t} = \delta A_t^{\ \phi-1} X_t^{\lambda} \tag{A.17}$$

Assuming that the stock of knowledge grows at a constant long-run rate g_A, this equation can be solved for A_t as:

$$A_t = \left(\frac{\delta}{g_A}\right)^{\frac{1}{1-\phi}} X_t^{\frac{\lambda}{1-\phi}} \tag{A.18}$$

It follows from (18) that $X_t^{\frac{\lambda}{1-\phi}}$ is proportional to A_t if the growth rate of knowledge is constant. In this case, the long-run growth rate of the knowledge stock is given by 10

$$g_A = \frac{\lambda}{1-\phi} g_X \qquad (A.19)$$

Along a balanced growth path, g_X is equal to g_L, implying that X_t is proportional to L_t. In a balanced growth equilibrium, equation (A.18) therefore implies

$$g_A = \frac{\lambda}{1-\phi} g_L \qquad (A.20)$$

It should be emphasized that equation (A.20) holds only under the assumption that the share of labor devoted to R&D remains constant over time. The allocation of resources to R&D activities is influenced by a broader set of structural and institutional factors such as government stability, policy incentives, and technological opportunities rather than by the scale of the labor force alone. As these determinants evolve, they generate temporal variations in X_t, such that L_t and X_t may not grow at identical rates over extended periods.

Following Jones (2002), it is therefore useful to distinguish between a constant growth path and a balanced growth path. Although both feature constant growth rates, the latter corresponds to a steady-state equilibrium in which all variables expand at the same rate indefinitely, ensuring that R&D intensity remains constant. The key implication is that, in semi-endogenous growth theory as opposed to the Schumpeterian framework R&D intensity may vary over time even when the knowledge growth rate is constant.

To illustrate this point, equation (A.18) can be rewritten as follows:

$$A_t = \left(\frac{\delta}{g_A}\right)^{\frac{1}{1-\phi}} \left(\frac{X_t}{L_t}\right)^{\frac{\lambda}{1-\phi}} L_t^{\frac{\lambda}{1-\phi}} \qquad (A.21)$$

Taking logarithms and differentiating with respect to time yields:

10 $\frac{\dot{A}_t}{A_t} = \frac{\partial \log(A_t)}{\partial t} = \frac{\partial}{\partial t}\left[\frac{1}{1-\phi}\log\left(\frac{\delta}{g_A}\right) + \frac{\lambda}{1-\phi}\log(X_t)\right] = \frac{\lambda}{1-\phi} g_X$

$$g_A = \frac{\lambda}{1-\phi} g_{(\frac{X}{L})} + \frac{\lambda}{1-\phi} g_L \qquad (A.22)$$

where $g_{(X/L)}$ is the growth rate of R&D intensity. Thus, out of steady state, the growth rate of knowledge can be constant and depend on both the growth rate of R&D intensity and the growth rate of the labor. In steady state, the first term in equation (A.22) must be zero, so that this equation reduces back to equation (A.20). In this case, it follows 11 :

$$g_y = \frac{1}{1-\alpha} g_A \qquad (A.23)$$

that the growth rate of output per worker g_y is given by

$$g_y = \frac{\lambda}{(1-\alpha)(1-\ \phi)} g_L \qquad (A.24)$$

For our empirical analysis, we estimate equation (A.14) while incorporating control variables as well as institutional quality and its interaction with R&D intensity. This allows us to test whether the effect of R&D on growth depends on the quality of institutions in each country. The empirical specification therefore becomes:

$$g_{y,it} = \mu_i + \beta_1 g_{L,it} + \beta_2 \frac{X_{it}}{Q_{it}} + \beta_3 \text{Instit}_{it} + \beta_4 \left(\frac{X_{it}}{Q_{it}} \times \text{Instit}_{it}\right) + \gamma' Z_{it} + \varepsilon_{it} \qquad (A.25)$$

[11] The output per worker is defined as $y_t = A_t^{\frac{1}{1-\alpha}} \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} h_t$. Taking logs and differentiating with respect to time gives $\frac{\dot{y}_t}{y_t} = \frac{\partial log(y_t)}{\partial t} = \frac{\partial}{\partial t}\left(\frac{1}{1-\alpha}\log(A_t) + \frac{\alpha}{1-\alpha}\log\left(\frac{K_t}{Y_t}\right) + \log\left(h_t\right)\right) = \frac{1}{1-\alpha} g_A$. Thus, the growth rate of output per worker is proportional to the growth rate of knowledge

Appendix C. Descriptive Maps

Figure Appendix C.1: GDP per capita (heatmap)

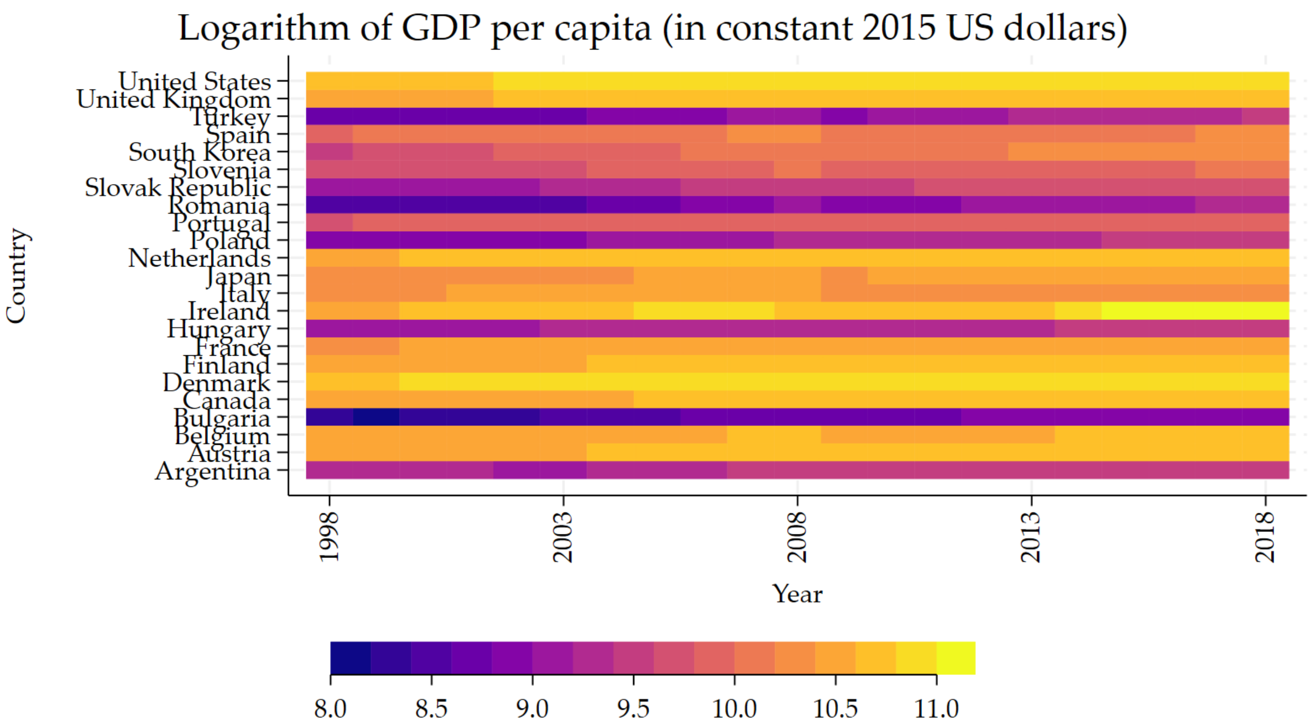


Figure Appendix C.2: Number of researchers (heatmap)

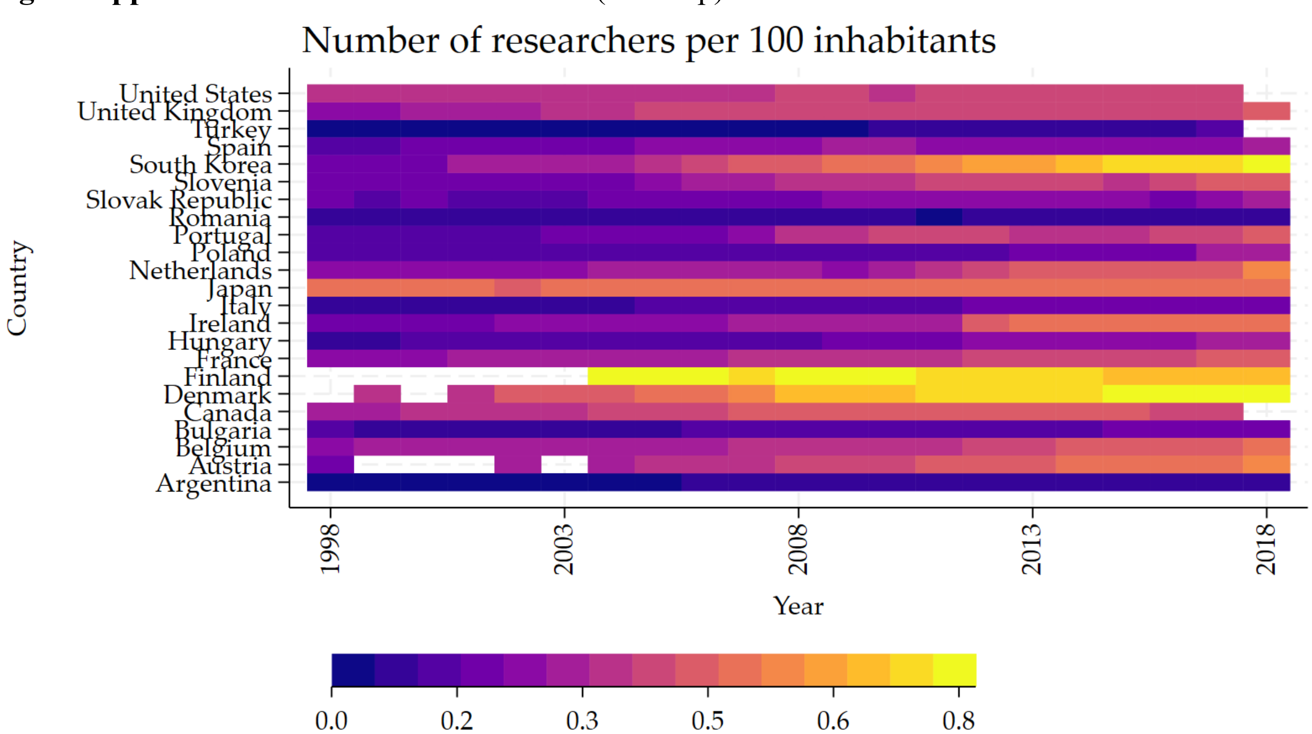


Figure Appendix C.3: Government stability (heatmap)

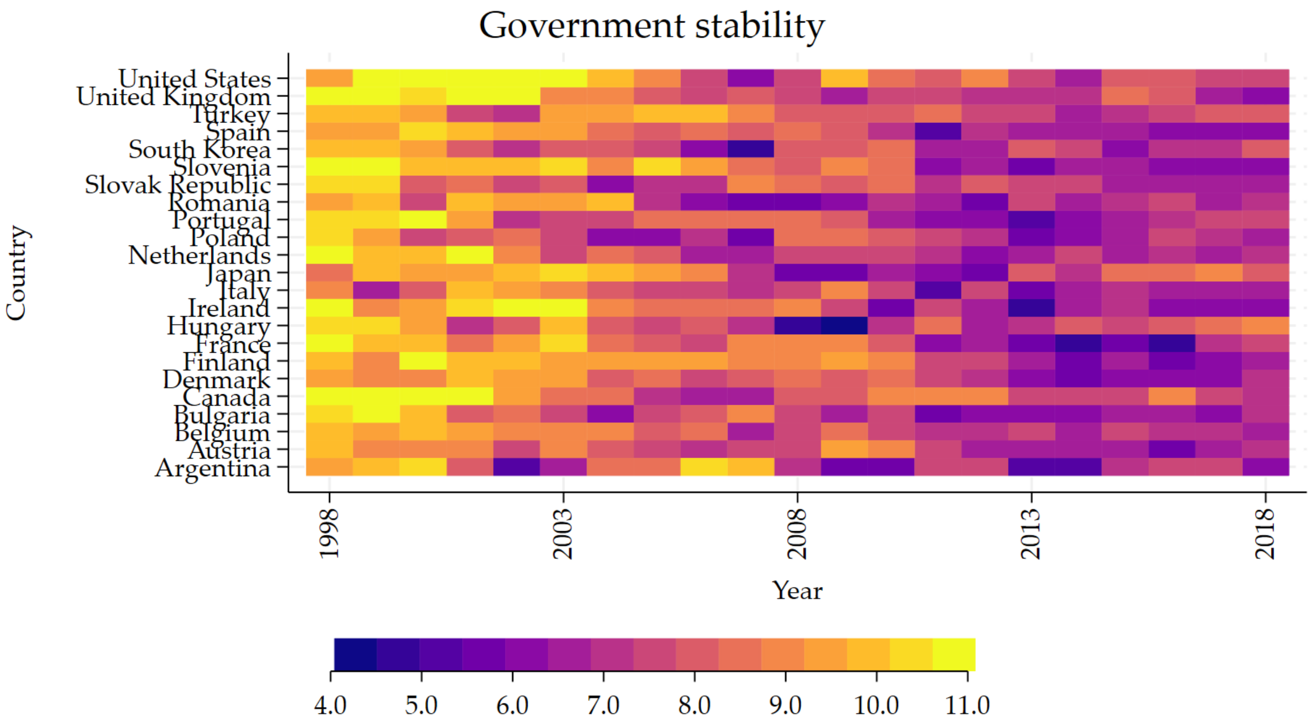


Figure Appendix C.4: Religious Stability (heatmap)

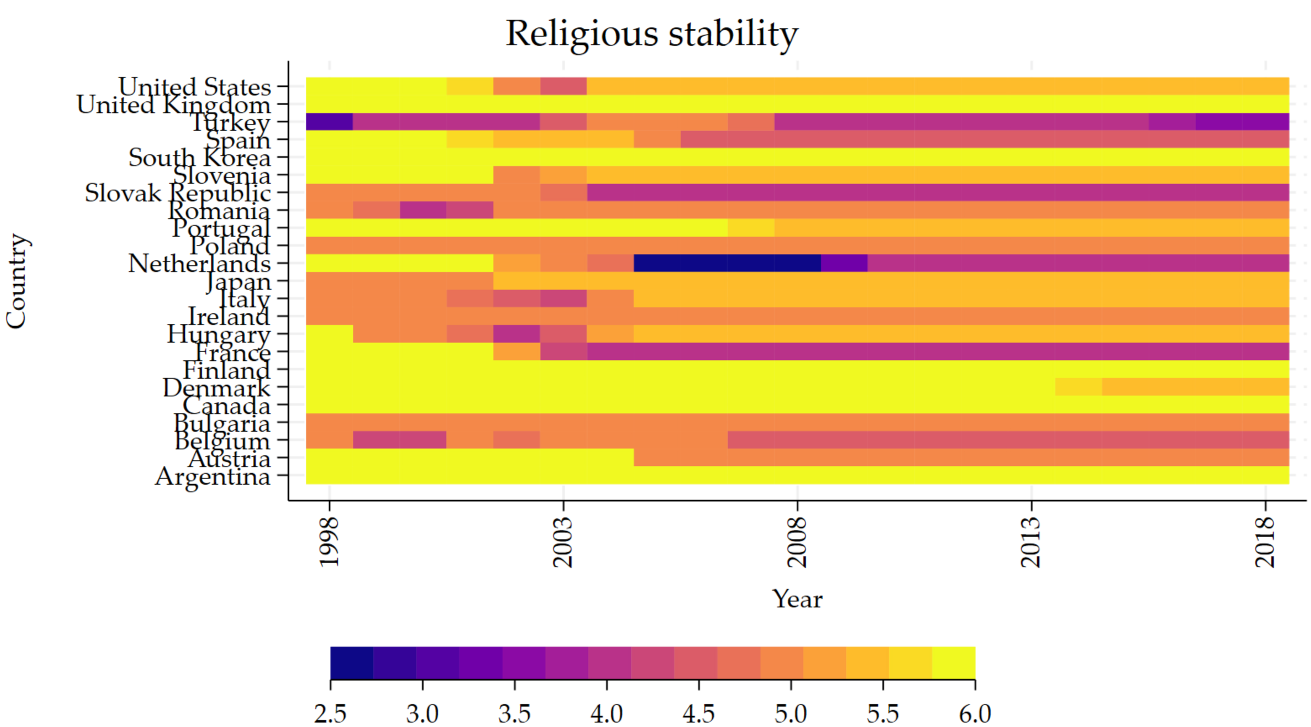


Figure Appendix C.5: Government Stability (map)

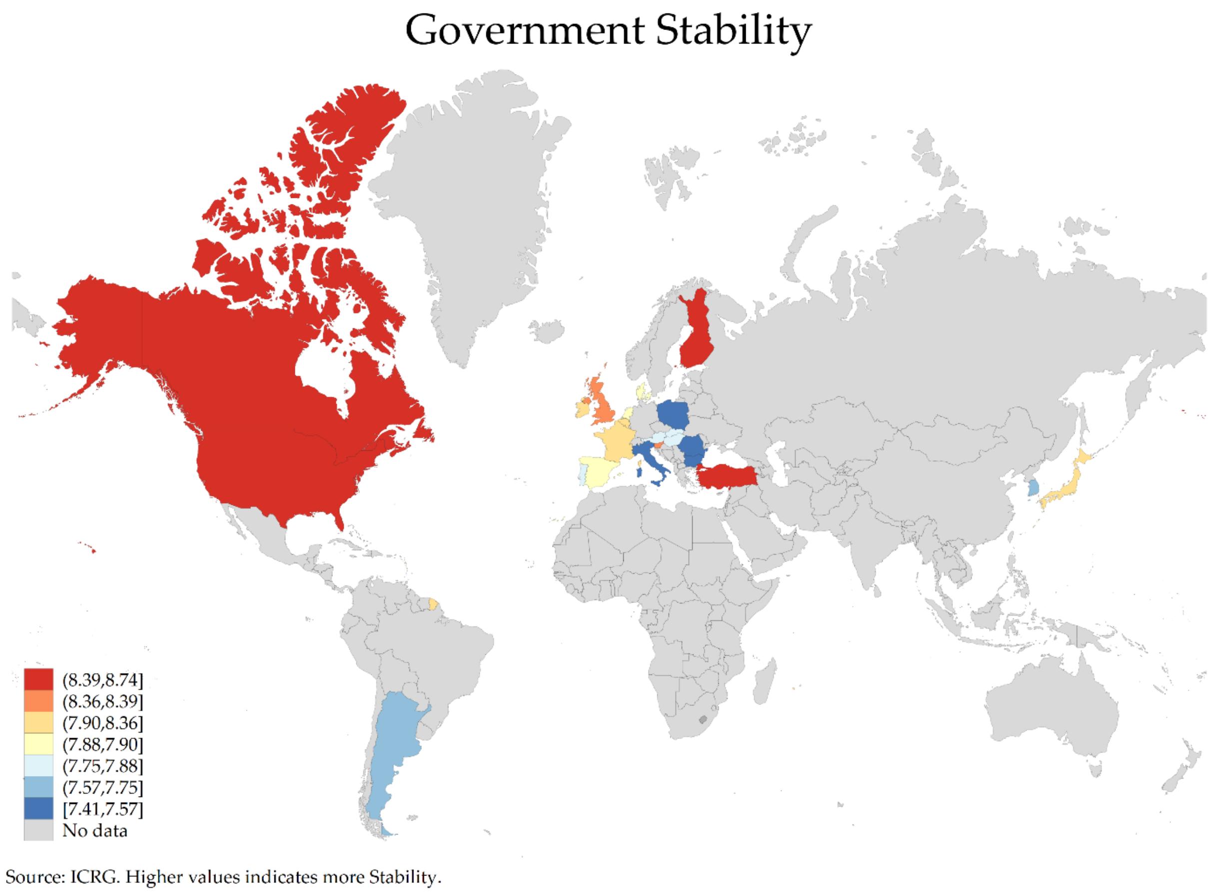


Figure Appendix C.6: Religious tensions (map)

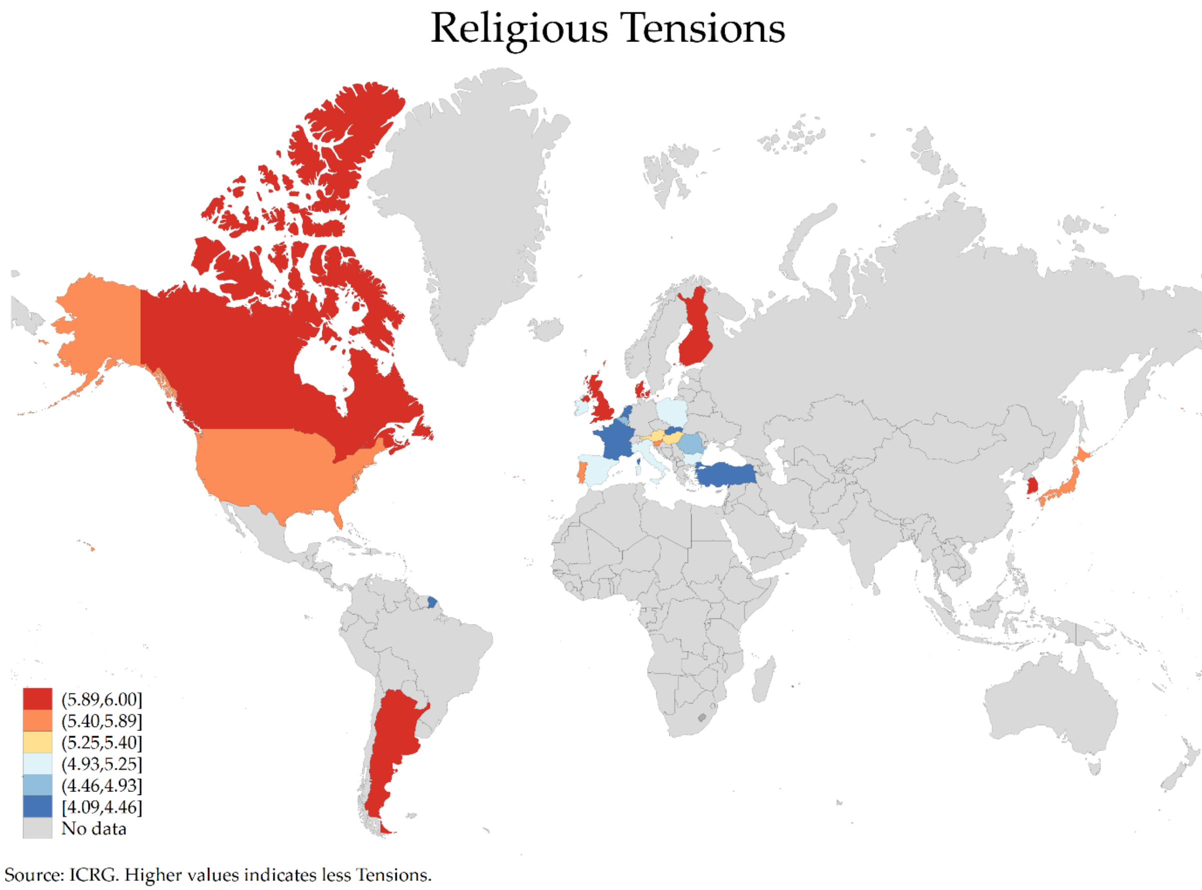


Figure Appendix C.7: R&D intensity (map)

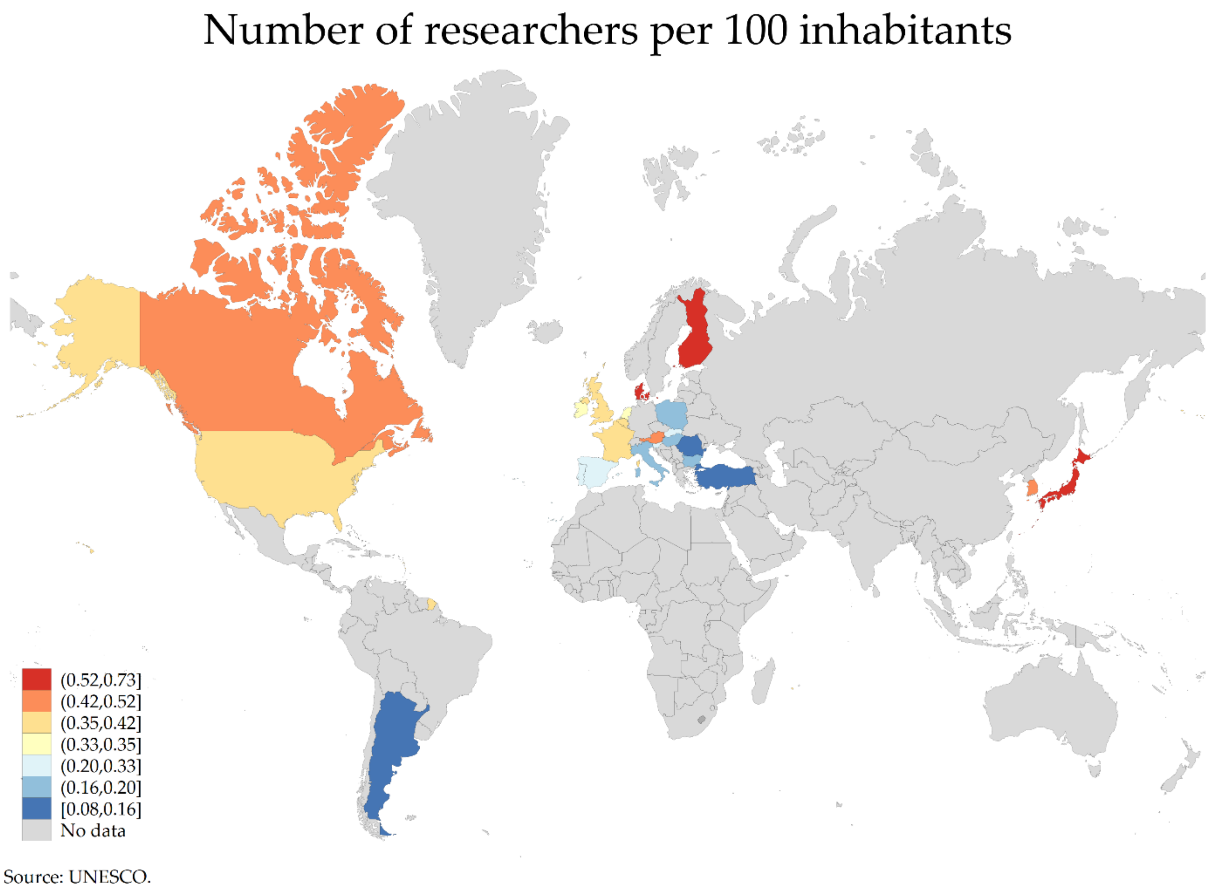
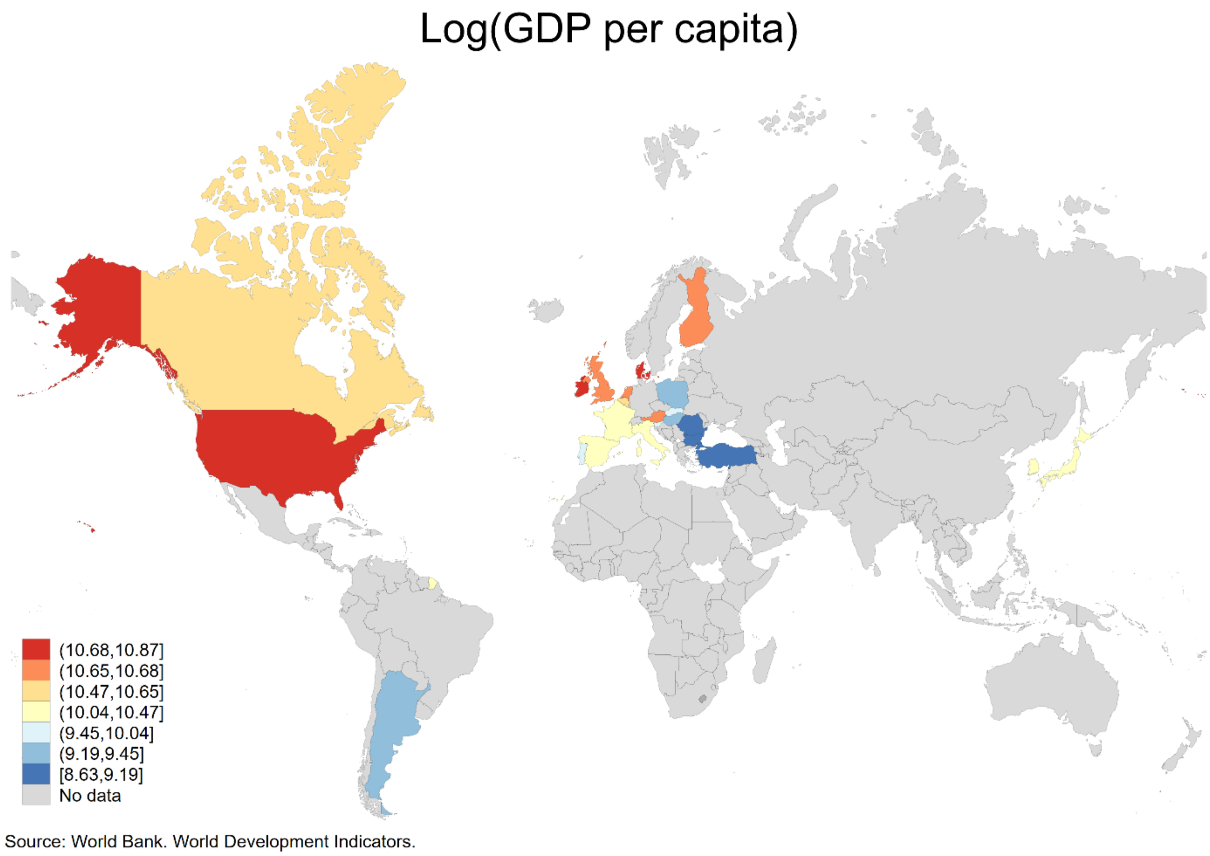


Figure Appendix C.8: Logarithm of GDP per capita (map)



Appendix D. ICRG institutional score dimensions.

- Government Stability

This is an assessment both of the government's ability to carry out its declared program(s) and its ability to stay in office. The risk rating assigned is the sum of three subcomponents, each with a maximum score of four points and a minimum score of 0 points. A score of 4 points equates to very low risk, and a score of 0 points to very high risk. The subcomponents are government unity, legislative strength, and popular support.

- Religious Tensions

Religious tensions may stem from the domination of society and/or governance by a single religious group that seeks to replace civil law with religious law and to exclude other religions from the political and/or social process; the desire of a single religious group to dominate governance; the suppression of religious freedom; or the desire of a religious group to express its own identity, separate from the country as a whole. The risk involved in these situations range from inexperienced people imposing inappropriate policies through civil dissent to civil war.