Can innovation reduce the size of the informal economy? Econometric evidence from 138 countries

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Can innovation reduce the size of the informal economy? Econometric evidence from 138 countries*

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Abstract

A substantial body of literature has examined the determinants of the informal economy. However, this literature has predominantly focused on proximate causes, such as unemployment and taxation, while largely overlooking the role of innovation. This paper contributes to filling this gap by studying the impact of innovation production on the size of the informal economy using a sample of 138 countries, spanning the period from 2007 to 2018. Estimations, based on the entropy balancing method for continuous treatments, demonstrate that innovation reduces the size of the informal economy, emphasizing the importance of innovation policies in addressing informality. This result remains robust across a wide array of controls, alternative estimation techniques, restricted samples, and different measures of both the informal economy and innovation. The study identifies economic development, domestic credit mobilization, and e-government as channels through which innovation influences the informal economy. Potential government policies are explored.

Keywords: Informal economy; Innovation; Economic development; Domestic credit mobilization; E-government; Entropy balancing
JEL Codes: O11; O17; O31; O38

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1 Introduction

The proliferation of informal economic activities is a significant contemporary development issue. These activities encompass all legal economic endeavors that would have contributed to the Gross Domestic Product (GDP) if they were officially recorded.[1] The extent to which these activities pose problems depends on the level of development in countries. Indeed, informality, like unemployment, is prevalent in all countries worldwide, irrespective of their level of development, but it is more pronounced in developing countries compared to developed economies. Estimations by Elgin et al. (2022) show that, in 2018, the informal production represented around 40% of GDP in Sub-Saharan Africa and Latin America and the Caribbean, and approximately 25% of GDP in East Asia and the Pacific, Europe and Central Asia, and Middle East and North Africa. It represented around 31% of GDP in South Asia and roughly 12% of GDP in North America. In terms of workforce, the informal economy provides jobs for around 86% of the active population in Africa, roughly 68% in Asia and Pacific, about 40% in the Americas, and approximately 25% in Europe and Central Asia (International Labour Organization 2018). As highlighted by Ulyssea (2018), the prominent role of the informal economy carries significant negative economic consequences for countries. Indeed, informality can lead to wage inequality, the loss of tax revenue, reduced productivity, and diminished economic growth, among other adverse effects.

Considering the adverse effects of informality, a substantial body of literature has emerged with the objective of uncovering the determinants of the size of the informal economy. A comprehensive review of this literature underscores that the potential role of innovation production as a determinant of the informal economy has been largely overlooked, despite its implications for economic, financial, and social development.[2] In fact, innovation can reasonably be expected to have a significant and negative impact on the size of the informal economy for at least three reasons.

First, innovation can reduce the size of the informal economy by promoting economic development. Indeed, innovation is recognized for driving economic development (Cantner et al. 2019, Schumpeter 1912), particularly through enhanced productivity (Amable et al. 2016). Moreover, innovation contributes to economic growth (Aghion & Howitt 1996, Akcigit & Kerr 2018), which, when sustained over time, can foster economic development.

[1]The term for these informal activities is the "informal economy," and the entities operating within the informal economy are referred to as "informal firms."

[2]Innovation is defined as the implementation of a new or significantly improved product (good or service), process, marketing method, or organizational method in business practices, workplace organization, or external relations (OECD & Eurostat 2005). This definition aligns with the Schumpeterian conception of innovation (see Schumpeter 1912). For a detailed understanding of innovation typology, readers may refer to OECD & Eurostat (2005).

Then, as a country becomes more developed, the size of its informal economy tends to decrease. This can be attributed to rising operational costs associated with informal activities, greater demand for modern manufactured products (typically found in the formal sector), the transition from informal (less educated) entrepreneurs to educated entrepreneurs with superior managerial skills who tend to operate formally, and increased economic opportunities (Berdiev & Saunoris 2016, Elbahnasawy 2021, Elbahnasawy et al. 2016, Goel & Nelson 2016, La Porta & Shleifer 2014), among other factors.

Second, innovation can also reduce the size of the informal economy by enhancing domestic credit mobilization. This is significant because financing constraints often hinder the formal registration of businesses (La Porta & Shleifer 2014). Access to credit is contingent, at least in part, on the creditworthiness of the borrower. Innovation can facilitate firms' access to credit by improving their productivity (Amable et al. 2016) and financial performance (Dong et al. 2020, Lu & Chesbrough 2022). Moreover, recent literature emphasizes that the adoption of financial innovation by banks enhances risk management, lowers the cost of capital, and results in increased credit availability and improved financing conditions for borrowers (Brewer III et al. 2000, Hirtle 2009, Nadauld & Weisbach 2012). Additionally, patents have been noted in the literature as instruments that enhance firms' access to external financing because they signal a firm's technological competencies (Hottenrott et al. 2016), can be used as collateral to secure funds (Mann 2018), and correlate with a firm's credit rating (Frey et al. 2019). Other studies by Bellucci et al. (2014), Chava et al. (2017), Freel (2007), and Jacolin et al. (2021) also shed light on the role of innovation in facilitating domestic credit mobilization. Domestic credit mobilization, and financial development in general, have been shown in the literature to significantly reduce the size of the informal economy (Berdiev & Saunoris 2016, Capasso & Jappelli 2013, Elbahnasawy et al. 2016). This is primarily due to the increased opportunities to fund the growth of formal businesses, among other factors.

Third, innovation can reduce the size of the informal economy through the utilization of e-government. E-government involves the use of information and communication technologies (ICTs) by public authorities to enhance the delivery of public services (Elbahnasawy 2021). Technological innovation, in fact, promotes the development of e-government by facilitating the creation of advanced digital solutions, including online platforms, mobile applications, artificial intelligence, and blockchain technologies. Implementing these solutions in the delivery of public services leads to the modernization of public administration and a substantial enhancement in the efficiency and accessibility of these services (Yang & Rho 2007). E-government, in turn, plays a significant role in reducing the size of the informal economy by eliminating certain barriers to the formalization of informal enterprises (Elbahnasawy

2021, Williams 2023). Indeed, the modernization of public services through e-government helps reduce bureaucratic complexity, a major driver of informal activities, as emphasized by Djankov et al. (2002) and Goel & Nelson (2016). Additionally, e-government, by minimizing human interaction, contributes to the reduction of corruption (Elbahnasawy 2014), which encourages economic activities to shift toward the formal sector (Choi & Thum 2005, Dreher & Schneider 2010, Schneider 2010).

In summary, innovation has the potential to enhance economic development, domestic credit mobilization, and e-government, and these factors, in turn, should reduce the size of the informal economy. Given these considerations, it is crucial to conduct empirical analyses to formally explore the relationship between innovation and the size of the informal economy within a country. A negative and significant impact of innovation would underscore the importance of implementing public policies that bolster a country's innovation capabilities, with the specific goal of limiting the extent of the informal economy and consequently promoting greater economic progress.

Furthermore, it is worth noting that a recent study by Nguimkeu (2022) demonstrated that none of the conventional policies, such as those related to taxation and registration costs, are capable of reducing informality to levels below 20-30%. Consequently, the author has advocated for the implementation of policies that extend beyond standard measures to address informality. Innovation is certainly among these non-standard factors and has the potential to significantly impact informality. Therefore, an analysis of its role in explaining the size of the informal economy is highly relevant.

This paper addresses the gap in the literature by examining the impact of innovation production on the size of the informal economy, utilizing a comprehensive panel dataset covering 138 countries observed between 2007 and 2018. Econometric estimations, based on the entropy balancing method for continuous treatments, reveal a consistently negative and significant effect of innovation on the size of the informal economy. This finding remains robust after conducting a wide range of sensitivity tests. The results also emphasize that economic development, domestic credit mobilization, and e-government are the channels through which innovation influences the size of the informal economy. These findings underscore the potential of innovation policies to play a pivotal role in reducing informality on a global scale, with expected significant ramifications for economic performance and social development.

Ultimately, this paper contributes to the literature on three distinct levels. First, to the best of our knowledge, this study is the first to demonstrate that innovation production diminishes the size of the informal economy. This extends the existing literature on informal economy determinants by highlighting a factor that is not a proximate cause of informality. It

also suggests that an approach centered on technology and creativity for reducing informality could be pertinent in confining the informal economy to a minimal scope. Second, to the best of our knowledge, this is also the first study to identify economic development, domestic credit mobilization, and e-government as transmission channels for the influence of innovation on the size of the informal economy. This contributes to understanding the mechanisms that underlie the macroeconomic-level relationship between innovation and informality on a global scale. Third, from a methodological standpoint, we employ the entropy balancing method, a novel and robust impact evaluation technique (see Hainmueller 2012, Tübbicke 2022, Vegetabile et al. 2021). It allows us to ascertain the causal effect of innovation while effectively addressing endogeneity issues. This paper is among the first to utilize the extended entropy balancing methodology for continuous treatments, as the existing empirical literature on entropy balancing has primarily focused on binary treatments.

The remainder of the paper is organized as follows. Section 2 presents the evolution of innovation and the size of the informal economy around the world, and deals with the development issues relating to the reduction of informality. Section 3 reviews the recent literature on the determinants of the size of the informal economy. Section 4 presents the methodology. Section 5 describes the data and variables used to implement this methodology, and presents some descriptive statistics. Section 6 presents and discusses the estimation results. Section 7 presents a wide array of robustness checks. Section 8 investigates the transmission channels, and section 9 concludes.

2 Innovation and the informal economy worldwide: Evolution and development issues

In this section, we provide a descriptive analysis of the evolution of both the size of the informal economy and innovation worldwide in recent years. We also address the development issues associated with reducing the informal economy.

2.1 Prevalence of informality worldwide

Figure 1 illustrates the evolution of the informal economy worldwide between 1993 and 2018 using estimates from Elgin et al. (2022). These estimates, based on the Multiple Indicators Multiple Causes (MIMIC) method, quantify the output of the informal economy as a percentage of the official GDP.[3]

[3]These estimates by Elgin et al. (2022) cover the period from 1993 to 2018. For a detailed explanation of the MIMIC method, refer to Subsection 5.1.

[Insert Figure 1 here]

We can observe from Figure 1 that the informal economy exists in all countries, albeit with varying sizes across different countries and regions. An overview of world maps reveals that countries can be broadly categorized into two groups based on the size of their informal economies. The first group comprises countries with a low level of informality (on average, not exceeding 20% of GDP). It includes some countries from North America, Europe and Central Asia, East Asia and Pacific, and the Middle East and North Africa. In this group, we can identify, on the one hand, countries with a very low level of informality (on average, below 15% of GDP), such as the US and Switzerland (around 9% of GDP), Austria (about 10% of GDP), China (approximately 12% of GDP), Japan (roughly 11% of GDP), and New Zealand (around 13% of GDP). On the other hand, there are countries with a somewhat larger informal economy, averaging between 15% and 20% of GDP), such as Canada, France and Germany (around 16% of GDP), Slovakia and Iran (about 18% of GDP), and Qatar (approximately 19% of GDP).

The second group comprises countries with a substantial informal economy, specifically exceeding 20% of GDP on average. Notably, Sub-Saharan Africa and Latin America, including the Caribbean, are the regions characterized by the highest levels of informality. Within Sub-Saharan Africa, countries such as Nigeria, Zimbabwe, and Tanzania stand out with the highest levels of informal activity, averaging more than 50% of GDP. Bolivia (around 66% of GDP), Peru (about 58% of GDP), and Panama (roughly 62% of GDP) are the countries that exhibit the largest informal economies in the Latin America and the Caribbean region. South Asian countries such as Sri Lanka (around 43% of GDP), Bangladesh (approximately 36% of GDP), Nepal (about 37% of GDP), and Pakistan (roughly 36% of GDP) also have large informal economies.

The level of informality is relatively high in Europe and Central Asia, with the largest informal economies predominantly located in Eastern European and Central Asian countries. Russia (around 45% of GDP), Belarus (roughly 47% of GDP), Ukraine (about 49% of GDP), and Georgia (approximately 66% of GDP) are among the Eastern European countries with the highest levels of informality. In Central Asia, countries like Kazakhstan, Kyrgyzstan, and Tajikistan exhibit informality levels averaging 40%, 39%, and 42% of GDP, respectively. Some countries in the Middle East and North Africa, as well as the East Asia and Pacific region, also exhibit high levels of informality. Notable examples include Tunisia (roughly 38% of GDP) and Cambodia (about 49% of GDP).

Figure A1 in Appendix A presents box plots of informality for different regions using the most recent estimates of the size of the informal economy. We can see from Figure A1 that the size of the informal economy is unevenly distributed across regions. This result is in line

with the descriptive evidence presented in Figure 1 concerning the prevalence of informality worldwide.

Besides, note that in 2018 the world average size of the informal economy was around 31% of GDP.[4] The size of the informal economy was higher than the world average in around half of the countries in the world. In Sub-Saharan Africa and Latin America and the Caribbean, approximately 83% and 75% of the countries had a level of informality that exceeds the world average, respectively. The size of the informal economy was below the world average in all G7 countries. This is not surprising since G7 comprises seven of the most advanced countries in the world.

2.2 Innovation landscape worldwide

Figure 2 presents maps illustrating the global evolution of innovation production. Innovation production is measured using the innovation output index published annually by the World Intellectual Property Organization (WIPO), Cornell University, and INSEAD. The index ranges from 0 to 100, with higher values indicating a higher level of innovation production.[5]

[Insert Figure 2 here]

Figure 2 reveals that the most innovative countries are found in North America, Europe, and Asia, while countries in Africa and Latin America tend to have lower levels of innovation. Countries can be classified into three groups based on their innovation levels. The first group includes the most innovative countries, with an average innovation index above 50, such as Switzerland (64), Sweden (58), and the US (54).[6] The second group comprises countries with a medium level of innovation, with an average index near 50, including China (49), France (47), and Japan (45). The third group consists of countries with low innovation levels, where their indices are significantly below 50 (typically less than 40), like Brazil (28), South Africa (27), and Bolivia (20).

Figure 2 also shows contrasting trends of innovation across countries and regions. Indeed, some countries have seen a drop in their level of innovation, while others have seen an increase. For instance, China's level of innovation has increased from 48 in 2009 to 53 in 2022, while Canada's has decreased from 54 to 39 over the same period. In Africa, the level of innovation has significantly deteriorated. The decrease in the levels of innovation of Nigeria and South Africa, the two most advanced economies in Africa, is a testimony of

[4]Recall that the most recent estimates of the size of informal economy are from 2018. See Elgin et al. (2022).

[5]For more details on the innovation output index, refer to Subsection 5.1.

[6]In parentheses, you will find the average innovation output indices over the study period.

such a negative trend. Indeed, Nigeria's level of innovation dropped significantly from 37 in 2009 to 8 in 2022, and South Africa's decreased from 39 in 2009 to 22 in 2022. Figure A2 in Appendix A presents box plots of innovation for different regions in 2022. We see from this figure that the level of innovation is heterogeneous across regions.

Besides, in 2022, the world average innovation output index was equal to 24, which implies a low level of innovation overall in the world. Sub-Saharan Africa, Latin America and the Caribbean, and South Asia, lag behind the other regions of the world in terms of innovation, with around 96%, 89%, and 80% respectively of the countries of these regions having in 2022, an innovation output index that is lower than the world average level. East Asia and Pacific, and Europe and Central Asia appear to be performing well in terms of innovation. Indeed, in 2022, more than 60% of the countries of these regions had a level of innovation above the world average. In North America, and more generally in G7 countries, all the countries exhibited in 2022 an innovation level that is higher than the world average.

2.3 Joint evolution of innovation and the size of the informal economy

Figure 3 presents a recent overview of the levels of innovation and informal economy worldwide. As the most recent estimates of the size of the informal economy are for the year 2018 (see Elgin et al. 2022), the mapping is done for 2018.

[Insert Figure 3 here]

Figure 3 shows that the level of innovation is inversely associated with the size of the informal economy. Indeed, geographic areas that exhibit a low level of innovation correspond to the areas where informality is high. Conversely, geographic areas with high levels of innovation are characterized by a small informal economy.

To further explore the nature, positive or negative, of the relationship between innovation and the size of the informal economy, we build two scatterplots by considering all the countries for which data on innovation and informal economy are available over the study period (2007-2018), as illustrated in Figure 4. The scatterplot displayed in the upper part of Figure 4 is a standard one. The scatterplot at the bottom of Figure 4 considers the average levels of innovation and informal economy for each country over the study period. Countries are represented by their standard country codes.

[Insert Figure 4 here]

The downward trend in the scatterplots indicates a negative correlation between innovation and the size of the informal economy. The higher the level of innovation, the smaller the size of the informal economy. Indeed, we can see that the most innovative countries (e.g. Switzerland (CHE), Sweden (SWE), Netherlands (NLD), UK (GBR), and Luxembourg (LUX)) have small informal economies. Conversely, in countries with a low level of innovation (e.g. Togo (TGO), Niger (NER), Zimbabwe (ZWE), Bolivia (BOL), and Georgia (GEO)), the size of the informal economy is large. These results are consistent with the observations made previously from Figure 3.

In summary, Figures 3 and 4 suggest that a country's innovation production is inversely related to the size of its informal economy. To formally examine this relationship, an econometric analysis is of paramount importance. This is particularly significant because the reduction of the informal economy is closely linked to various critical development challenges, which we will explore in the following subsection.

2.4 Reducing the size of the informal economy: What are the development issues?

The reduction of informality has gathered significant interest from both policymakers and academia given the substantial size of the informal economy in many regions around the world and its implications for sustainable economic development. Indeed, although the informal economy can act as a safety net (Loayza & Rigolini 2011), it should be noted that it creates a number of challenges that affect the productive system, public finance and monetary policy, as well as the social fabric.

At the level of the productive system, the informal economy is a source of low productivity as informal firms are usually less productive than their formal counterparts (La Porta & Shleifer 2014). As stressed by La Porta & Shleifer (2008), low productivity hampers the growth of informal firms. It also gives rise to the "working poor" phenomenon as highlighted by the International Labour Organization (2019).[7] Moreover, the informal sector produces goods that are similar to those of the formal economy but of lower quality (Banerji & Jain 2007). It has also been shown to limit economic growth (Loayza 2016).

At the level of public finance and monetary policy, note that the expansion of the informal economy limits tax revenue mobilization (Besley & Persson 2014). Indeed, in countries with a large informal sector, the tax authorities collect less tax revenue, ceteris paribus. For instance, in 2020, tax revenues represented on average 16% of GDP in Africa and 20%

[7]The "working poor" phenomenon is when individuals work long hours but cannot provide proper sustenance for their families.

of GDP in Latin America and the Caribbean, compared with 34% of GDP in the Organisation for Economic Co-operation and Development (OECD) area.[8] The low level of tax revenue mobilization reduces the government's ability to finance its spending and promotes the growth of public debt (Cooray et al. 2017). In addition to restricting public spending, it has been shown in the literature that the informal economy makes monetary policy less effective, although it contributes to mitigating inflation volatility for most types of macroeconomic shocks (see Alberola & Urrutia 2020). This has significant importance from a Central Bank perspective.

On the social front, the informal economy exacerbates the vulnerability of part of the population it employs. In fact, informal workers have no social protection. According to the International Labour Organization (2017), more than half of the world's population (55%) had no social coverage. In regions where informal employment is widespread, the statistics are even more alarming. For instance, in Africa, at least 4 out of 5 people have no social protection (International Labour Organization 2017). The informal economy also accentuates poverty and inequality (Ohnsorge et al. 2022). The lack of social protection combined with low wages makes informal workers particularly vulnerable. Note that the recent COVID-19 pandemic has somehow also exacerbated the fragility of informal employment. Indeed, lockdown measures affected around 75% of informal workers worldwide (International Labour Organization 2020).

In summary, the high prevalence of the informal economy in many regions worldwide represents a significant development challenge. It is associated with several critical development issues, including exacerbating economic and social vulnerabilities, increasing poverty and inequality, reducing the effectiveness of economic policies, hampering economic performance, limiting governments' capacity to engage effectively in self-financed development processes, and contributing to higher levels of public debt. As a result, the expansion of the informal economy hinders progress toward achieving the Sustainable Development Goals (Ohnsorge et al. 2022). Therefore, it is imperative for governments and development agencies to prioritize addressing the informal economy in their development strategies.

Given the discussion above, it is essential to explore the policies that can effectively reduce informality on a global scale. This paper modestly contributes to this inquiry by conducting an econometric analysis of the role played by innovation. As evidenced by Figures 3 and 4, it is suggested that fostering innovation may offer public authorities a potential means to curb the expansion of the informal economy.

[8] See the Global Revenue Statistics Database.

3 What do we know about the determinants of the size of the informal economy?

The extant literature explains the size of the informal economy by focusing on a number of economic, institutional, political, and social factors. In this section, we give an overview of this literature by focusing on the recent studies.

At the economic level, there is evidence that when a country exhibits significant economic growth or development, the size of its informal economy tends to decrease (Berdiev & Saunoris 2016, Elbahnasawy 2021, Elbahnasawy et al. 2016, Goel & Nelson 2016, La Porta & Shleifer 2014). Inflation has been found to enlarge the size of the informal economy by increasing the demand for informal sector goods (Alm & Embaye 2013, Goel & Nelson 2016). Similarly, it has been argued that increases in the level of unemployment play as an incentive to work in the informal sector (Buehn & Schneider 2012, Dell'Anno & Solomon 2008), at least as a result of lack of opportunity, which increases the scope of the informal economy. Greater economic openness has been highlighted as a factor that reduces significantly the size of the informal economy (Blanton et al. 2018). In the same vein, Berdiev & Saunoris (2018) point out that economic globalization, a concept that is broader than economic openness, decreases the scope of the informal economy. In contrast to Berdiev & Saunoris (2018) and Blanton et al. (2018), Pham (2017) managed to demonstrate that trade and financial openness increase the size of the informal economy, as measured by informal employment. Trade restrictions also appeared to have a role in explaining the scope of the informal economy (Elbahnasawy et al. 2016). Chatterjee & Turnovsky (2018) finds that larger remittances are associated with a larger size of the informal economy.

Financial development has been highlighted in the literature as significantly and negatively impacting informality. It has been argued that financial development encourages firms to operate formally as external financing becomes available at a lower cost (Berdiev & Saunoris 2016, Capasso & Jappelli 2013). Taxation also plays a role in explaining the proliferation of informal activities. A high tax burden may stimulate informal activities by increasing production costs (Dabla-Norris et al. 2008, Djankov et al. 2010, Friedman et al. 2000, La Porta & Shleifer 2008, Schneider 2010), suggesting a positive effect on the size of the informal economy. However, the effect of taxation might also be negative. It has been argued that high taxation can reduce the informal economy when law enforcement institutions are strong and the credit market is developed (Mitra 2017). In addition to monetary costs such as taxes, Djankov et al. (2002) and Goel & Nelson (2016) have found that non-monetary costs, particularly lengthy procedures for starting a business and paying taxes, reduce incentives to operate in the formal sector. Excessive regulation, especially in the labor market,

has also been found to stimulate the growth of informal activities (Schneider 2010, Schneider et al. 2010).

At the institutional level, the literature highlights the importance of good quality institutions in significantly limiting the proliferation of informal activities. For instance, Dabla-Norris et al. (2008) and Dreher et al. (2009) show that government efficiency helps reduce the size of the informal economy. Greater control of corruption has been found to significantly reduce informality (Choi & Thum 2005, Dreher & Schneider 2010, Schneider 2010). The enforcement of laws has also emerged in recent literature as an important determinant of the informal economy (Elbahnasawy 2021, Liu-Evans & Mitra 2019). The idea is that because informal activities are illegal, the more rule of law is respected and enforced in a country, the smaller the size of the informal economy.

At the political and social levels, the literature identifies several factors that play a crucial role in explaining the expansion of informal activities. Political stability is a key factor in this regard, as an unstable political environment limits the government's ability to effectively detect informal production (Elbahnasawy et al. 2016). Additionally, the type of political regime influences individuals' decisions to operate in the formal or informal sector. For example, in a democratic regime, tax policies often align more closely with citizens' preferences, reducing the likelihood of operating in the informal sector (Teobaldelli & Schneider 2013). Elbahnasawy (2021) demonstrates that internal conflict can increase the size of the informal economy by reducing tax compliance. Population size and urbanization are other social factors that have been found in the literature to contribute to limiting the proliferation of informal activities (Elbahnasawy 2021, Elgin & Oyvat 2013, Ndoya & Djeufack 2021).

Beyond these purely economic, institutional, political, and social factors, there have been very few recent studies that examine the role of ICTs (mobile phones and the internet), e-government, and financial mobile services in explaining the evolution of the informal economy. Indeed, research has shown that ICTs can significantly impact the size of the informal economy by improving human capital, financial development, and control of corruption (Ndoya et al. 2023). Financial mobile services can help reduce informal activities by facilitating access to financial services (Jacolin et al. 2021). Elbahnasawy (2021) shows that e-government may reduce informality by increasing efficiency in tax collection, among other factors.

From the foregoing, it is striking that the role of the production of innovation in explaining the size of the informal economy has been overlooked despite its implications in terms of economic, financial, and social development. Indeed, as we explained in the Introduction section, economic development, domestic credit mobilization, and e-government are possible

channels through which the production of innovation may reduce the size of the informal economy. Additionally, the effect of innovation on the size of the informal economy is worth investigating as the reduction of informality is associated with a number of development issues relating to factors such as growth, productivity, tax revenue mobilization, vulnerabilities, and inequality, as outlined previously (see Subsection 2.4). The next section presents the methodology we have adopted in this paper to make this investigation.

4 Methodology

This paper aims to analyze the impact of innovation on the size of the informal economy. Establishing a causal link between innovation and the informal economy is a more significant challenge than it may initially appear. Indeed, innovation may be endogenous for various reasons. One of the most critical factors is that achieving a certain level or intensity of innovation, whether low, medium, or high, is not a random process. The level or intensity of innovation can be influenced by a country's economic progress, political stability, urbanization, unemployment, trade openness, financial openness, and taxation. In econometric terms, this introduces a selection bias. These factors may also affect the size of the informal economy, making innovation endogenous. Reverse causality presents another econometric challenge, rendering innovation endogenous. In fact, microeconomic literature has shown that informality significantly reduces innovation (see for instance Fu et al. 2018, Kouakou 2023*b*). Reduced innovation at the firm level negatively impacts a country's overall innovation production.

Following Balima (2017), to address these endogeneity issues related to innovation, we employ an impact evaluation methodology. Specifically, we use the entropy balancing method, a novel and robust impact evaluation technique. This method is an extension of traditional matching techniques, initially developed by Hainmueller (2012) for binary treatments. Recently, it has been further extended by Vegetabile et al. (2021) and Tübbicke (2022) to accommodate continuous treatments. In this paper, we utilize the extended entropy balancing method for continuous treatments since our treatment variable, innovation, is continuous. The entropy balancing method has garnered increasing interest in recent economics literature. For instance, recent studies that have employed it include Apeti (2023) and Apeti & Edoh (2023) on the impacts of mobile money on consumption volatility and tax revenues, respectively; Neuenkirch & Neumeier (2016) on the effect of US economic sanctions on poverty; Balima (2017) on the impact of domestic sovereign bond market participation on financial dollarization; Balima (2020) on the impact of coups d'état on the cost of debt; Balima & Sy (2021) on the effects of IMF-supported programs on the likelihood of sovereign

default; and Balima et al. (2021) on the impact of sovereign credit default swaps on the probability of sovereign debt crises. It is worth noting that the existing empirical literature on entropy balancing has primarily focused on binary treatments. This paper is one of the first to employ the extended entropy balancing methodology for continuous treatments.

As we previously outlined, the approach adopted in this research is based on the idea that innovation is the treatment variable and the size of the informal economy is the outcome variable. In our context, where the treatment is continuous, all units received some treatment with different intensity or dose.[9] Estimating the treatment effect of innovation using the entropy balancing method involves two consecutive steps.

The first step consists in computing weights so that in the re-weighted sample, the balancing property is respected. Entropy balancing for continuous treatments is essentially a weight-based covariate balancing scheme that addresses a globally convex optimization problem to derive balancing weights. This is achieved by minimizing the deviation from (uniform) base weights while adhering to zero correlation and normalization constraints.

Assume that T_i is a non-negative variable denoting the treatment variable (innovation) for unit i, where treated units have $T_i > 0$. Unlike the binary treatment case, balancing weights (w_i) are computed for the treated units. This is done to estimate the average outcomes of treated units under specific treatment doses or intensities (Tübbicke 2022). Define $X_i \in \mathbb{R}^K$ as a vector of pre-treatment covariates and Y_i as a post-treatment outcome (the size of the informal economy) for unit i, where K is the number of covariates. Let $\tilde{X}_i$ be the de-meaned version of X_i. Similarly, define $\tilde{T}_i^r$ as the de-meaned rth order term of the treatment intensity. Consider the column vector $g(r, \tilde{X}_i, \tilde{T}_i) = (\tilde{X}_i', \tilde{T}_i, ..., \tilde{T}_i^r, \tilde{X}_i'\tilde{T}_i, ..., \tilde{X}_i'\tilde{T}_i^r)'$. Entropy balancing weights are obtained by solving the following constrained optimization problem:

$$\begin{cases} \min\limits_{w} \; H(w) = \sum_{i|T_i>0} h(w_i) \\ \text{s.t.:} \quad \sum_{i|T_i>0} w_i g(r, \tilde{X}_i, \tilde{T}_i) = 0, \\ \qquad\qquad \sum_{i|T_i>0} w_i = 1, \\ \qquad\qquad \text{and } w_i > 0 \; \forall i | T_i > 0 \end{cases} \tag{1}$$

where H is the loss function. It is minimized subject to both balancing constraints in terms of $g(r, \tilde{X}_i, \tilde{T}_i)$ and normalizing constraints that weights are strictly positive and sum up to one. The fundamental concept of entropy balancing is to calculate weights that render the treatment variable uncorrelated with the covariates. However, despite its intuitiveness, this approach may prove insufficient in eliminating bias arising from observed covariates when analyzing the causal effect of a continuous treatment (Tübbicke 2022, Yiu & Su 2018). In-

[9]The assessment of the impact of continuous treatments has attracted significant interest recently in the economics literature. Tübbicke (2022) briefly reviews some of the recent studies.

deed, as emphasized by Tübbicke (2022), achieving uncorrelatedness between $\tilde{T}_i$ and $\tilde{X}_i$ does not guarantee independence; the distributions of covariates may still differ across the treatment intensity distribution, even with flexible $\tilde{X}_i$. To overcome this challenge, entropy balancing weights also ensure that higher orders of the treatment variable are uncorrelated with the covariates. This is operationalized by choosing r that shows the order to which the treatment variable (innovation) has been rendered uncorrelated with the covariates. In practice, weights are usually estimated for $r = 1, 2,$ and 3. Through Monte-Carlo simulations, Tübbicke (2022) demonstrated that setting $r = 2$ yields superior results in terms of both bias and Root Mean Squared Error (RMSE) compared to choices of $r = 1$ and $r = 3$. From this backdrop, we set $r = 2$ in our analysis. This means that both T_i and T_i^2 are rendered uncorrelated with the covariates. As it will be seen, this leads to achieve excellent covariate balance.

The optimization problem is solved using the Lagrange method. The entropy metric by Kullback (1959) is employed, defined as $h(w_i) = w_i \ln(w_i/q_i)$, where a uniform base weight scheme $q_i = 1/N_1$, with N_1 representing the size of the treatment group, is set as the default. The loss function is undefined for non-positive weights and reaches its minimum when $w_i = q_i$. Therefore, when using the Lagrange method, the normalizing constraint that weights must be positive can be omitted. This yields the following equation:

$$\min_{w,\lambda,\gamma} \mathcal{L}(w, \lambda, \gamma) = \sum_{i=1}^{N_1} w_i \ln(w_i/q_i) - \lambda \left(\sum_{i=1}^{N_1} w_i - 1 \right) - \gamma' \left(\sum_{i=1}^{N_1} w_i g(r, \tilde{X}_i, \tilde{T}_i) \right) \tag{2}$$

where $\mathcal{L}$ is the Lagrange function, and λ and γ are Lagrange multipliers. Solving equation (2) yields the weights (w_i) as a function of the base weights (q_i), γ, and the data $g(r, \tilde{X}_i, \tilde{T}_i)$. We obtain the following equation:

$$w_i = \frac{q_i \exp\left(\gamma' g(r, \tilde{X}_i, \tilde{T}_i)\right)}{\sum_{i=1}^{N_1} q_i \exp\left(\gamma' g(r, \tilde{X}_i, \tilde{T}_i)\right)} \tag{3}$$

where λ was cancelled out. To obtain the final expression for w_i, we need to estimate γ. To do so, we proceed in three steps. First, we derive the dual Lagrange function ($\mathcal{L}^d$) by substituting (3) into the Lagrange function $\mathcal{L}$. Then, we determine γ^*, the value of γ at the optimum, by differentiating $\mathcal{L}^d$ with respect to γ. Finally, we obtain the balancing weights by replacing γ with γ^* in equation (3).

In the second step, the balancing weights obtained in the first step are used in a regression analysis to determine the treatment effect and the Dose-Response Function (DRF). More specifically, the treatment effect of innovation is obtained using the weighted least squares

method. We perform a nonparametric estimation of the DRF using local linear regression with an Epanechnikov kernel.

By combining weighting and regression approaches, the entropy balancing method has several advantages over conventional impact evaluation methods such as Generalized Propensity Score (GPS) or Difference-in-Differences (DID). First, the re-weighting scheme of entropy balancing allows us to achieve a high degree of covariate balance even in the case of small samples. Second, as stressed by Tübbicke (2022), entropy balancing helps obviate the estimation of the GPS, which is notoriously difficult to estimate. Many GPS-based methods may require implementing an iterative estimation procedure until satisfactory covariate balance is achieved. Third, the entropy balancing scheme is nonparametric. This means that there is no need to define an empirical model for either the treatment variable (innovation) or the outcome variable (size of the informal economy) to obtain balancing weights. Consequently, entropy balancing reduces model dependency by avoiding misspecification issues related, for instance, to the functional form of the empirical model.

Fourth, the treatment effects obtained using the entropy balancing method are not biased by multicollinearity issues. The covariates are actually orthogonalized with respect to the treatment variable. Fifth, entropy balancing allows us to avoid information loss and retain efficiency for the subsequent estimations by using a more flexible re-weighting scheme that keeps the weights as close as possible to the base weights. Sixth, as the entropy balancing method combines weighting and regression analysis, it allows us to account for unobservable factors related to the panel structure of the data in the estimation of the treatment effect by including fixed effects in the second step. Seventh, as shown by Tübbicke (2022) through Monte-Carlo simulations, the entropy balancing method for continuous treatment with $r = 2$ can outperform in terms of bias and RMSE other re-weighting approaches such as Generalized Boosted Modeling (see Zhu et al. 2015), Covariate Balancing GPS (see Fong et al. 2018), and Inverse Probability Weighting with continuous treatment (see Robins et al. 2000).

Eight, the entropy balancing methodology is very versatile. The balancing weights obtained in the first step can be used in any standard regression model of the outcome variable (size of the informal economy) on the treatment variable (innovation) to obtain the treatment effects, provided that this model is one that would have been estimated in the absence of any re-weighting scheme. Ninth, from a computational perspective, entropy balancing is appealing. The optimization problem used to compute the weights is globally convex and well-behaved. In general, it requires only a few seconds to attain the weighting solution, even in the case of moderately large datasets.

5 Data, variables and descriptive statistics

In this section, we start by introducing the variables used in this study and the data sources. Following that, we present and discuss the key descriptive statistics.

5.1 Data and variables

To assess the effect of innovation on the size of the informal economy, we utilize an unbalanced large panel dataset comprising 138 countries observed from 2007 to 2018.[10] The selection of countries in the dataset and the chosen time span are based on data availability for both the size of the informal economy and innovation. Notably, the unavailability of data on the composite and comprehensive measure of innovation production at the global level prior to 2007 dictated the time frame. Our main variables consist of innovation (the treatment variable) and the size of the informal economy (the outcome variable).

We utilize Elgin et al.'s (2022) estimates of the size of the informal economy, which reflect all legal economic activities that would have contributed to the GDP if they were recorded. This excludes all economic activities that are classified as criminal by public authorities. The estimates of the size of the informal economy are obtained using the MIMIC method. MIMIC-based estimates are widely used in the literature (see Dell'Anno (2016), Dreher & Schneider (2010), Elbahnasawy (2021), Elbahnasawy et al. (2016), Goel & Nelson (2016), Pham (2017), and Schneider (2010), among others). MIMIC is a type of structural equations model that combines multiple causes and outcome indicators of informal activities to estimate their relative size. It is based on the statistical theory of unobserved variables that draws upon the multiple causes and indicators of a given phenomenon to measure it. Combining the causes and outcome indicators of the informal economy allows us to better capture informal activities and, therefore, to have more reliable estimations of their scope.

An important feature of the MIMIC method is that it can readily be used to obtain the size of the informal economy of a large set of countries worldwide over time (more than 150 countries worldwide). Very importantly, this method takes into account both the levels of employment and productivity of the informal sector when measuring the size of the informal economy. This allows us to have a more comprehensive measure of the informal economy compared to estimations that focus on informal employment and which merely reflect the level of employment in the informal sector. Note that we use Elgin et al.'s (2022) MIMIC-based estimates of the size of the informal economy because they are more recent and/or available over a longer time span compared to other existing estimations (see Medina &

[10] The list of the countries is presented in Table B1 in Appendix B.

Schneider (2018) and Medina & Schneider (2019), among others). They actually cover 160 economies observed over the period 1993-2018.

Two alternative measures of the informal economy are considered for robustness checks. The first one is Medina & Schneider's (2019) MIMIC-based estimates that are available for 157 countries from 1991 to 2017. This measure is used mainly because it is obtained using a set of variables that is not identical to the one used by Elgin et al. (2022). This allows us to check the robustness of our results to the choice of the variables included in the MIMIC. In the same line as Elgin & Oyvat (2013) and Ndoya et al. (2023), the second alternative measure is non-agricultural informal employment. Non-agricultural informal employment is considered, among others, because in many regions worldwide, informal employment is usually more prevalent outside of the agricultural sector. See, for instance, Figure 1 in Ndoya et al. (2023) for an illustration of this fact in 2018. The estimates of the size of the informal economy are obtained using survey data, that is, through a direct approach, which is not the case for the MIMIC-based measures.

To measure innovation, in line with Kouakou (2022), we use the innovation output index. This index is extracted from the report titled "Global Innovation Index," published yearly by the World Intellectual Property Organization (WIPO), Cornell University, and INSEAD, since 2007. It is computed based on two pillars, namely "knowledge and technology outputs" and "creative outputs." Knowledge and technology outputs encompass knowledge creation (e.g., patents), knowledge impact (e.g., high- and medium-high-tech manufacturing), and knowledge diffusion (e.g., high-tech net exports). Creative outputs refer to intangible assets (e.g., industrial designs), creative goods and services (e.g., creative goods exports), and online creativity (e.g., mobile app creation). The innovation output index is a composite index, providing a comprehensive measure of the production of innovation, as highlighted by Kouakou (2022). It measures a country's level of innovation production on a scale from 0 to 100, where a higher index indicates a higher level of innovation production.

Two alternative measures of innovation are used for robustness checks. The first measure is patent applications by residents, which is a traditional indicator of a country's innovation level. A higher number of patents indicates a higher level of innovation production in a country. The second alternative measure of innovation is Research and Development (R&D) intensity, expressed as R&D expenditure as a percentage of GDP. R&D plays a significant role in driving innovation, making it a suitable proxy. In the empirical literature on the determinants and effects of innovation (see, for instance, Gong & Hanley (2021)), R&D intensity is commonly used as an alternative measure of innovation. A higher R&D intensity in a country is associated with a greater likelihood of producing innovations.

Regarding the control variables, as emphasized by Apeti (2023), it is essential for these

variables to exhibit correlations with both the treatment (innovation) and outcome (size of the informal economy) variables to better identify the treatment effect. Specifically, including variables that exhibit correlations with both the size of the informal economy and innovation helps mitigate potential omitted variable bias and enhances balancing quality. To select these variables, we draw from the literature on the determinants of innovation and the size of the informal economy. The chosen variables include political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. These variables constitute the set of baseline control variables (covariates). In line with Apeti & Edoh (2023), all the control variables are lagged by one year to address potential issues of reverse causality.

Political stability plays a crucial role in our analysis as it allows us to consider the political environment's impact on both innovation and the extent of the informal economy. Political instability can hinder a government's ability to effectively detect informal production, thereby fostering the proliferation of informal activities (Elbahnasawy et al. 2016). Moreover, it has been noted in the literature that political instability tends to reduce the introduction of product innovation and weaken the national system of innovation (Allard et al. 2012, Krammer & Kafouros 2022). This is often attributed to declines in long-term investments, such as R&D, and frequent instability in the regulatory framework. It is worth noting that the informal sector often serves as a safety net (Loayza & Rigolini 2011). Informal employment tends to expand as the unemployment rate rises. To be precise, the informal sector absorbs part of the workforce unable to secure employment in the formal sector (Dell'Anno & Solomon 2008, Fields 1975). Furthermore, informal activities typically flourish in unfavorable economic contexts and contract as the economic situation improves. Therefore, an increase in economic growth is expected to reduce the size of the informal economy, while an increase in the unemployment rate is likely to lead to an expansion of the informal economy.

While innovation drives economic growth, economic growth can also fuel further innovation. This occurs through economic revitalization, increased business opportunities, and improved economic conditions, often resulting from expanded infrastructure development. Countries with high unemployment rates often experience increased international emigration (White & Buehler 2018). This encourages the "brain drain" phenomenon, where skilled workers emigrate in pursuit of better job opportunities and an improved quality of life abroad. However, the emigration of skilled workers may reduce innovation by depleting the country's human capital. Skilled employees play a vital role in innovation as they enhance firms' absorptive capacity (Leiponen 2005). This emigration can potentially hinder a country's innovation potential.

Taxation is another crucial economic factor considered in this research. Formal firms face various taxes that can be burdensome. High taxes can incentivize participation in the informal economy to reduce this burden, suggesting a positive correlation between taxation and the size of the informal economy (Dabla-Norris et al. 2008, La Porta & Shleifer 2008, Schipper 2020, Ulyssea 2018). However, the literature also notes that higher tax rates may have a negative impact on informality when institutions are of better quality and the credit market is developed (Goel & Nelson 2016, Mitra 2017). Therefore, the effect of taxation on the size of the informal economy is not straightforward. Taxation may also reduce the quantity of innovation produced in a country (Akcigit et al. 2022). High taxation increases production costs, which can impede innovation by reducing R&D investment. Trade openness is another economic factor relevant to understanding the scope of the informal economy (Elbahnasawy 2021, Elgin & Oyvat 2013). Indeed, trade openness can create economic opportunities, generate jobs, and promote economic progress, conditions that deter the proliferation of informal activities. It can also stimulate R&D investment (Teteryatnikova 2018), potentially increasing a country's likelihood to produce innovations, possibly due to greater exposure to international market competition.

Financial openness, by expanding financing opportunities through increased cross-border financial transactions, can potentially reduce the size of the informal economy. It may also stimulate innovation by providing greater support for innovative activities. Urbanization is another factor considered in this research to account for the social environment of countries. As cities modernize, they tend to attract rural workers seeking better-paying jobs (Harris & Todaro 1970, Todaro 1969), which are often found in the formal economy. Urbanization can thus play a significant role in reducing the informal economy's size (Elgin & Oyvat 2013, Ndoya & Djeufack 2021). Additionally, urbanization can have a notable impact on innovation, as shown by Chen et al. (2020). It has the potential to increase innovation at the country level by enhancing regional innovation capabilities.

For robustness checks, we consider a set of additional control variables, following the literature on the determinants of innovation and the size of the informal economy. These variables are: government effectiveness, control of corruption, rule of law, inflation, trade restrictions, financial development, political system, and regime durability. These covariates are also lagged by one year to address potential issues of reverse causality.

Government effectiveness and control of corruption control for the economic and institutional dimensions of governance in explaining informality, as outlined by Elbahnasawy (2021). These variables also contribute to long-term macroeconomic efficiency in the production of innovation (Kouakou 2022). The rule of law further addresses the institutional environment. Weaker law enforcement is detrimental to innovation, as it may fail to guaran-

tee the property rights of innovators. Strong institutional quality makes it easier to detect informal economic activity, reinforces people's trust in institutions, and increases their likelihood to engage in the formal economy (Elbahnasawy 2021). Since informal activities are illegal (as they are not registered), stricter enforcement of the rule of law should reduce their prevalence in a country (Kouakou 2023*a*). Political system and regime durability allow us to consider additional aspects of the political environment in countries, beyond what is covered by the political (in)stability variable. They are expected to have a negative impact on both innovation and the informal economy, as a deteriorating political environment is unfavorable for innovation and the development of the formal sector, as explained previously.[11]

Inflation is expected to increase the size of the informal economy. In a high inflation scenario, there is an increased demand for informal goods because they are relatively cheaper than those produced in the formal sector (Buehn & Schneider 2012, Goel & Nelson 2016). This stimulates the proliferation of informal activities. Inflation may also reduce innovation by weakening firms' ability to invest in R&D activities (Chu et al. 2019, Costamagna 2015). Financial development is expected to reduce the scope of the informal economy because a developed financial system provides greater access to low-cost financing, which encourages firms to operate in the formal sector (Berdiev & Saunoris 2016, Capasso & Jappelli 2013).[12] Financial development may also foster innovation (Hsu et al. 2014) due to increased financing for innovation activities. Restrictions on international trade may increase the size of the informal economy. One rationale is that these restrictions are correlated with rural areas and shift demand toward domestic output, making it more difficult to detect informal activities and stimulating their proliferation (Elbahnasawy et al. 2016). Restrictions on international trade may also reduce innovation, primarily by limiting exposure to competition on international markets.

Table C1 in Appendix C gives information on how each variable is measured. The data sources are also indicated. As explained in the Introduction section, we test three transmission channels in this study, that is, economic development, domestic credit mobilization, and e-government. The measures and data sources of these channels are also presented in Table C1.

[11]Political system and regime durability have recently been found by Elbahnasawy et al. (2016) to reduce the size of the informal economy.

[12]Financial development is a concept that is different and broader than financial openness. These two concepts should not be considered equivalent.

5.2 Descriptive statistics

Descriptive statistics are presented in Table C2 in Appendix C. It emerges that over the study period, on average, the informal economy represents approximately 32% of GDP. It ranges from around 8% to 69% of GDP. Non-agricultural informal employment represents between approximately 1% and 96% of total employment, with an average level of around 33%. The average level of innovation is around 32 on a scale of 0 to 100. This means that, on average, countries have had a poor level of innovation over the study period. Indeed, 50 can be seen as an intermediate value that separates poor performers (countries that have an innovation index less than 50) from good performers (those countries having an innovation index higher than 50). The average level of R&D intensity is about 1% of GDP, with a minimum level of 0.01%. This is relatively low and corroborates the statistics on the innovation production index.

Figure A3 in Appendix A shows the distributions of informality and innovation. The size of the informal economy displays a bimodal distribution. The distributions of informality and innovation are somewhat skewed to the left, meaning that they have a tail stretching toward the lower values. The upper end of the distribution for each variable is located on the far right, indicating a high level of informality and innovation in several countries. This aligns with the observation that the level of innovation tends to be high in developed countries, while the size of the informal economy is substantial in developing countries, as emphasized in Figures 1 and 2.

Furthermore, it is worth noting that, on average, approximately 60% of the population resides in urban areas, indicating a significant level of urbanization. The average unemployment rate is below 8% of the total labor force, but in several countries, it exceeds 25%, which is quite high. As seen in Table C2, the average total tax and contribution rate amounts to around 42% of profits, reflecting a high tax burden. Importantly, the average levels of government effectiveness, control of corruption, and the rule of law are positive. This indicates that, on average, the countries in the sample have demonstrated strong performances in terms of government effectiveness, control of corruption, and the enforcement of laws during the study period. However, it is worth noting that the variable measuring political stability exhibits a negative mean, suggesting a significant level of political instability throughout the study period.

Table C2 also reveals that the countries in the sample are, on the whole, quite open to international markets. The average trade openness rate stands at approximately 88% of GDP. In contrast, the average inflation rate hovers around 6%, indicating that some countries may need to make additional efforts to target inflation levels around the typical 2% threshold often sought in monetary policy. Moreover, the sample countries, on average, experience

relatively low restrictions on international trade. The mean of the variable measuring these restrictions exceeds 50. The average level of domestic credit to the private sector is roughly 59% of GDP, which is significant. Nonetheless, the relatively high standard deviation of approximately 46% provides valuable context for understanding the substantial average domestic credit to the private sector. Taking a broader perspective on financial development, the average level appears to be low, with the mean of the financial development index being less than 0.5. Additionally, the e-government index, with an average of 0.53, suggests a moderate level of e-government adoption in the sample during the study period.

Table C3 in Appendix C shows the correlation coefficients. The correlation between the MIMIC-based estimates is equal to 97%, which is very high. This is an interesting result because the sets of variables used by Elgin et al. (2022) and Medina & Schneider (2019) are not identical, showing that Elgin et al.'s (2022) estimates of the size of the informal economy are not biased by the choice of the variables included in the MIMIC. The correlation between the Elgin et al. (2022) MIMIC-based estimates and non-agricultural employment is equal to around 60%, which is high.

As expected, the innovation production index is highly correlated and negatively associated with all three measures of the size of the informal economy. It is also highly correlated and positively associated with R&D intensity and patent applications. These alternative measures of innovation are negatively correlated with all three measures of the size of the informal economy, with the correlation being more significant for R&D intensity.

The transmission channels also exhibit high negative correlations with the measures of informality, but high positive correlations with innovation, which is expected. We also see from Table C3 that many of the control variables are highly correlated with both innovation and the informal economy. This shows that the choice of the control variables is appropriate overall. Very importantly, this suggests that many of the control variables will effectively help to mitigate a possible omitted variable bias, thereby helping to better identify the effect of innovation on the size of the informal economy.

Table C4 in Appendix C reports the Variance Inflation Factors (VIFs). Regardless of the specification, the VIFs are all less than 5. This means that the econometric estimations do not suffer from collinearity issues.

6 Results

We begin by analyzing the performance of the entropy balancing method. To do so, we present in Table 1 the summary statistics on balancing quality obtained from a (weighted) regression of the treatment variable ("Innovation 1") on the covariates (Tübbicke 2022).

Recall that the (baseline) set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation, with all covariates lagged by one year to prevent potential issues of reverse causality. The balancing statistics are the R-squared and F-statistic from this regression (Tübbicke 2022). The p-value associated with the F-statistic is also reported. Table 1 reports the statistics obtained before and after applying the entropy balancing weighting used to estimate the treatment effect of innovation, allowing us to assess the performance of the entropy balancing method.

[Insert Table 1 here]

Before weighting, the R-squared is equal to 0.49, meaning that the covariates explain 49% of the variance in the treatment variable. As for the F-test, the p-value is equal to 0.000, indicating that we reject the null hypothesis that the covariates do not significantly influence the treatment variable overall. This implies that before weighting, achieving a certain level of innovation, whether high, low, or medium, is not random. It is determined by countries' characteristics, resulting in a self-selection into different levels or intensities of innovation. This self-selection makes innovation endogenous, as many of these characteristics may also impact the size of the informal economy.

After applying the entropy balancing weighting, the R-squared is equal to 0, indicating that the covariates no longer induce differences in the treatment variable, as expected. Regarding the F-test, the F-statistic is equal to 0, and the p-value in the F-test is 1, which means that we fail to reject the null hypothesis that the covariates do not have a significant effect on the treatment variable overall. This supports the results from the R-squared. The balancing property is upheld. These findings highlight the effectiveness of the entropy balancing method in estimating the effect of innovation, as the influence of countries' characteristics observed before weighting has disappeared.

Since the balancing property is satisfied, we can proceed to interpret the entropy balancing treatment effect. The weights acquired in the first step of entropy balancing are employed in a second step to estimate the effect of innovation on the size of the informal economy using the weighted least squares method. The results are presented in Table 2.

[Insert Table 2 here]

Columns (1) to (4) present the effects without the matching covariates used in the first step of entropy balancing. Following Balima et al. (2021), we include year and regional fixed effects in the second step of the entropy balancing methodology. To be precise, column (1) excludes year and regional fixed effects, columns (2) and (3) include year and regional fixed effects, respectively, while column (4) includes these effects jointly. Columns (5) to (8) repeat

the exercise by including the matching covariates used in the first step of entropy balancing, which are the one-year lagged values of political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. Year fixed effects control for macroeconomic shocks or time-related factors impacting the informal economy and innovation, while regional fixed effects allow us to account for region-specific factors affecting the informal economy, as discussed by Elbahnasawy (2021), and innovation.

Indeed, Elbahnasawy (2021) shows that region-specific fixed effects significantly influence the size of the informal economy at the country level. For instance, he found that countries in the North America (NA) and South Asia (SA) regions have considerably smaller informal economies, while membership in the Latin America region substantially increases a country's informal economy size. These findings support the notion that region-specific factors play a crucial role in explaining informal economies at the national level. In alignment with Elbahnasawy (2021), we consider the regions identified by The World Bank, which include Latin America and the Caribbean (LAC), North America (NA), South Asia (SA), Sub-Saharan Africa (SSA), Middle East and North Africa (MENA), East Asia and Pacific (EAP), and Europe and Central Asia (ECA). In the same light, Figures discussed in Section 2 highlight regional patterns in the evolution of both innovation production and the informal economy, justifying the inclusion of regional fixed effects. The incorporation of matching covariates in the second step of the entropy balancing methodology, analogous to including control variables in a randomized experiment, enhances estimation efficiency (Neuenkirch & Neumeier 2016).

As seen in Table 2, regardless of the specification, innovation significantly decreases the size of the informal economy. The magnitude of the reduction varies between 0.33% (column (7)) and 0.68% (column (2)). The average effect is equal to -0.51%. This means that, on average, a 1% increase in the level of innovation decreases the size of the informal economy by 0.51%, which is significant. As discussed in the Introduction section, a plausible explanation of this result can be obtained via the economic development, domestic credit mobilization, and e-government channels. We formally test these three transmission channels in Section 8.

Figure 5 presents the DRF along with the 95% confidence interval. Standard errors are obtained using the bootstrap method (Efron & Tibshirani 1986, MacKinnon 2006). Bootstrap has been found by Vegetabile et al. (2021) to work well in the context of entropy balancing for continuous treatments. It has also been used by Tübbicke (2022) to derive the standard errors when estimating the DRF. We use 500 bootstrap replications.

[Insert Figure 5 here]

The DRF reflects the response of the size of the informal economy to different intensities (levels) of innovation. Figure 5 shows a decline in the size of the informal economy with the treatment intensity, that is, the higher the level of innovation, the lower the size of the informal economy. This confirms previous results on the negative impact of innovation on the development of the informal economy.

7 Robustness checks

Our estimations indicate that innovation has a negative and significant effect on the size of the informal economy. In this section, we seek to check the robustness of this main result. To this end, we make six different analyses. First, we test the sensitivity of our finding to potential omitted variables by considering eight more control variables. Second, we estimate the effect of innovation on the size of the informal economy using the two-step system Generalized Method of Moment (GMM). Third, we estimate the effect of innovation by considering restricted samples. Fourth, we consider alternative measures of the size of the informal economy. Fifth, we also consider alternative measures of innovation. Sixth, we estimate the effect of innovation using pooled cross-section, fixed-, and random-effects regressions. As it will be seen, all these analyses show that innovation reduces significantly the size of the informal economy. These results argue in favor of the robustness of our finding.

7.1 Additional controls

We extend our baseline specification to a set of eight additional control variables. These variables are: government effectiveness, control of corruption, rule of law, inflation, trade restrictions, financial development, political system, and regime durability.[13] These variables capture institutional, political, and economic aspects of the determinants of the size of the informal economy and innovation. This analysis allows us to test the robustness of our finding to a possible omitted variable bias.

To mitigate potential multicollinearity issues, the additional control variables are entered one at a time in the entropy balancing analysis. The results are presented in Table 3.

[Insert Table 3 here]

In all these estimations, the summary statistics on balancing quality are adequate. For the sake of brevity, they are presented in Appendix D. We see from these tables that, regardless

[13]See Subsection 5.1 for a discussion on the choice of these variables. Their definitions are summarized in Table C1 in Appendix C.

of the additional control variable, innovation has a negative and significant effect on the size of the informal economy, that is, the effect of innovation is still strong and negative and does not disappear with the inclusion of additional controls. This suggests that our finding is robust to a potential omitted variable bias.

7.2 Two-step system GMM

Using the two-step system GMM is another approach to handle the endogeneity of innovation.[14] The system GMM estimator is an improved version of the difference GMM estimator proposed by Arellano & Bond (1991). The methodology was first outlined by Arellano & Bover (1995) and then fully developed by Blundell & Bond (1998). The model to be estimated is specified as follows:

$$Inf_{i,t} = \alpha + \delta Inf_{i,t-1} + \lambda Innov_{i,t} + X'_{i,t}\beta + \mu_i + \upsilon_{i,t} \tag{4}$$

where $Inf_{i,t}$ denotes the output of the informal economy as a percentage of the official GDP for country i in year t, with $i = 1, ...,$N and $t = 1, ...,$T; N and T are the total numbers of countries and years, respectively. δ is a parameter to estimate, and $Inf_{i,t-1}$ is the lagged informal economy of country i. $Innov_{i,t}$ represents the level of innovation of country i in year t, and $X_{i,t}$ is a vector of control variables for country i in year t. α is a constant term, and λ is the main parameter of interest. It allows us to capture the effect of innovation on the size of the informal economy. β is a vector of parameters to estimate. μ_i denotes the unobserved time-invariant country-specific effects, and υ_{it} represents the usual error term which varies across countries and years. It has the usual properties, namely, a mean of 0, constant variance, and for all countries and years, the υ_{it} are independent of the regressors and μ_i, and uncorrelated with themselves.

As emphasized by Elbahnasawy (2021), the dynamic nature of the model allows us to account for the persistence of the informal economy[15] while the Instrumental Variables (IVs) help address the suspected endogeneity of all the regressors, not limited to innovation. This methodology enables the capture of country heterogeneity by including country effects. Country heterogeneity can stem from cross-country variations in economic, political, institutional, and social environments. The methodology also enables the handling of unobserved country-specific factors that could lead to omitted variable bias and efficient

[14]For previous studies using the two-step system GMM to analyze the determinants of the size of the informal economy, see Elbahnasawy (2021), Elbahnasawy et al. (2016), Ndoya & Djeufack (2021), and Ndoya et al. (2023), among others.

[15]Indeed, it has been argued (Eilat & Zinnes 2002) that the informal/shadow economy develops through a phenomenon of hysteresis, making it difficult to eliminate once established.

management of measurement errors (Baltagi et al. 2009).

We use the two-step variant of the system GMM because it is more asymptotically efficient than the one-step variant. However, it is worth noting that the two-step standard errors often exhibit significant downward bias. To address this bias, we employ the variance correction method proposed by Windmeijer (2005), which yields bias-corrected robust standard errors.

In the implementation of the system GMM methodology, we begin by first-differencing equation (4). This allows us to deal with fixed effects. The transformed model is described in equation (5):

$$\begin{aligned} Inf_{i,t} - Inf_{i,t-1} &= \delta(Inf_{i,t-1} - Inf_{i,t-2}) + \lambda(Innov_{i,t} - Innov_{i,t-1}) \\ &+ (X'_{i,t} - X'_{i,t-1})\beta + (\upsilon_{i,t} - \upsilon_{i,t-1}) \end{aligned} \tag{5}$$

Then, in a second step, the equations in levels and differences are simultaneously estimated. This is done using different sets of instruments. To avoid the issue of IV proliferation, which occurs when there are too many IVs, the IV matrix is collapsed (Roodman 2009*a*,0). As previously explained, the system GMM methodology allows us to deal efficiently with suspected endogeneity of all the regressors. This concerns all three common sources of endogeneity: simultaneity bias (where the relationship between variables is bidirectional and simultaneous), omitted variables, and measurement errors, and is operationalized using the IV technique.[16] The system GMM methodology also helps avoid dynamic panel data bias (Nickell 1981). Note that in the estimations, we include time-specific dummy variables. This allows us to account for possible time-specific factors, such as the global financial crisis, that might have affected both the informal economy and innovation. By doing so, we eliminate any possible omitted variable bias that may be due to time-specific variables.

Table 4 displays the results of the dynamic panel model estimated using the two-step system GMM methodology. The Windmeijer (2005) robust standard errors are reported in parentheses.

[Insert Table 4 here]

All diagnostics are satisfactory. The Arellano-Bond tests indicate a rejection of the null hypothesis of no first-order autocorrelation but do not reject the null hypothesis of no second-order autocorrelation. The Hansen test for overidentifying restrictions does not reject the null hypothesis that all instruments are valid. The number of instruments is significantly less than the number of countries.

[16]For a comprehensive discussion on the use of IVs to address endogeneity issues stemming from simultaneity bias (reverse causality), omitted variables bias, or measurement errors, refer to Angrist & Krueger (2001), Baltagi et al. (2009), and Becker (2016).

The GMM estimates confirm the previous result obtained using the entropy balancing method, showing that innovation significantly reduces the size of the informal economy. This reinforces the robustness of our finding.

7.3 Restricted samples

In this subsection, we restrict the full sample by either focusing on specific groups of countries or excluding particular regions or sets of countries. We then examine whether our main result remains consistent. This approach enables us to evaluate the robustness of our main finding with respect to restricted samples. More specifically, we consider four cases.

First, we focus on the sub-sample of developing countries as informality is an issue that is more prevalent in developing countries. Second, we focus on the sub-sample of developed countries. Indeed, as informality is less prevalent in these countries as compared to developing countries, we are trying to know if the negative effect of innovation on the size of informal economy is specific to developing countries or if it does also exist in developed countries. Third, we remove countries from the G7. Indeed, G7 contains seven of the most advanced countries in the world. They exhibit significant levels of innovation and are among countries where informally is the less prevalent in the world. So, by removing G7 countries, we somehow try to focus on countries for which informally is more or less an important issue, while going beyond developing countries. Fourth, we remove from the sample countries from Sub-Saharan Africa and Latin America and the Caribbean. In fact, these regions have the highest levels of informality in the world. They also exhibit low levels of innovation. Hence, the negative effect of innovation on the size of the informal economy may have been influenced to some extent by the presence of countries from these regions in the sample. Thus, it is worth investigating whether our main result holds or not when countries from Sub-Saharan Africa and Latin America and the Caribbean are removed from the sample.

The effects of innovation obtained from the entropy balancing method are presented in Table 5. The summary statistics on balancing quality can be found in Appendix D and are all adequate.

[Insert Table 5 here]

In all cases, the effect of innovation is consistently negative and significant, indicating that innovation reduces the size of the informal economy. This reaffirms our previous findings. Within developing countries, the average effect amounts to -0.46%, meaning that a 1% increase in the level of innovation decreases the size of the informal economy by 0.46%. The magnitude of this effect is close to that obtained with the full sample (-0.51%). However,

in developed countries, the average effect is -1.01%, more than twice that of developing countries. This difference can be attributed to the generally higher levels of innovation in developed countries. Interestingly, the average effects of innovation when countries from the G7 (-0.49%) or Sub-Saharan Africa and Latin America and the Caribbean (-0.55%) are excluded closely resemble those obtained with the full sample.

7.4 Alternative measures of the size of the informal economy

In this subsection, we assess the robustness of our finding by examining alternative measures of the informal economy. We consider two specific measures. The first one is the MIMIC-based estimates of the informal economy, as proposed by Medina & Schneider (2019). These estimates cover a shorter time span. Notably, the variables used in the MIMIC differ from those considered by Elgin et al. (2022). Therefore, utilizing Medina & Schneider's (2019) estimates enables us to evaluate the robustness of our main result concerning the choice of variables in the MIMIC when gauging the size of the informal economy. The second alternative measure is non-agricultural informal employment, aligning with the approach of Elgin & Oyvat (2013) and Ndoya et al. (2023). Unlike the MIMIC-based estimates, this measure is derived from survey data, representing a direct measurement approach. Importantly, exploring alternative measures of the informal economy allows us to test the resilience of our results to potential measurement errors in estimating the size of the informal economy.

We refer to the Medina & Schneider (2019) MIMIC-based estimates of the informal economy as "Informal economy 2" and the non-agricultural informal employment measure as "Informal economy 3."[17] The entropy balancing treatment effect estimates obtained using these two variables as outcome variables are presented in Table 6. Summary statistics are provided in Appendix D and meet the required standards.

[Insert Table 6 here]

We see from Table 6 that the effect of innovation is consistently negative and significant for both alternative measures of the informal economy. This demonstrates the robustness of our main result, indicating that it is not likely influenced by potential errors in measuring the size of the informal economy.

7.5 Alternative measures of innovation

We assess the robustness of our results by examining alternative measures of innovation. Specifically, we consider two alternative measures: patent applications by residents, denoted

[17]For detailed definitions and data sources of these variables, please consult Table C1.

as "Innovation 2," and R&D intensity, denoted as "Innovation 3." For more comprehensive definitions and data sources of these variables, please refer to Table C1. Patent applications provide protection for inventions, encompassing products or processes that introduce new methods or novel technical solutions to problems. They also serve as records for inventions and the innovations associated with them. Therefore, the number of patents serves as a valuable indicator for measuring a country's level of innovation production. R&D intensity serves as a reliable proxy for a country's level of innovation. Generally, the most innovative countries in the world are those with the highest levels of R&D intensity.

Table 7 displays the results obtained when using "Innovation 2" and "Innovation 3" as alternative measures of innovation. The summary statistics for balancing quality can be found in Appendix D and meet the required standards.

[Insert Table 7 here]

We can observe from Table 7 that, in all cases, regardless of the specification, innovation consistently exhibits a negative and significant effect on the informal economy. For patent applications, the average effect of innovation is -0.07%, meaning that a 1% increase in the level of innovation reduces the size of the informal economy by 0.07%. As for R&D intensity, the average effect is -0.13%. It is important to highlight that these effects are notably lower than the one obtained using our primary measure of innovation, the innovation output index, which resulted in a reduction of -0.51% in the size of the informal economy. This variation is expected because our primary measure of innovation is a composite index. Its composite nature offers a more comprehensive representation of the production of innovation by incorporating a variety of indicators. In contrast, patents and R&D capture only a portion of the innovations produced in a country. In fact, not all innovations are patented, and firms can innovate without investing in R&D. However, innovations obtained in this manner are generally incremental and are less likely to significantly impact value creation processes (Zanello et al. 2016). Therefore, as patents and R&D intensity are partial measures of innovation, they fail to fully capture the comprehensive effect of innovation on the informal economy compared to our primary measure. In summary, these results consistently demonstrate that innovation reduces the scope of the informal economy, and this effect remains robust across various measures of innovation.

7.6 Additional robustness

In our final robustness check, we estimate standard pooled cross-sectional, fixed-effects, and random-effects models. The estimates are provided in Appendix E for reference. These esti-

mations reaffirm our previous findings, demonstrating that innovation consistently reduces the size of the informal economy.

8 Channels

Our results indicate that innovation reduces the size of the informal economy. The objective of this section is to elucidate the underlying mechanisms behind this finding, as introduced in the Introduction section. We investigate three potential mechanisms: economic development, domestic credit mobilization, and e-government. Our analysis encompasses two approaches. First, we conduct a descriptive analysis that involves examining the co-evolution of innovation and each potential channel, as well as the relationship between each potential channel and the informal economy. Scatterplots are employed for this analysis. Second, aligning with the approach of Apeti (2023) and Apeti & Edoh (2023), we formally test these channels using the entropy balancing method. Specifically, we utilize the entropy balancing method to evaluate the impact of innovation on the potential channels on one hand, and the impact of each channel on the informal economy on the other hand.

Figure 6 illustrates the central concept of our analysis regarding the transmission channels. To establish economic development, domestic credit mobilization, and e-government as effective channels, we need to demonstrate two key points. First, innovation must exhibit a positive and significant impact on each of these channels. Second, it should be evident that economic development, domestic credit mobilization, and e-government exert a negative and significant influence on the size of the informal economy.

[Insert Figure 6 here]

Figures 7, 8, and 9 provide scatterplots for the descriptive analysis. They focus respectively on economic development (Figure 7), domestic credit mobilization (Figure 8), and e-government (Figure 9) as potential transmission channels.

[Insert Figures 7, 8, and 9 here]

We see from the left part of Figure 7 that, on average, the higher a country's level of innovation, the higher its level of economic development. At the same time, increases in its level of economic development reduce the size of its informal economy, as illustrated by the right part of Figure 7. These results suggest that economic development is a channel through which innovation impacts the size of the informal economy.

We obtain a similar result with domestic credit mobilization. Indeed, the left part of Figure 8 shows that, on average, the higher a country's level of innovation, the higher its

level of domestic credit mobilization. Concomitantly, increases in its level of domestic credit mobilization result in decreases in the size of its informal economy (right part of Figure 8), suggesting that domestic credit mobilization is a transmission channel for the effect of innovation on informality.

The descriptive analysis also suggests that e-government is a transmission channel of the effect of innovation. Indeed, the left part of Figure 9 shows that, on average, the higher a country's level of innovation, the higher its level of e-government. At the same time, increases in its level of e-government decrease the size of its informal economy (right part of Figure 9).

Let us now go one step further in the analysis of the channels by testing them formally using the entropy balancing method. Using this method allows us to identify causal effects, while dealing effectively with the endogeneity of innovation and the transmission channels. The results of the estimations are reported in Tables 8, 9, and 10, focusing on economic development (Table 8), domestic credit mobilization (Table 9), and e-government (Table 10), respectively. For the effects of innovation on the channels, the summary statistics on balancing quality are those presented previously in Table 1 and are all adequate. As to the effects of the channels on the size of the informal economy, the summary statistics on balancing quality are reported in Appendix D. They all meet the required standards.

[Insert Tables 8, 9, and 10 here]

We see from Table 8 that innovation has a positive and significant effect on economic development, and economic development significantly reduces the size of the informal economy. We find similar results for domestic credit mobilization and e-government. Indeed, Table 9 shows that innovation stimulates domestic credit mobilization, and domestic credit mobilization, in turn, decreases the informal economy. As for e-government, it is found to be significantly and positively affected by innovation and has a negative effect on the size of the informal economy (Table 10).

In summary, innovation increases economic development, domestic credit mobilization, and e-government, and these factors, in turn, reduce the size of the informal economy. This demonstrates that they are channels through which innovation impacts the size of the informal economy. The consistency of the results across different types of analysis argues in favor of the robustness and relevance of the highlighted channels.

9 Conclusion

This paper analyzes the effect of innovation on the size of the informal economy worldwide using a large panel dataset of 138 countries observed from 2007 to 2018. Econometric estimations, based on the entropy balancing method for continuous treatments, demonstrate that innovation significantly reduces the size of the informal economy. This result remains robust after conducting a series of robustness checks. Economic development, domestic credit mobilization, and e-government play crucial roles as channels through which innovation influences the informal economy. These findings support the notion that innovation is a powerful driver of development. Countries that enhance their innovation capacity are more likely to achieve remarkable macroeconomic performance, including the reduction of their informal sectors, which is expected to improve tax revenue mobilization.

Effective innovation policies are therefore warranted to limit the scope of the informal economy worldwide. Such policies are particularly needed in low-income countries as these countries generally have significantly lower levels of innovation than their developed counterparts due to weaker absorptive capacity and limited financial and knowledge resources, among others. A number of policies could be considered by countries to improve their levels of innovation.[18] Among others, countries could give firms tax incentives for R&D. R&D investment is, indeed, a key driver of innovation. In practice, firms that invest in R&D activities could be offered tax reduction. The extent of the reduction, often referred to as the "R&D tax credit," should be proportionate to the level of investment in R&D. While such a policy is implemented in developed countries like France (the famous "Crédit Impôt Recherche"), UK, and US, it does not exist in most developing countries. R&D tax credit is a lever that these countries can activate to provide firms with significant incentives to invest in R&D. As to developed countries, intensifying existing tax policies intended to give firms incentives for R&D may help increase the number of firms that invest in R&D, thereby improving their levels of innovation.

Besides, note that it can be difficult for small firms to innovate compared to their larger counterparts due to a weaker financing capacity, among others. Public policy may have a role in supporting these firms to improve their innovativeness. One option could involve providing direct financial support to small firms for their R&D activities, tailored to their financing capacity.[19] As we mentioned previously, lack of absorptive capacity and limited knowledge resources are factors that alter firms' ability to innovate, in particular, in developing economies. Public authorities could help to alleviate these issues by providing technical

[18] For a taxonomy of innovation policy instruments, see Edler & Fagerberg (2017).

[19] For a recent discussion on the theoretical framework of the public financing of innovation, see Mazzucato & Semieniuk (2017).

services and advice to firms that express a need. As Edler & Fagerberg (2017) rightly stressed, such a policy should help improve access to expertise, a milestone for successful innovation activities.

Beyond technical services and advice, however, policies for training are expected to play a key role in improving a country's level of innovation by enhancing both absorptive capacity and knowledge. The policies to be implemented could take the form of financial support for firms that make substantial investments in workers' training related to the technological knowledge relevant to their sector.

The present research can be extended in several directions. Among others, future research can investigate the possible existence of a threshold effect in the impact of innovation on the size of the informal economy. The existence of such a threshold would indicate distinct regimes, where the impact of innovation on the informal economy varies from one regime to another. This analysis could be conducted using the Panel Threshold Modeling approach.[20] In this study, we focused on the effect of innovation output, that is, the production of innovation. The analysis could be extended to the innovation inputs, that is, to factors that drive a country's level of innovation (infrastructure, business sophistication, etc.). A comparative analysis of their effects on the informal economy compared to innovation output may lead to relevant conclusions regarding which element, innovation output or innovation inputs, public policies should prioritize to minimize the size of the informal economy. Further studies could also differentiate between female and male employment when measuring the informal economy through informal employment. This may help determine whether there is a gender gap in the impact of innovation on the informal economy.

Another avenue for future research consists in going beyond the simple production of innovation to deal with "innovation efficiency," that is, the efficiency in the production of innovation. Innovation efficiency refers to a country's ability to achieve the maximum possible level of innovation given its endowment in innovation inputs (R&D, infrastructure, business sophistication, etc.).[21] In fact, the more efficient a country is in producing innovations, the higher its level of innovation, which should significantly reduce the size of the informal economy. In the same line as Kouakou (2022), one could distinguish between short-run efficiency and long-run efficiency, and then analyze which between innovation short-run efficiency and innovation long-run efficiency reduces the most the size of the informal economy. Innovation efficiency scores can be obtained by making a Stochastic Frontier Analysis.[22]

[20]For a recent contribution to Panel Threshold Modeling, see Seo & Shin (2016).

[21]While the concept of production efficiency, also known as "technical efficiency," has its foundations in microeconomics, there exists a substantial body of literature dedicated to the analysis of macroeconomic innovation efficiency. For a recent literature review, refer to Kouakou (2022).

[22]For a recent stochastic frontier model that distinguishes between short-run and long-run efficiencies, see

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Data availability statement

For access to the data and Stata Do-file, please feel free to contact us.

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Appendix A

[Insert Figures A1, A2, and A3 here]

Appendix B

[Insert Table B1 here]

Appendix C

[Insert Tables C1, C2, C3, and C4 here]

Appendix D

[Insert Tables D1 to D17 here]

Appendix E

[Insert Table E1 here]

Table B1. List of the countries

Albania	Cabo Verde	Gambia	Kuwait	New Zealand	Sri Lanka
Algeria	Cambodia	Georgia	Kyrgyz Republic	Nicaragua	Swaziland
Angola	Cameroon	Germany	Latvia	Niger	Sweden
Argentina	Canada	Ghana	Lebanon	Nigeria	Switzerland
Armenia	Chile	Greece	Lesotho	Norway	Syrian Arab Republic
Australia	China	Guatemala	Libya	Oman	Tajikistan
Austria	Colombia	Guinea	Lithuania	Pakistan	Tanzania
Azerbaijan	Costa Rica	Guyana	Luxembourg	Paraguay	Thailand
Bahrain	Côte d'Ivoire	Honduras	Madagascar	Peru	Togo
Bangladesh	Croatia	Hungary	Malawi	Philippines	Trinidad and Tobago
Belarus	Cyprus	Iceland	Malaysia	Poland	Tunisia
Belgium	Czech Republic	India	Mali	Portugal	Turkey
Belize	Denmark	Indonesia	Malta	Qatar	Uganda
Benin	Dominican Republic	Iran	Mauritania	Romania	Ukraine
Bhutan	Ecuador	Ireland	Mauritius	Russian Federation	United Arab Emirates
Bolivia	Egypt	Israel	Mexico	Rwanda	United Kingdom
Bosnia and Herzegovina	El Salvador	Italy	Moldova	Saudi Arabia	United States
Botswana	Estonia	Jamaica	Mongolia	Senegal	Uruguay
Brazil	Ethiopia	Japan	Morocco	Singapore	Venezuela
Brunei Darussalam	Fiji	Jordan	Mozambique	Slovak Republic	Vietnam
Bulgaria	Finland	Kazakhstan	Namibia	Slovenia	Yemen
Burkina Faso	France	Kenya	Nepal	South Africa	Zambia
Burundi	Gabon	Korea (Rep.)	Netherlands	Spain	Zimbabwe

Table C1. Definition of the variables and data sources

	Definition	Source
Informal economy 1	Output of the informal economy as a percentage of the official GDP. (in log)	Elgin et al. (2022)
Informal economy 2	Output of the informal economy as a percentage of the official GDP. (in log)	Medina & Schneider (2019)
Informal economy 3	Informal employment as a percentage of the total non-agricultural employment. (in log)	ILOSTAT
Innovation 1	Innovation output index. Ranges from 0 to 100. (in log)	WIPO, Cornell University, and INSEAD
Innovation 2	Patent applications by residents. (in log)	WDI
Innovation 3	R&D intensity, measured as R&D expenditure as a percentage of GDP. (in log)	WDI
Political stability	Political stability and absence of violence/terrorism index. Ranges from approximately -2.5 (weak performance) to approximately 2.5 (strong performance).	WGI
GDP growth	Annual percentage growth rate of the real GDP.	WDI
Urban population	Urban population as a percentage of the total population. (in log)	WDI
Unemployment	Unemployment as a percentage of the total labor force. (in log)	WDI
Trade openness	Sum of exports and imports of goods and services as a percentage of GDP. (in log)	WDI
Financial openness	De jure capital account openness index. The higher the index, the more financially open the country is.	Chinn & Ito (2006)
Taxation	Total tax and contribution as a percentage of profit. (in log)	WDI
Government effectiveness	Government effectiveness index. Ranges from approximately -2.5 (weak performance) to approximately 2.5 (strong performance).	WGI
Control of corruption	Control of corruption index. Ranges from approximately -2.5 (weak performance) to approximately 2.5 (strong performance).	WGI
Rule of law	Rule of law index. Ranges from approximately -2.5 (weak performance) to approximately 2.5 (strong performance).	WGI
Inflation	Inflation, measured by the annual growth rate of the GDP implicit deflator.	WDI
Trade restrictions	De jure trade globalization index . Ranges from 0 (high restrictions) to 100 (low restrictions). (in log)	Dreher (2006) and Gygli et al. (2019)
Financial development	Financial development index. Ranges from 0 to 1.	Svirydzenka (2016)
Political system	Polity index. Ranges from -10 (strongly autocratic) to 10 (strongly democratic).	Polity5 Database version 2018
Regime durability	Number of years since the most recent regime change or the end of transition period defined by the lack of stable political institutions. (in log)	Polity5 Database version 2018
Economic development	GDP per capita in constant 2017 international Dollar (PPP). (in log)	WDI
Domestic credit mobilization	Domestic credit to private sector as a percentage of GDP. (in log)	WDI
E-government	E-government development index. Ranges from 0 to 1.	United Nations E-Government Development Database

Notes: log: Natural logarithm. PPP: Purchasing Power Parity. WDI: World Development Indicators (The World Bank). WGI: Worldwide Governance Indicators. WIPO: World Intellectual Property Organization. ILOSTAT: Database on labor statistics by the International Labour Organization (ILO).

Table C2. Summary statistics

	Observation	Mean	Std. dev.	Min.	Max.
Informal economy 1	1,652	3.36	0.45	2.09	4.23
		[31.54]	[12.41]	[8.07]	[68.91]
Informal economy 2	1,518	3.19	0.50	1.63	4.14
		[27.15]	[11.71]	[5.10]	[62.80]
Informal economy 3	513	3.02	1.11	0.26	4.57
		[33.30]	[27.10]	[1.30]	[96.20]
Innovation 1	1,259	3.39	0.40	1.94	4.36
		[31.95]	[12.12]	[6.99]	[78.47]
Innovation 2	1,163	5.60	2.82	0	14.15
		[16,198.74]	[90,488.91]	[1]	[1,393,815]
Innovation 3	991	-0.53	1.22	-4.57	1.57
		[1.04]	[1.01]	[0.01]	[4.80]
Political stability	1,644	-0.08	0.92	-3.01	1.62
GDP growth	1,652	3.43	4.85	-50.34	86.83
Urban population	1,656	4.01	0.47	2.29	4.61
		[60.26]	[22.47]	[9.86]	[100]
Unemployment	1,656	1.75	0.80	-2.21	3.39
		[7.55]	[5.53]	[0.11]	[29.62]
Trade openness	1,602	4.34	0.50	3.03	6.08
		[87.60]	[51.21]	[20.72]	[437.33]
Financial openness	1,632	0.53	1.60	-1.93	2.31
Taxation	1,580	3.63	0.45	2.08	5.66
		[42.10]	[25.36]	[8.00]	[285.90]
Government effectiveness	1,644	0.11	0.94	-2.26	2.43
Control of corruption	1,644	0.03	1.01	-1.68	2.44
Rule of law	1,644	0.05	0.97	-2.26	2.12
Inflation	1,652	5.77	9.84	-27.63	200.77
Trade restrictions	1,644	4.00	0.44	2.48	4.55
		[59.48]	[22.46]	[11.89]	[94.35]
Financial development	1,644	0.36	0.24	0.06	1
Political system	1,584	4.65	5.95	-10	10
Regime durability	1,592	2.92	1.19	0.00	5.14
		[30.66]	[31.61]	[0.00]	[170.00]
Economic development	1,620	9.45	1.15	6.61	11.70
		[21,923.49]	[21,429.11]	[740.45]	[120,647.82]
Domestic credit mobilization	1,523	3.78	0.82	0.98	5.54
		[59.18]	[45.59]	[2.66]	[254.67]
E-government	822	0.53	0.20	0	0.95

Note: For the variables that are measured in natural logarithm, the values without logarithm are presented in brackets.

Table C3. Correlation coefficients

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
(1) Inf. eco. 1	1																							
(2) Inf. eco. 2	0.97	1																						
(3) Inf. eco. 3	0.59	0.67	1																					
(4) Innov. 1	-0.62	-0.64	-0.75	1																				
(5) Innov. 2	-0.48	-0.47	-0.28	0.55	1																			
(6) Innov. 3	-0.62	-0.67	-0.71	0.73	0.64	1																		
(7) Pol. stab.	-0.49	-0.55	-0.69	0.55	0.14	0.49	1																	
(8) GDP gr.	0.10	0.11	0.32	-0.15	-0.12	-0.18	-0.06	1																
(9) Urban pop.	-0.43	-0.45	-0.44	0.54	0.36	0.47	0.44	-0.19	1															
(10) Unemploy.	-0.01	-0.04	-0.29	0.12	0.10	0.11	0.09	-0.21	0.24	1														
(11) Tra. open.	-0.20	-0.23	-0.54	0.30	-0.22	0.13	0.46	0.02	0.25	0.07	1													
(12) Fin. open.	-0.44	-0.49	-0.56	0.50	0.06	0.33	0.49	-0.13	0.45	0.04	0.24	1												
(13) Taxation	0.19	0.19	0.15	-0.05	0.28	0.02	-0.22	-0.02	-0.09	0.11	-0.34	-0.23	1											
(14) Gov. eff.	-0.72	-0.77	-0.75	0.76	0.41	0.75	0.73	-0.14	0.55	0.05	0.34	0.62	-0.22	1										
(15) C. of corr.	-0.69	-0.75	-0.72	0.68	0.32	0.69	0.76	-0.12	0.50	0.06	0.32	0.56	-0.23	0.93	1									
(16) R. of law	-0.72	-0.79	-0.76	0.74	0.37	0.73	0.76	-0.13	0.49	0.08	0.33	0.61	-0.23	0.95	0.95	1								
(17) Inflation	0.17	0.19	0.29	-0.20	-0.06	-0.22	-0.24	0.04	-0.17	0.01	-0.13	-0.23	0.11	-0.30	-0.27	-0.29	1							
(18) Trade rest.	-0.51	-0.55	-0.73	0.65	0.31	0.54	0.52	-0.22	0.56	0.18	0.41	0.59	-0.27	0.71	0.62	0.68	-0.21	1						
(19) Fin. dev.	-0.73	-0.75	-0.60	0.73	0.66	0.74	0.52	-0.17	0.57	0.04	0.15	0.52	-0.16	0.84	0.76	0.80	-0.27	0.65	1					
(20) Pol. sys.	-0.13	-0.19	-0.48	0.31	0.11	0.31	0.36	-0.12	0.18	0.23	0.02	0.36	0.09	0.44	0.41	0.44	-0.17	0.34	0.35	1				
(21) R. durab.	-0.54	-0.55	-0.44	0.51	0.32	0.43	0.57	-0.09	0.42	0.10	0.13	0.44	-0.09	0.62	0.58	0.60	-0.18	0.46	0.56	0.24	1.00			
(22) Econ. dev.	-0.65	-0.68	-0.79	0.71	0.44	0.64	0.61	-0.22	0.80	0.16	0.37	0.61	-0.26	0.80	0.71	0.75	-0.23	0.76	0.77	0.24	0.54	1		
(23) D. cred. m.	-0.61	-0.62	-0.56	0.64	0.47	0.63	0.51	-0.20	0.52	0.06	0.29	0.46	-0.23	0.75	0.68	0.71	-0.29	0.67	0.81	0.29	0.48	0.71	1	
(24) E-gov.	-0.63	-0.68	-0.74	0.70	0.54	0.71	0.58	-0.27	0.69	0.09	0.27	0.60	-0.15	0.82	0.73	0.77	-0.21	0.76	0.81	0.36	0.57	0.87	0.75	1

Notes: Inf. eco. 1: Informal economy 1; Inf. eco. 2: Informal economy 2; Inf. eco. 3: Informal economy 3; Innov. 1: Innovation 1; Innov. 2: Innovation 2; Innov. 3: Innovation 3; Pol. stab.: Political stability; GDP gr.: GDP growth; Urban pop.: Urban population; Unemploy.: Unemployment; Tra. open.: Trade openness; Fin. open.: Financial openness; Gov. eff.: Government effectiveness; C. of corr.: Control of corruption; R. of law: Rule of law; Trade rest.: Trade restrictions; Fin. dev.: Financial development; Pol. sys.: Political system; R. durab.: Regime durability; Econ. dev.: Economic development; D. cred. m.: Domestic credit mobilization; E-gov.: E-government.

Table C4. Variances Inflation Factors (VIFs) in the different specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Innovation 1	1.92	2.72	2.27	2.60	1.92	2.24	2.64	1.93	1.97
Political stability	1.90				1.91	1.91	2.00	2.00	2.27
GDP growth	1.16	1.15	1.15	1.15	1.16	1.20	1.17	1.16	1.17
Urban population	1.71	1.76	1.73	1.69	1.71	1.78	1.81	1.74	1.76
Unemployment	1.17	1.17	1.17	1.17	1.17	1.22	1.18	1.30	1.18
Trade openness	1.44	1.32	1.31	1.31	1.44	1.53	1.52	1.42	1.49
Financial openness	1.66	1.71	1.68	1.75	1.67	1.80	1.66	1.79	1.74
Taxation	1.23	1.24	1.25	1.25	1.23	1.28	1.26	1.29	1.23
Government effectiveness		3.22							
Control of corruption			2.31						
Rule of law				2.85					
Inflation					1.08				
Trade restrictions						2.86			
Financial development							2.65		
Political system								1.45	
Regime durability									1.91
Mean	1.52	1.79	1.61	1.72	1.48	1.76	1.77	1.57	1.63

Notes: We report the VIFs by including "Innovation 1," our primary innovation measure. Using alternative measures, namely "Innovation 2" and "Innovation 3," yields the same conclusion. Results obtained with these alternative measures are available upon request. In (2), (3), and (4), we exclude political stability to mitigate collinearity issues. Similarly, introducing additional variables one at a time into the baseline specification helps to address collinearity problems.

Table D1. Summary statistics on balancing quality when controlling for government effectiveness

	R-squared	F-statistic	p-value
Before balancing	0.636	281.53	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes the baseline variables (GDP growth, urban population, unemployment, trade openness, financial openness, and taxation) and government effectiveness, with all covariates lagged by one year to prevent potential issues of reverse causality. We remove political stability from the covariates to avoid collinearity issues.

Table D2. Summary statistics on balancing quality when controlling for corruption

	R-squared	F-statistic	p-value
Before balancing	0.566	210.64	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes the baseline variables (GDP growth, urban population, unemployment, trade openness, financial openness, and taxation) and control corruption, with all covariates lagged by one year to prevent potential issues of reverse causality. We remove political stability from the covariates to avoid collinearity issues.

Table D3. Summary statistics on balancing quality when controlling for rule of law

	R-squared	F-statistic	p-value
Before balancing	0.620	263.60	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes the baseline variables (GDP growth, urban population, unemployment, trade openness, financial openness, and taxation) and rule of law, with all covariates lagged by one year to prevent potential issues of reverse causality. We remove political stability from the covariates to avoid collinearity issues.

Table D4. Summary statistics on balancing quality when controlling for inflation

	R-squared	F-statistic	p-value
Before balancing	0.485	132.78	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes the baseline variables (political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation) and inflation, with all covariates lagged by one year to prevent potential issues of reverse causality.

Table D5. Summary statistics on balancing quality when controlling for trade restrictions

	R-squared	F-statistic	p-value
Before balancing	0.559	178.49	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes the baseline variables (political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation) and trade restrictions, with all covariates lagged by one year to prevent potential issues of reverse causality.

Table D6. Summary statistics on balancing quality when controlling for financial development

	R-squared	F-statistic	p-value
Before balancing	0.628	235.90	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes the baseline variables (political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation) and financial development, with all covariates lagged by one year to prevent potential issues of reverse causality.

Table D7. Summary statistics on balancing quality when controlling for political system

	R-squared	F-statistic	p-value
Before balancing	0.488	129.99	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes the baseline variables (political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation) and political system, with all covariates lagged by one year to prevent potential issues of reverse causality.

Table D8. Summary statistics on balancing quality when controlling for regime durability

	R-squared	F-statistic	p-value
Before balancing	0.499	136.49	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes the baseline variables (political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation) and regime durability, with all covariates lagged by one year to prevent potential issues of reverse causality.

Table D9. Summary statistics on balancing quality for the sub-sample of developing countries

	R-squared	F-statistic	p-value
Before balancing	0.271	36.23	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality.

Table D10. Summary statistics on balancing quality for the sub-sample of developed countries

	R-squared	F-statistic	p-value
Before balancing	0.506	46.67	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality.

Table D11. Summary statistics on balancing quality when removing G7 countries

	R-squared	F-statistic	p-value
Before balancing	0.462	131.24	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality. G7 includes Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

Table D12. Summary statistics on balancing quality when removing LAC and SSA countries

	R-squared	F-statistic	p-value
Before balancing	0.555	127.07	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality. LAC: Latin America and the Caribbean. SSA: Sub-Saharan Africa.

Table D13. Summary statistics on balancing quality when using "Innovation 2" (Patent applications by residents) as an alternative measure of innovation

	R-squared	F-statistic	p-value
Before balancing	0.269	50.11	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 2" (see Table C1). The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality.

Table D14. Summary statistics on balancing quality when using "Innovation 3" (R&D intensity) as an alternative measure of innovation

	R-squared	F-statistic	p-value
Before balancing	0.376	69.41	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 3" (see Table C1). The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality.

Table D15. Summary statistics on balancing quality when the treatment variable is economic development

	R-squared	F-statistic	p-value
Before balancing	0.761	602.05	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Economic development" (see Table C1). The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality.

Table D16. Summary statistics on balancing quality when the treatment variable is domestic credit mobilization

	R-squared	F-statistic	p-value
Before balancing	0.431	135.06	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Domestic credit mobilization" (see Table C1). The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality.

Table D17. Summary statistics on balancing quality when the treatment variable is e-government

	R-squared	F-statistic	p-value
Before balancing	0.622	172.82	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "E-government" (see Table C1). The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality.

Table E1. Additional robustness

	OLS estimates	Fixed-effects estimates	Random-effects estimates
Innovation 1	-0.015***	-0.015**	-0.018***
	(0.005)	(0.007)	(0.006)
Political stability	-0.015***	-0.015***	-0.016***
	(0.003)	(0.004)	(0.004)
GDP growth	-0.002***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)
Urban population	-0.063*	-0.063	-0.125**
	(0.037)	(0.068)	(0.056)
Unemployment	0.031***	0.031***	0.031***
	(0.004)	(0.007)	(0.007)
Trade openness	0.003	0.003	0.001
	(0.007)	(0.010)	(0.010)
Financial openness	-0.002	-0.002	-0.003
	(0.001)	(0.002)	(0.002)
Taxation	-0.013	-0.013	-0.013
	(0.009)	(0.014)	(0.014)
Constant	3.780***	3.652***	3.936***
	(0.153)	(0.273)	(0.220)
Time dummies	Yes	Yes	Yes
Country dummies	Yes	No	No
Fisher/Wald test (p-value)	0.000	0.000	0.000
Observations	1,148	1,148	1,148

Notes: The dependent variable is "Informal economy 1." Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 1. Summary statistics on balancing quality

	R-squared	F-statistic	p-value
Before balancing	0.485	151.75	0.000
After balancing	0	0	1

Notes: Results from a (weighted) regression of the treatment variable on the covariates. The treatment variable is "Innovation 1" (see Table C1). The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality.

Table 2. The impact of innovation on the size of the informal economy

Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.500***	-0.681***	-0.372***	-0.582***	-0.500***	-0.620***	-0.327***	-0.484***
	(0.071)	(0.063)	(0.050)	(0.054)	(0.062)	(0.068)	(0.048)	(0.053)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.198	0.340	0.410	0.498	0.378	0.426	0.595	0.626
Observations	1,137	1,137	1,137	1,137	1,137	1,137	1,137	1,137

Notes: This table presents the effect of innovation on the size of the informal economy, obtained using the entropy balancing method. The treatment variable is innovation. The outcome variable is the size of the informal economy. "Informal economy 1" and "Innovation 1" are our main measures of the size of the informal economy and innovation, respectively. See Table C1 for a description of the variables. The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. This constitutes the baseline set of covariates, with all covariates lagged by one year to prevent potential issues of reverse causality. Following Balima et al. (2021), we include year and regional fixed effects in the second step of the entropy balancing methodology. Year fixed effects control for macroeconomic shocks or time-related factors impacting the informal economy and innovation. Regional fixed effects allow us to control for region-specific factors affecting the informal economy (see Elbahnasawy 2021) and innovation. Unreported constant included. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3. Robustness checks – Additional controls

(A) Controlling for government effectiveness								
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.238**	-0.504***	-0.182*	-0.518***	-0.238***	-0.324***	-0.226***	-0.381***
	(0.097)	(0.096)	(0.100)	(0.099)	(0.075)	(0.083)	(0.076)	(0.090)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.060	0.202	0.280	0.392	0.409	0.424	0.521	0.542
Observations	1,137	1,137	1,137	1,137	1,137	1,137	1,137	1,137
(B) Controlling for corruption								
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.358***	-0.549***	-0.216***	-0.464***	-0.358***	-0.497***	-0.170***	-0.336***
	(0.084)	(0.083)	(0.079)	(0.072)	(0.070)	(0.080)	(0.057)	(0.067)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.119	0.245	0.353	0.445	0.292	0.342	0.502	0.531
Observations	1,137	1,137	1,137	1,137	1,137	1,137	1,137	1,137
(C) Controlling for rule of law								
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.300**	-0.470***	-0.247**	-0.539***	-0.300***	-0.396***	-0.234***	-0.405***
	(0.117)	(0.105)	(0.115)	(0.107)	(0.092)	(0.100)	(0.088)	(0.093)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.039	0.166	0.232	0.332	0.283	0.316	0.439	0.465
Observations	1,137	1,137	1,137	1,137	1,137	1,137	1,137	1,137
(D) Controlling for inflation								
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.494***	-0.681***	-0.365***	-0.583***	-0.494***	-0.614***	-0.323***	-0.484***
	(0.072)	(0.064)	(0.051)	(0.056)	(0.061)	(0.069)	(0.047)	(0.056)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.194	0.337	0.409	0.496	0.385	0.429	0.596	0.626
Observations	1,137	1,137	1,137	1,137	1,137	1,137	1,137	1,137
(E) Controlling for trade restrictions								
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.422***	-0.680***	-0.228***	-0.486***	-0.422***	-0.607***	-0.268***	-0.456***
	(0.088)	(0.072)	(0.071)	(0.063)	(0.072)	(0.076)	(0.049)	(0.054)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.151	0.325	0.427	0.521	0.367	0.420	0.598	0.633
Observations	1,137	1,137	1,137	1,137	1,137	1,137	1,137	1,137
(F) Controlling for financial development								
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.348**	-0.676***	-0.342***	-0.695***	-0.348***	-0.422***	-0.393***	-0.591***
	(0.148)	(0.124)	(0.099)	(0.106)	(0.085)	(0.081)	(0.064)	(0.086)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.111	0.271	0.453	0.562	0.549	0.587	0.695	0.729
Observations	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128
(G) Controlling for political system								
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.504***	-0.684***	-0.366***	-0.583***	-0.504***	-0.627***	-0.342***	-0.510***
	(0.070)	(0.061)	(0.050)	(0.053)	(0.047)	(0.047)	(0.044)	(0.045)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.200	0.338	0.407	0.497	0.483	0.532	0.618	0.652
Observations	1,098	1,098	1,098	1,098	1,098	1,098	1,098	1,098
(H) Controlling for regime durability								
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.395***	-0.637***	-0.252***	-0.526***	-0.395***	-0.519***	-0.273***	-0.410***
	(0.064)	(0.060)	(0.049)	(0.056)	(0.056)	(0.065)	(0.051)	(0.057)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.141	0.312	0.369	0.480	0.407	0.440	0.619	0.641
Observations	1,106	1,106	1,106	1,106	1,106	1,106	1,106	1,106

Notes: This table presents the effect of innovation on the size of the informal economy, obtained using the entropy balancing method, by controlling for government effectiveness, control of corruption, rule of law, inflation, trade restrictions, financial development, political system, and regime durability, respectively. The summary statistics on balancing quality are reported in Appendix D. The treatment variable is innovation ("Innovation 1"). The outcome variable is the size of the informal economy ("Informal economy 1"). See Table C1 for a description of the variables. The set of covariates includes the baseline variables (political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation) and the additional control considered, with all covariates lagged by one year to prevent potential issues of reverse causality. From (A) to (C), we remove political stability from the covariates to avoid collinearity issues. In (C), $r = 1$. Following Balima et al. (2021), we include year and regional fixed effects in the second step of the entropy balancing methodology. Year fixed effects control for macroeconomic shocks or time-related factors impacting the informal economy and innovation. Regional fixed effects allow us to control for region-specific factors affecting the informal economy (see Elbahnasawy 2021) and innovation. Unreported constant included. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4. Robustness checks – Two-step system GMM estimates

Informal economy 1 (-1)	0.819***
	(0.063)
Innovation 1	-0.049***
	(0.016)
Political stability	0.004
	(0.012)
GDP growth	-0.003***
	(0.001)
Urban population	-0.137**
	(0.058)
Unemployment	0.016*
	(0.009)
Trade openness	0.033
	(0.023)
Financial openness	-0.010*
	(0.006)
Taxation	-0.029
	(0.021)
Constant	1.271***
	(0.413)
Time dummies	Yes
Fisher test (p-value)	0.000
Arellano-Bond test for AR(1) (p-value)	0.000
Arellano-Bond test for AR(2) (p-value)	0.758
Hansen test of overidentifying restrictions (p-value)	0.882
Number of instruments	34
Number of countries	131
Average observations per country	8.76
Observations	1,148

Notes: The dependent variable is "Informal economy 1." Windmeijer-corrected robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5. Robustness checks – Restricted samples

	(A) Sub-sample of developing countries							
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.437***	-0.681***	-0.305***	-0.511***	-0.437***	-0.628***	-0.267***	-0.413***
	(0.073)	(0.072)	(0.051)	(0.062)	(0.067)	(0.083)	(0.047)	(0.058)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.151	0.276	0.385	0.446	0.307	0.366	0.510	0.532
Observations	691	691	691	691	691	691	691	691
	(B) Sub-sample of developed countries							
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.714***	-1.426***	-1.034***	-1.352***	-0.714***	-1.021***	-0.735***	-1.044***
	(0.237)	(0.160)	(0.138)	(0.124)	(0.152)	(0.123)	(0.146)	(0.128)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.138	0.461	0.597	0.677	0.696	0.752	0.700	0.752
Observations	327	327	327	327	327	327	327	327
	(C) Removing G7 countries							
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.477***	-0.655***	-0.369***	-0.567***	-0.477***	-0.601***	-0.325***	-0.477***
	(0.073)	(0.066)	(0.048)	(0.050)	(0.065)	(0.071)	(0.045)	(0.048)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.187	0.316	0.394	0.477	0.350	0.399	0.586	0.618
Observations	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077
	(D) Removing LAC and SSA countries							
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.455***	-0.646***	-0.493***	-0.665***	-0.455***	-0.533***	-0.523***	-0.605***
	(0.126)	(0.083)	(0.076)	(0.072)	(0.069)	(0.069)	(0.070)	(0.068)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.143	0.315	0.293	0.424	0.528	0.560	0.647	0.679
Observations	721	721	721	721	721	721	721	721

Notes: This table presents the effects of innovation on the size of the informal economy, obtained using the entropy balancing method, by focusing on the sub-sample of developing countries, the sub-sample of developed countries, by removing G7 countries, and by removing LAC and SSA countries. G7 includes Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States. LAC: Latin America and the Caribbean. SSA: Sub-Saharan Africa. The summary statistics on balancing quality are reported in Appendix D. The treatment variable is innovation ("Innovation 1"). The outcome variable is the size of the informal economy ("Informal economy 1"). See Table C1 for a description of the variables. The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. All the covariates are lagged by one year to prevent potential issues of reverse causality. Following Balima et al. (2021), we include year and regional fixed effects in the second step of the entropy balancing methodology. Year fixed effects control for macroeconomic shocks or time-related factors impacting the informal economy and innovation. Regional fixed effects allow us to control for region-specific factors affecting the informal economy (see Elbahnasawy 2021) and innovation. Unreported constant included. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6. Robustness checks – Alternative measures of the size of the informal economy

	(A) "Informal economy 2" (Medina & Schneider 2019)							
Informal economy 2	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-0.512***	-0.703***	-0.347***	-0.564***	-0.507***	-0.618***	-0.328***	-0.474***
	(0.087)	(0.070)	(0.066)	(0.068)	(0.071)	(0.078)	(0.056)	(0.063)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.156	0.326	0.368	0.458	0.446	0.489	0.600	0.631
Observations	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021
	(B) "Informal economy 3" (Informal employment)							
Informal economy 3	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	-1.889***	-2.065***	-0.683***	-0.853***	-1.345***	-1.546***	-0.488***	-0.630***
	(0.133)	(0.147)	(0.106)	(0.124)	(0.133)	(0.151)	(0.110)	(0.132)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.522	0.536	0.775	0.781	0.694	0.713	0.827	0.829
Observations	470	470	470	470	470	470	470	470

Notes: This table presents the effects of innovation on the size of the informal economy, obtained using the entropy balancing method, with "Informal economy 2" (Medina & Schneider 2019) [(A)] and "Informal economy 3" (Informal employment) [(B)] as alternative measures of the size of the informal economy. The summary statistics on balancing quality are those reported in Table 1. The treatment variable is innovation ("Innovation 1"). The outcome variable is the size of the informal economy ('Informal economy 2" or "Informal economy 3"). See Table C1 for a description of the variables. The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. This constitutes the baseline set of covariates, with all covariates lagged by one year to prevent potential issues of reverse causality. Following Balima et al. (2021), we include year and regional fixed effects in the second step of the entropy balancing methodology. Year fixed effects control for macroeconomic shocks or time-related factors impacting the informal economy and innovation. Regional fixed effects allow us to control for region-specific factors affecting the informal economy (see Elbahnasawy 2021) and innovation. Unreported constant included. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7. Robustness checks – Alternative measures of innovation

	(A) "Innovation 2" (Patent applications by residents)							
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 2	-0.083***	-0.084***	-0.053***	-0.053***	-0.083***	-0.083***	-0.074***	-0.074***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.007)	(0.007)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.237	0.233	0.305	0.302	0.521	0.521	0.575	0.574
Observations	963	963	963	963	963	963	963	963
	(B) "Innovation 3" (R&D intensity)							
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 3	-0.159***	-0.156***	-0.106***	-0.108***	-0.159***	-0.153***	-0.109***	-0.104***
	(0.026)	(0.023)	(0.020)	(0.019)	(0.021)	(0.020)	(0.016)	(0.016)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.201	0.212	0.354	0.349	0.345	0.354	0.507	0.506
Observations	816	816	816	816	816	816	816	816

Notes: This table presents the effects of innovation on the size of the informal economy, obtained using the entropy balancing method, with "Innovation 2" (Patent applications by residents) [(A)] and "Innovation 3" (R&D intensity) [(B)] as alternative measures of innovation. The summary statistics on balancing quality are reported in Appendix D. The treatment variable is innovation ("Innovation 2" or "Innovation 3"). The outcome variable is the size of the informal economy ("Informal economy 1"). See Table C1 for a description of the variables. The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. This constitutes the baseline set of covariates, with all covariates lagged by one year to prevent potential issues of reverse causality. Following Balima et al. (2021), we include year and regional fixed effects in the second step of the entropy balancing methodology. Year fixed effects control for macroeconomic shocks or time-related factors impacting the informal economy and innovation. Regional fixed effects allow us to control for region-specific factors affecting the informal economy (see Elbahnasawy 2021) and innovation. Unreported constant included. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 8. Transmission channels – Economic development

	(A) Impact of innovation on economic development							
Economic development	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	0.970***	1.346***	0.496***	0.893***	0.992***	1.144***	0.589***	0.763***
	(0.110)	(0.131)	(0.106)	(0.109)	(0.077)	(0.074)	(0.057)	(0.068)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.179	0.335	0.498	0.574	0.689	0.726	0.837	0.848
Observations	1,117	1,117	1,117	1,117	1,117	1,117	1,117	1,117
	(B) Impact of economic development on the size of the informal economy							
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Economic development	-0.193***	-0.197***	-0.261***	-0.268***	-0.190***	-0.192***	-0.278***	-0.277***
	(0.034)	(0.031)	(0.037)	(0.033)	(0.027)	(0.025)	(0.020)	(0.020)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.066	0.065	0.275	0.276	0.290	0.291	0.661	0.660
Observations	1,330	1,330	1,330	1,330	1,330	1,330	1,330	1,330

Notes: This table offers evidence regarding economic development as a transmission channel. It presents the effect of innovation on economic development on the one hand [(A)], and the effect of economic development on the size of the informal economy on the other hand [(B)], obtained using the entropy balancing method. The summary statistics on balancing quality are reported in Table 1 [(A)] and Appendix D [(B)]. In (A), the treatment variable is innovation ("Innovation 1") and the outcome variable is economic development. In (B), the treatment variable is economic development and the outcome variable is the size of the informal economy ("Informal economy 1"). See Table C1 for a description of the variables. The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. This constitutes the baseline set of covariates, with all covariates lagged by one year to prevent potential issues of reverse causality. Following Balima et al. (2021), we include year and regional fixed effects in the second step of the entropy balancing methodology. Year fixed effects control for macroeconomic shocks or time-related factors. Regional fixed effects allow us to control for region-specific factors. Unreported constant included. In (B), as the Hessian is not negative semidefinite for $r > 1$ (2 or 3), we set $r = 1$. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 9. Transmission channels – Domestic credit mobilization

	(A) Impact of innovation on domestic credit mobilization							
Domestic credit mobilization	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	0.696***	0.948***	0.299***	0.542***	0.729***	0.891***	0.366***	0.530***
	(0.113)	(0.096)	(0.094)	(0.090)	(0.103)	(0.113)	(0.091)	(0.097)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.151	0.279	0.349	0.396	0.338	0.391	0.524	0.543
Observations	1,058	1,058	1,058	1,058	1,058	1,058	1,058	1,058
	(B) Impact of domestic credit mobilization on the size of the informal economy							
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Domestic credit mobilization	-0.300***	-0.296***	-0.231***	-0.226***	-0.300***	-0.295***	-0.172***	-0.169***
	(0.030)	(0.029)	(0.020)	(0.020)	(0.030)	(0.029)	(0.023)	(0.023)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.325	0.325	0.397	0.399	0.372	0.375	0.523	0.523
Observations	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253

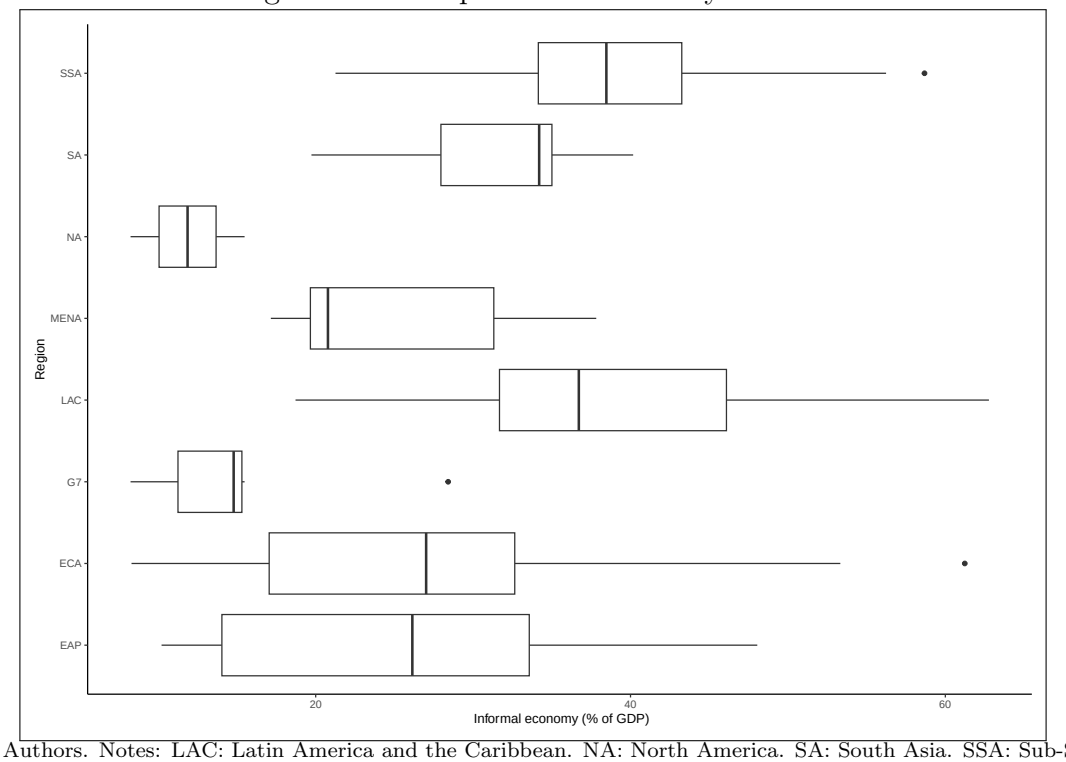
Notes: This table offers evidence regarding domestic credit mobilization as a transmission channel. It presents the effect of innovation on domestic credit mobilization on the one hand [(A)], and the effect of domestic credit mobilization on the size of the informal economy on the other hand [(B)], obtained using the entropy balancing method. The summary statistics on balancing quality are reported in Table 1 [(A)] and Appendix D [(B)]. In (A), the treatment variable is innovation ("Innovation 1") and the outcome variable is domestic credit mobilization. In (B), the treatment variable is domestic credit mobilization and the outcome variable is the size of the informal economy ("Informal economy 1"). See Table C1 for a description of the variables. The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. This constitutes the baseline set of covariates, with all covariates lagged by one year to prevent potential issues of reverse causality. Following Balima et al. (2021), we include year and regional fixed effects in the second step of the entropy balancing methodology. Year fixed effects control for macroeconomic shocks or time-related factors. Regional fixed effects allow us to control for region-specific factors. Unreported constant included. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 10. Transmission channels – E-government

	(A) Impact of innovation on e-government							
E-government	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Innovation 1	0.199***	0.302***	0.100***	0.228***	0.184***	0.267***	0.075***	0.179***
	(0.019)	(0.025)	(0.031)	(0.026)	(0.017)	(0.018)	(0.019)	(0.021)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.239	0.568	0.502	0.721	0.614	0.756	0.745	0.829
Observations	577	577	577	577	577	577	577	577
	(B) Impact of e-government on the size of the informal economy							
Informal economy 1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
E-government	-0.798***	-0.933***	-1.086***	-1.148***	-0.798***	-0.790***	-1.358***	-1.535***
	(0.166)	(0.134)	(0.318)	(0.320)	(0.143)	(0.114)	(0.144)	(0.163)
Covariates in the second step	No	No	No	No	Yes	Yes	Yes	Yes
Year fixed effects in the second step	No	Yes	No	Yes	No	Yes	No	Yes
Regional fixed effects in the second step	No	No	Yes	Yes	No	No	Yes	Yes
R-squared	0.255	0.410	0.436	0.508	0.509	0.569	0.726	0.741
Observations	741	741	741	741	741	741	741	741

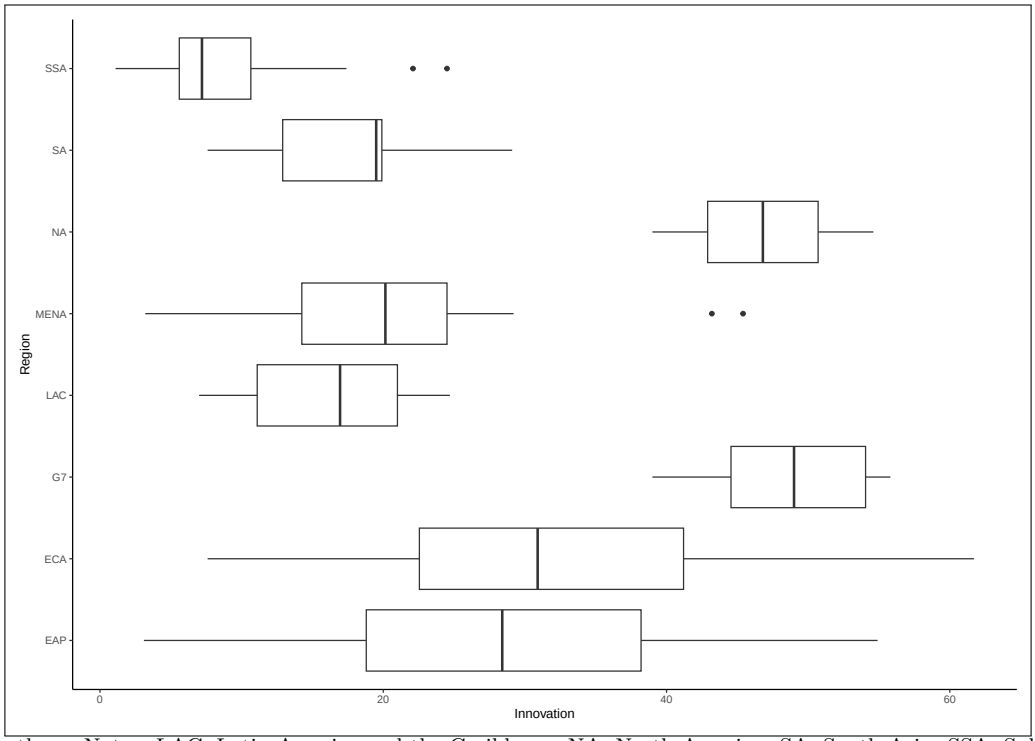
Notes: This table offers evidence regarding e-government as a transmission channel. It presents the effect of innovation on e-government on the one hand [(A)], and the effect of e-government on the size of the informal economy on the other hand [(B)], obtained using the entropy balancing method. The summary statistics on balancing quality are reported in Table 1 [(A)] and Appendix D [(B)]. In (A), the treatment variable is innovation ("Innovation 1") and the outcome variable is e-government. In (B), the treatment variable is e-government and the outcome variable is the size of the informal economy ("Informal economy 1"). See Table C1 for a description of the variables. The set of covariates includes political stability, GDP growth, urban population, unemployment, trade openness, financial openness, and taxation. This constitutes the baseline set of covariates, with all covariates lagged by one year to prevent potential issues of reverse causality. Following Balima et al. (2021), we include year and regional fixed effects in the second step of the entropy balancing methodology. Year fixed effects control for macroeconomic shocks or time-related factors. Regional fixed effects allow us to control for region-specific factors. Unreported constant included. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure A1. Box plots of informality in 2018



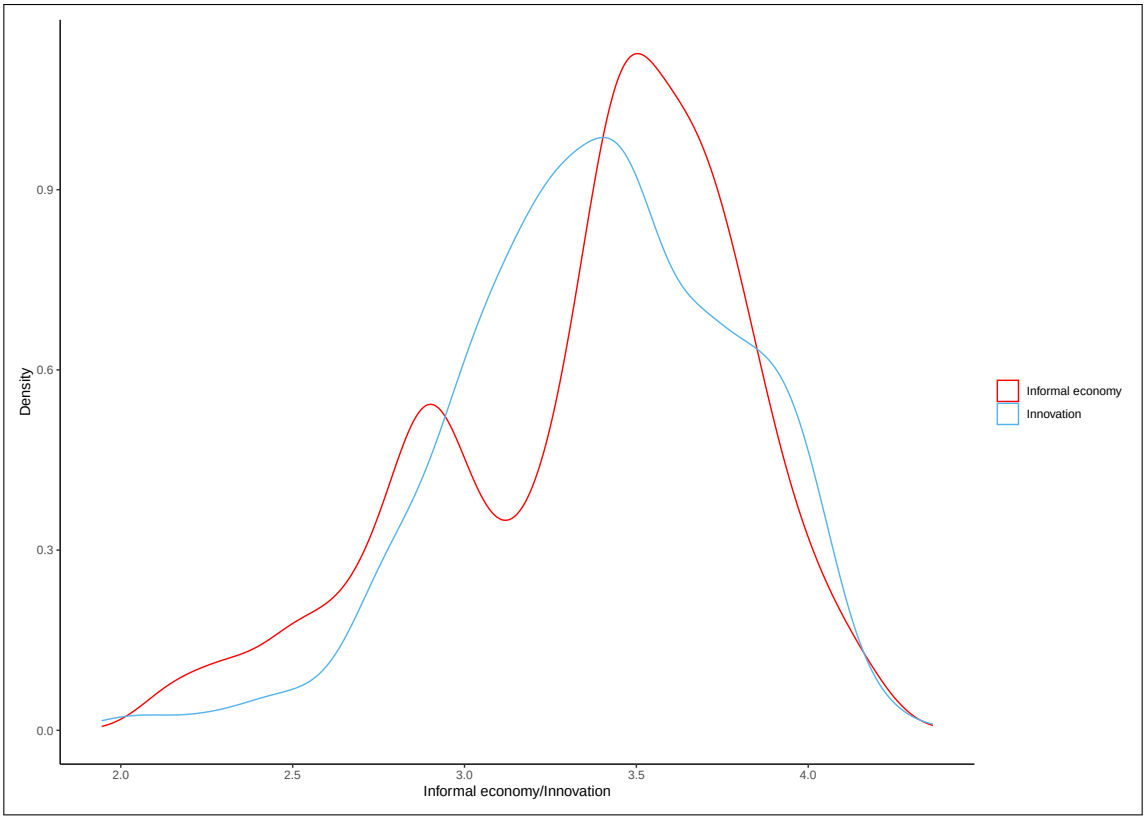
Source: Authors. Notes: LAC: Latin America and the Caribbean. NA: North America. SA: South Asia. SSA: Sub-Saharan Africa. MENA: Middle East and North Africa. EAP: East Asia and Pacific. ECA: Europe and Central Asia. G7 includes Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

Figure A2. Box plots of innovation in 2022



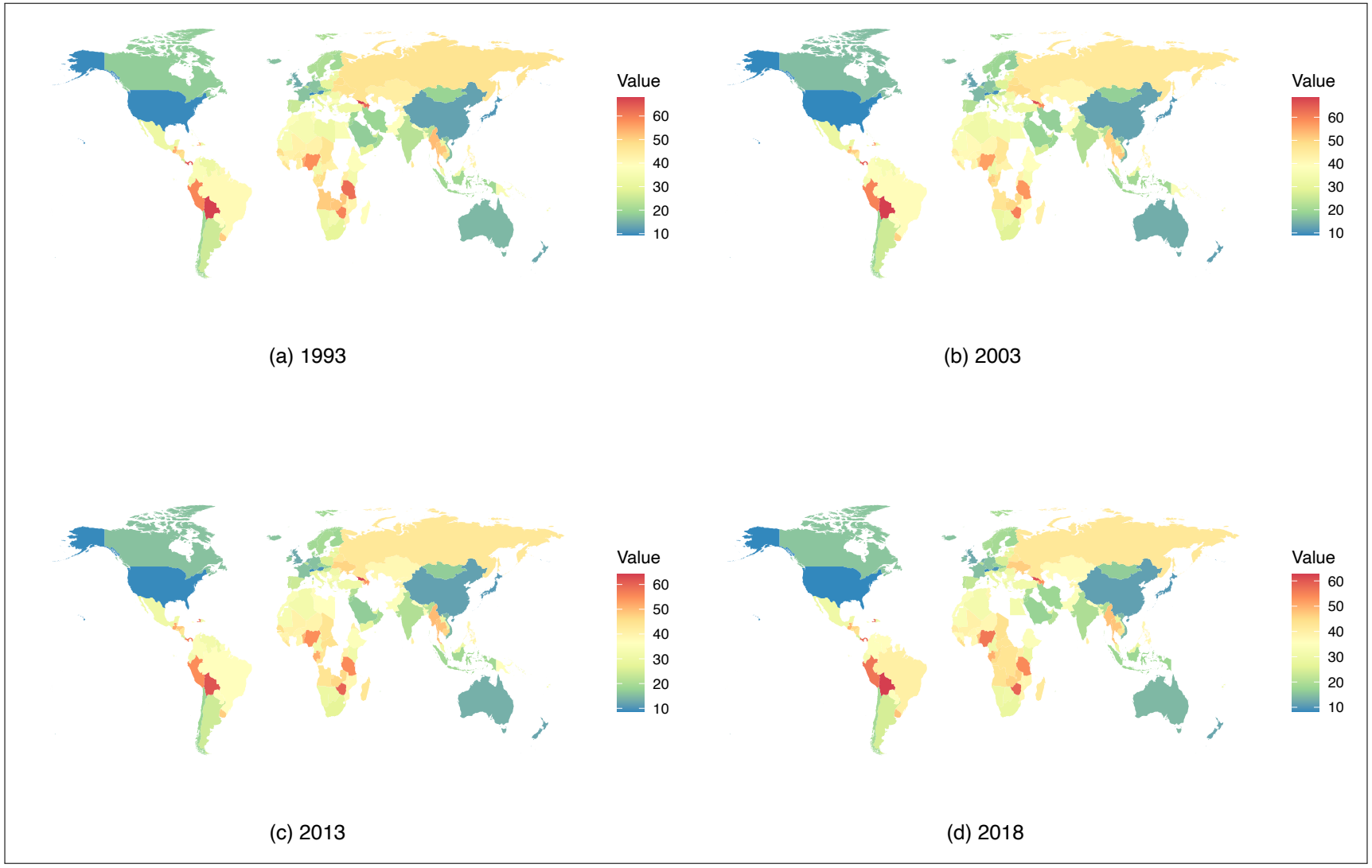
Source: Authors. Notes: LAC: Latin America and the Caribbean. NA: North America. SA: South Asia. SSA: Sub-Saharan Africa. MENA: Middle East and North Africa. EAP: East Asia and Pacific. ECA: Europe and Central Asia. G7 includes Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

Figure A3. Distributions of the informal economy and innovation



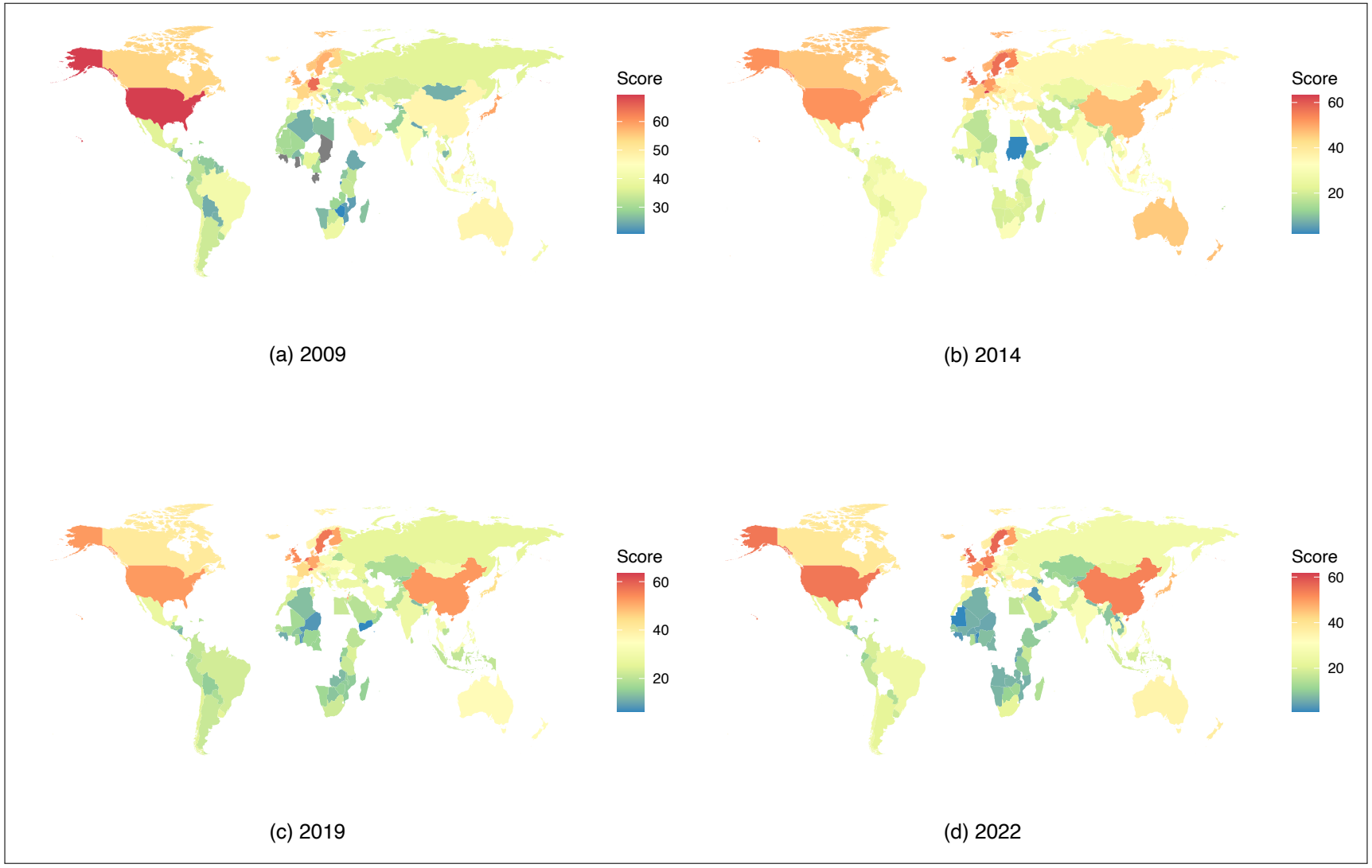
Source: Authors

Figure 1. World maps depicting the informal economy (% of GDP)



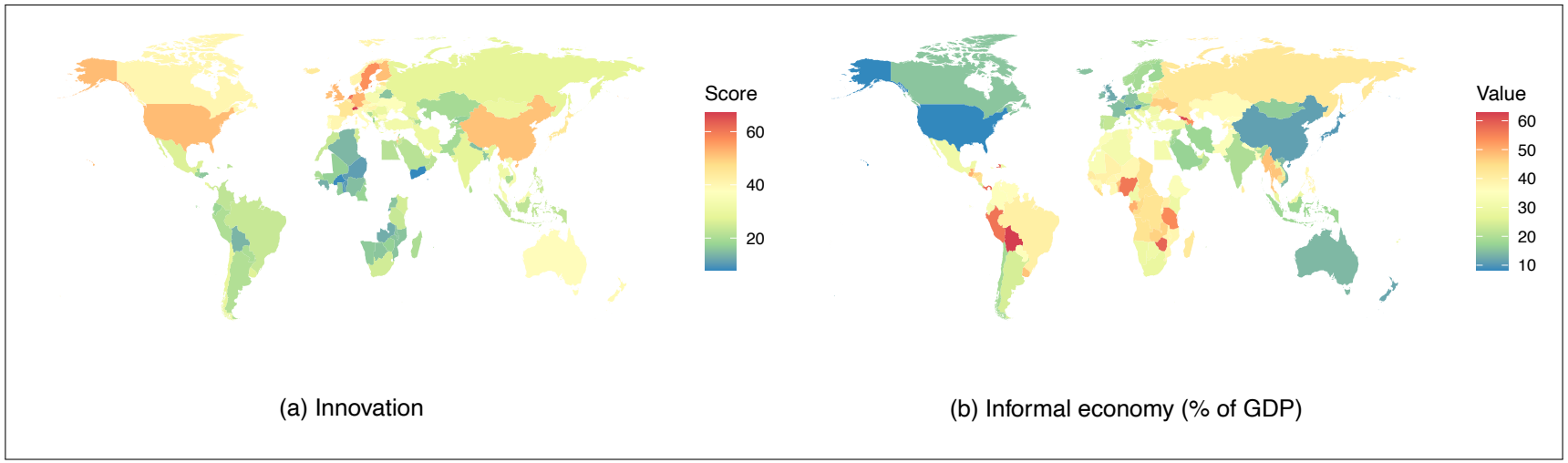
Source: Authors

Figure 2. World maps depicting innovation (innovation output index)



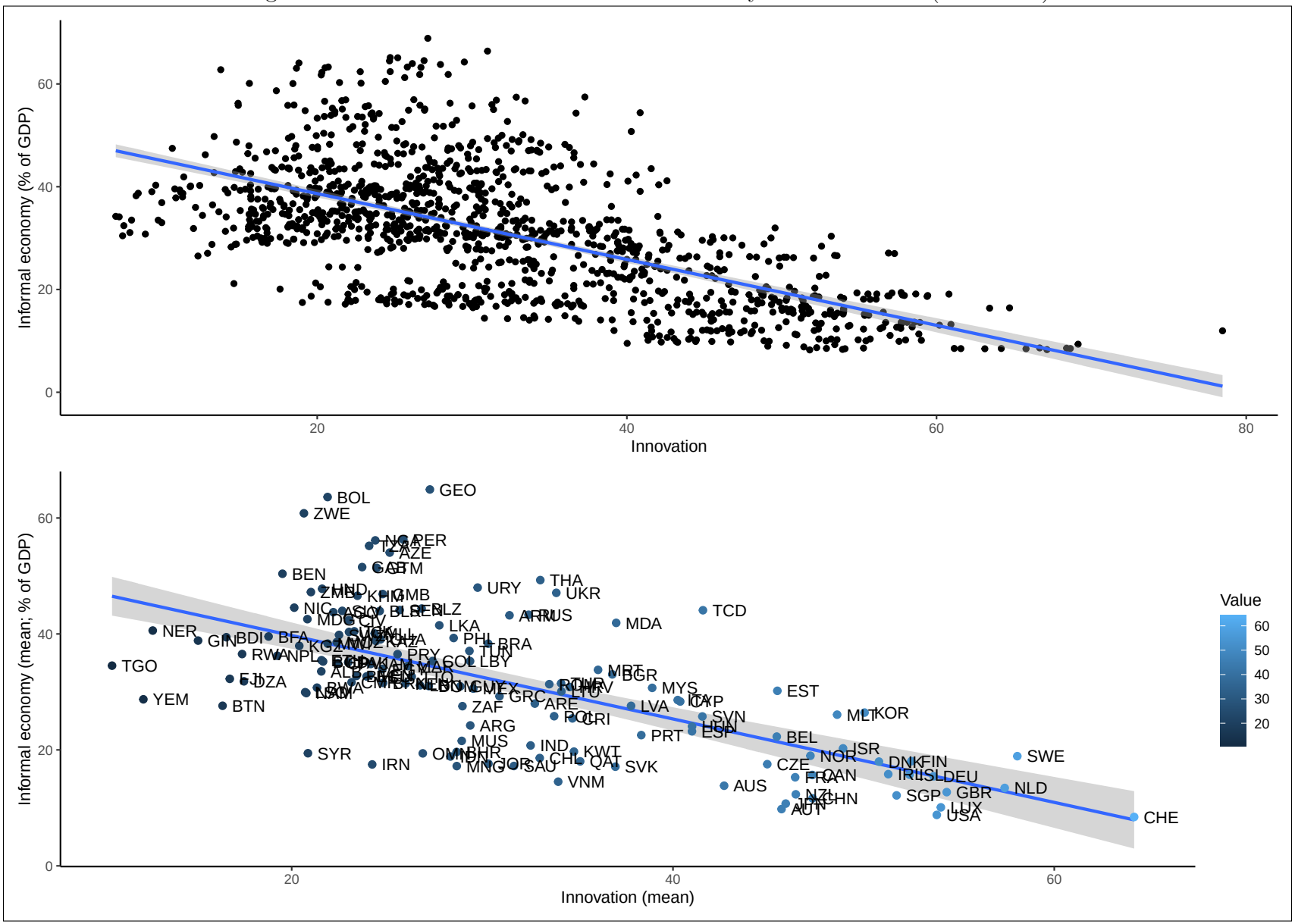
Source: Authors

Figure 3. World maps depicting innovation and the informal economy in 2018



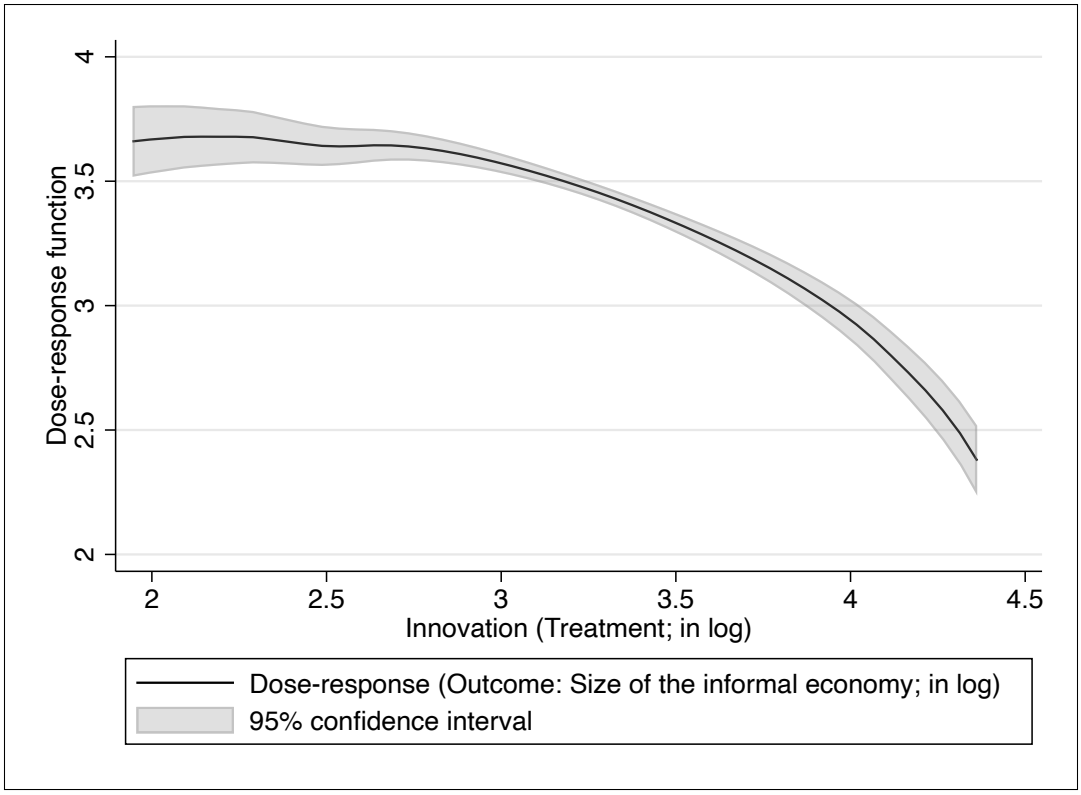
Source: Authors

Figure 4. Joint evolution of the informal economy and innovation (2007-2018)



Source: Authors

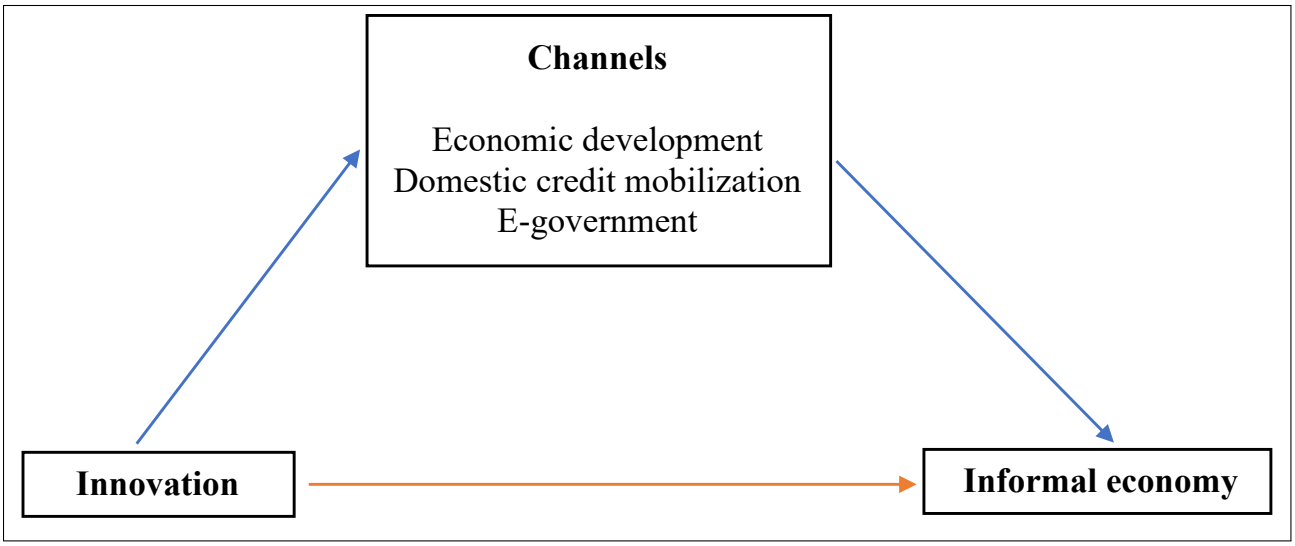
Figure 5. Dose-response function



Source: Authors

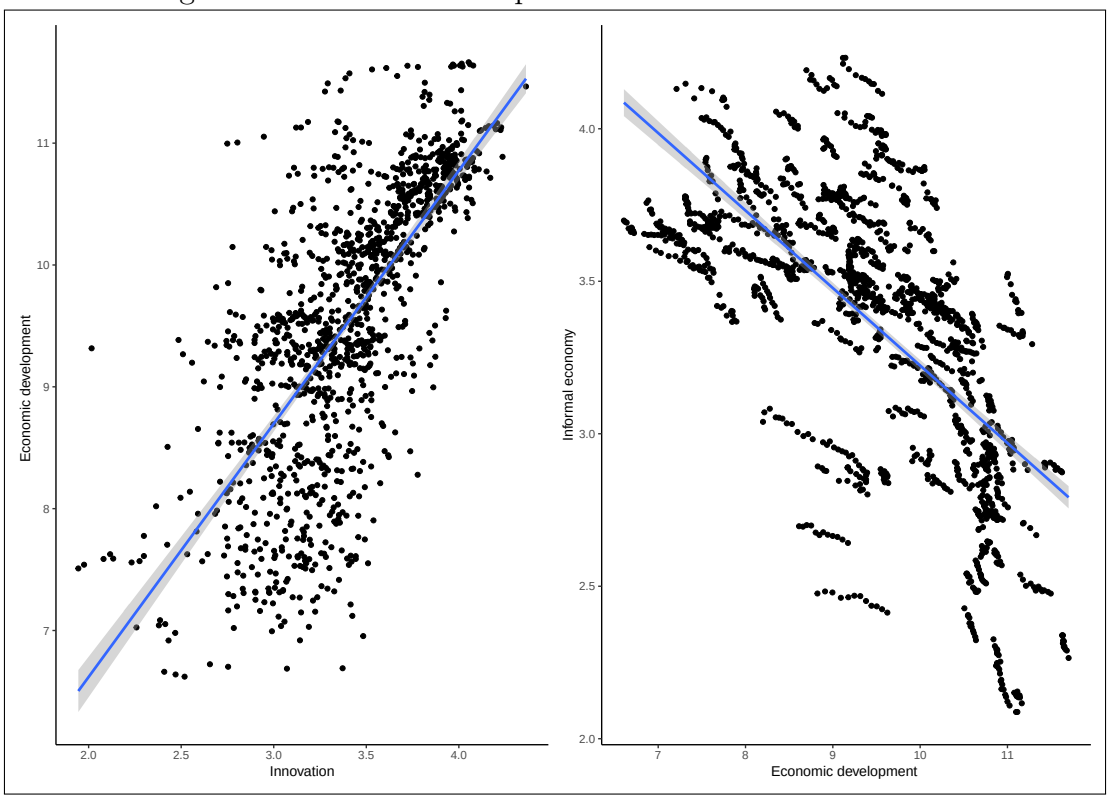
Notes: The treatment variable is "Innovation 1." The outcome variable is "Informal economy 1."

Figure 6. Visualizing the mediating role of the channels



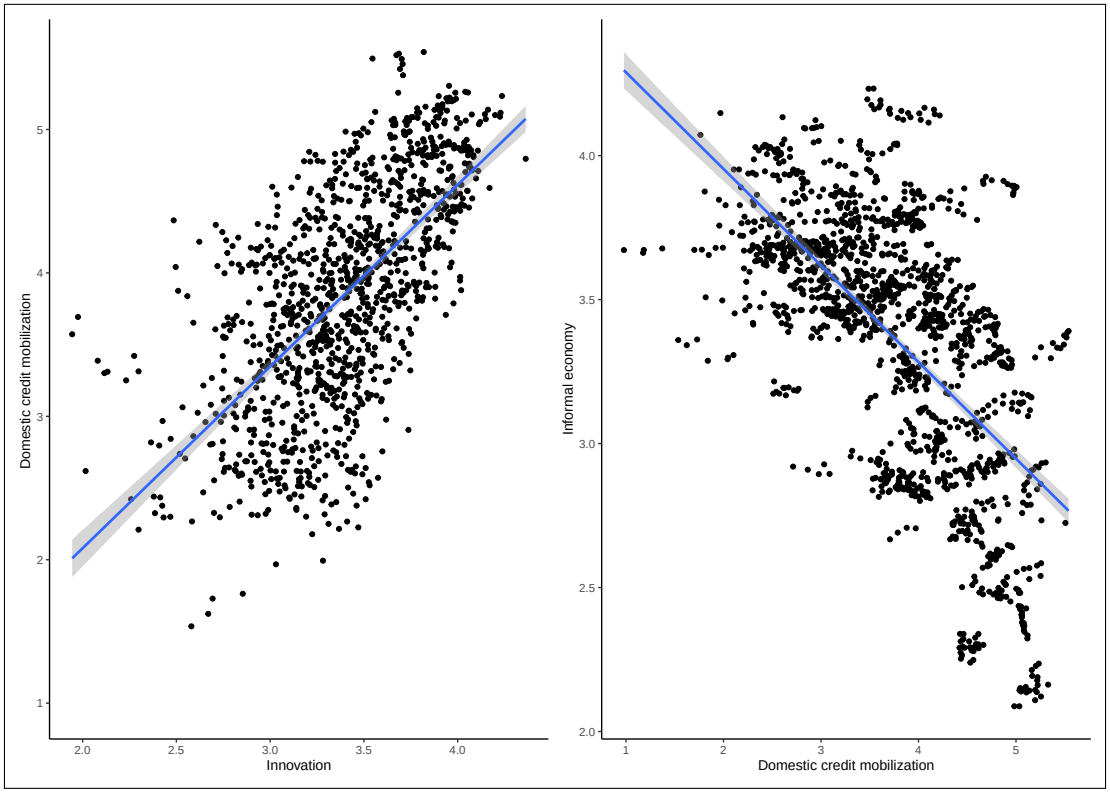
Source: Authors

Figure 7. Economic development as a transmission channel



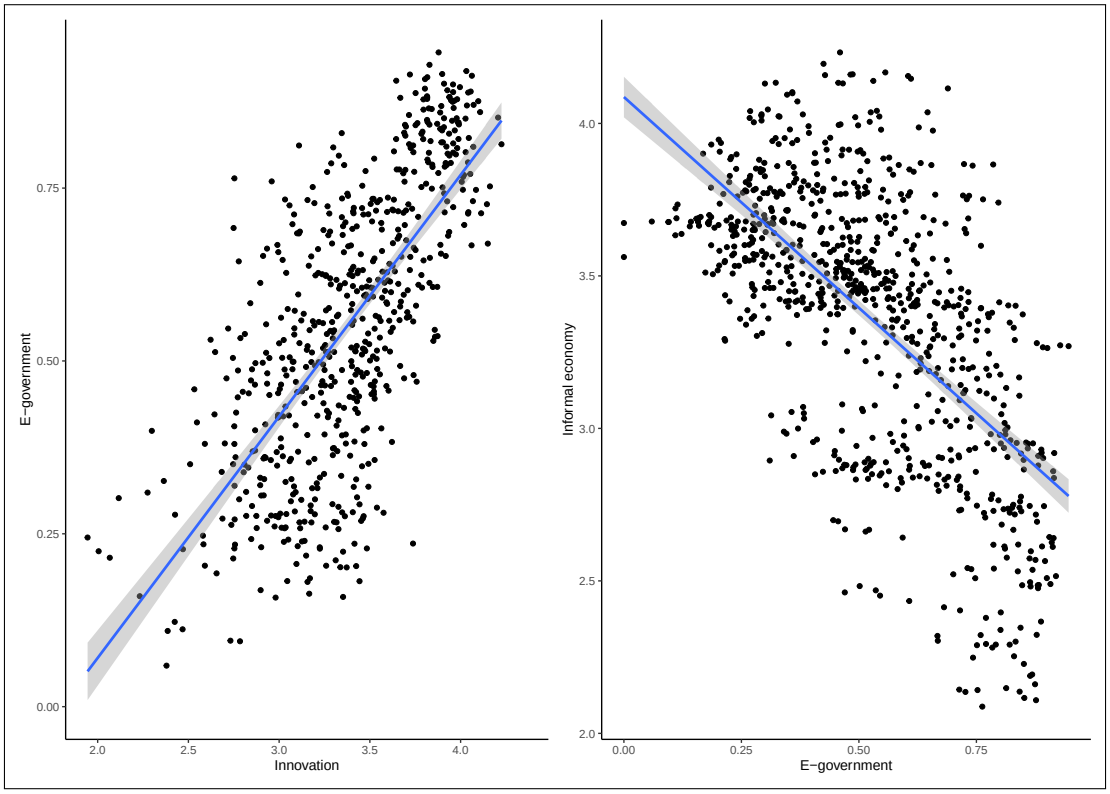
Source: Authors

Figure 8. Domestic credit mobilization as a transmission channel



Source: Authors

Figure 9. E-government as a transmission channel



Source: Authors