

From Financial Development to Informality

A Causal Link

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Abstract

Financial development reduces the cost of accessing external financing and thus incentivizes investment in higher-productivity projects that allow firms to expand to the scale needed to operate in the formal economy. It also encourages participants of the informal sector to join the formal sector to gain access to credit and financial services. This paper documents two findings. First, countries with less pervasive informality are associated with greater financial development. Second, the impact of financial development,

and especially banking sector development, on informality is causal. This causal link is established using a novel instrumental variable for domestic financial development: financial development in other (neighboring) countries. The causal link between informality and financial development is stronger in countries with greater trade openness and capital account openness. The findings are robust to alternative specifications.

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From Financial Development to Informality: A Causal Link

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1. Introduction

Informal economic activity is widespread around the world. On average, such activity accounts for about one-third of output, and informal employment captures almost one-third of total employment (Ohnsorge and Yu 2021).¹ It undermines revenue collections, stunts productivity, hinders investment, and traps some of the most vulnerable workers in low-paying, unproductive employment. For policy makers in countries with widespread informality, it is a formidable challenge.² However, without a clear understanding of the causes of informality, beyond its correlates, it is challenging to decide on the appropriate policy actions.

This paper documents one cause of informality: underdeveloped financial systems.³ Financial development can influence the benefits and costs of informal economic activity undertaken by firms and households (Straub 2005). Firms in the informal sector are typically characterized by small scale, low capital-to-labor ratios, lack of investment, low productivity, a low propensity to implement new, and even high-return, technologies, and unskilled managers (Amin and Okou 2020; Capasso and Jappelli 2013; Dabla-Norris, Gradstein, and Inchauste 2008; Quintin 2008). By influencing firms' behavior, financial development can encourage capital accumulation and productivity improvements and thus promote the transition of informal firms into the formal sector (Antunes and Cavalcanti 2007).

The negative relationship between financial development and the informal economy is well-established. For different sets of countries, different time periods, different definitions of financial development, multiple different definitions of informality, and controlling for numerous alternative co-factors, many empirical studies have found a robust and significant result: greater financial development is associated with less informality (see Capasso, Ohnsorge, and Yu 2022 for a recent review).

¹ In the literature, the term “informality” indicates all economic activities that are not, or only partially, covered by formal agreements. The term is very general and encompasses other more specific terms such as underground economy, shadow economy, or unofficial economy. In our analysis we refer to this general meaning.

² For instance, Pappada and Zylberg (2017) showed that economic activity at the margin of informality can change the response of tax compliance to tax rates across countries. Prado (2011) showed that most countries, in a sample of OECD countries, would benefit from a reduction in informality. Restrepo-Echavaria (2014) demonstrated that mismeasurement of the size of the informal sector can create challenges for policy makers in understanding measured cyclical fluctuations. Ohnsorge and Yu (2021) offer a comprehensive review of policy challenges caused by large informal sectors.

³ Others have documented additional causes of informality at the firm or worker level. Kanbur (2017) and Loayza (2018) discuss the causes of informal activity at the firm and household levels. Ulyssea (2020) summarizes the effect of various policies (registration support, enforcement of employment laws, VAT credit system, trade agreements) on individual firms and of various social programs on individual workers.

Several theoretical studies have identified the various channels that may give rise to a negative relationship between financial development and informality, with causality running in either direction. These studies essentially compare benefits, such as access to finance, with costs, such as regulatory and tax compliance burdens, of operating in the formal sector. Broadly speaking, these studies differ in three dimensions: the modeling of financial market frictions (Straub 2005; Capasso and Jappelli 2013; Guo and Hung 2020; Bittencourt, Gupta, and Stander 2014), the incorporation of technological choices (Amaral and Quintin 2006; Elgin and Uras 2013), and the nature of informality choices (Antunes and Cavalcanti 2007, Quintin 2008; Blackburn, Bose and Capasso 2012). The main notion behind most of these studies is that in the presence of information asymmetries informal firms and individuals face a higher cost of access to credit since they are opaquer to external investors, with the result that it may be optimal to stay out of the credit market. As financial markets develop, financial contracts become more profitable, and the opportunity cost of accessing credit decreases as does the cost of formality. Moreover, since investments strongly depend on access to external financing, the choice between operating formally or informally often involves a technology choice. Conversely, aggregate constraints on the size of the financial system can also weaken the link between financial development and informality (Massenot and Straub 2016).

Hence, an open question is the direction of causality. We show the causal impact of financial development on the extent of informal output for a large sample of countries using a novel instrumental variable in the two-stage least squares (2SLS) estimation. We do so in a panel setting and use a time-variant external instrumental variable, in contrast to previous studies.⁴ Such an approach brings the benefits of using long panel data where the fixed effects estimator becomes more consistent as the sample grows (Madsen, Islam, and Doucouliagos 2018; Davidson and MacKinnon 2006).

Our choice of instrumental variable is inspired by a large literature that documents the link between domestic and foreign banking sector development. Specifically, we focus on one aspect of financial development that is likely to be most relevant for the vast majority of informal workers and firms: relationship banking, which is typically conducted through close interaction between the bank and the borrower, which often requires the establishment of bank branches. Drawing on the clear evidence of strong cross-country

⁴ Former studies also used the instrumental variable approach to identify the causal impact of financial development, but they tend to use time-invariant instruments or internal instruments. For instance, following La Porta et al. (1997), a large literature has explored the impact of financial development on economic development using legal origin as an instrument for financial development (see Levin 2021 and Amissah et al. 2021 for recent reviews). Other studies have instrumented financial development with variables that are also largely time-invariant, such as the legal system or latitude (Levine 1999; Levine, Loayza, and Beck 2000), religious composition (Beck and Levine 2002), and ethnic fractionalization (Naceur and Zhang 2016). Studies such as Beck, Levine, and Loayza (2000) and Rashid and Intartaglia (2017) used internal instruments via the GMM method.

linkages in banking activities over the past three decades, we instrument the extent of branch networks with the strength of branch networks in geographically close countries.⁵ This approach allows us to identify a causal link between financial development and the share of informal output in GDP.

This paper documents two main findings. First, in line with former studies, less pervasive informality is associated with greater financial development. Second, the negative impact of financial development (especially banking sector development) on informality is causal. This causal link is stronger in countries with greater trade openness and capital account openness. The findings are robust to the use of alternative indicators of informality and financial development.

As such, this paper makes two contributions to the literature: it is the first study to document a causal link between financial development and informal economic activity in a multi-country setting. The only previous studies that established such a causal link were specific to single countries and relied on microdata or sectoral data. Capasso and Jappelli (2013) use data on loan applications to show that access to finance increased formal activity in Italy; Catão, Pages, and Rosales (2009) and Moron, Salgado, and Seminario (2012) use household survey data to show that financial deepening increased formal employment in sectors that were most dependent on external finance in Brazil and Peru, respectively.

Second, this study introduces a novel instrumental variable for domestic banking sector development: banking sector development in other (neighboring) countries. We establish that cross-country banking sector links can go beyond those established for lending (Kılınç, Seven, Yetkiner 2017; Bahadır and Valev 2015; Sever and Yucel 2021; Csonto et al. 2018), efficiency (Matousek et al. 2015; Nurboja and Košak 2017), interest rates (Rughoo and Sarantis 2014), or profitability (Olson and Zoubi 2017). Significant cross-country links exist even for banking system access, such as that captured by the extent of branch networks.

The next section describes the data and correlations between financial development and informality. Section 3 introduces our novel instrumental variable for domestic financial sector development and the empirical approach. Section 4 presents the main results and results from a battery of robustness tests. The conclusion summarizes our findings and offers policy recommendations and avenues for future research.

2. Data choices and description

The association between financial development and informality is well established

⁵ In different contexts, financial development in other (neighboring) countries has been used as an instrumental variable for domestic financial development in studies such as De Haan et al. (2021) and Pleninger and Sturm (2020). Our study is the first to use this approach to establish a causal link between financial development and informality.

(Capasso, Ohnsorge, and Yu 2022). However, the direction of causality has yet to be identified, especially in a multi-country context. This section aims to demonstrate the presence of a causal link from financial development to informality by employing an instrumental variable approach. However, before we move on to the instrumental variable estimation, we document the association between output informality and financial development without any presumption of causality.

2.1 Data

As summarized by Svirydzienka (2016), financial development materializes in different forms— as also reflected in the wide range of indicators of financial development used in the literature. Indicators range from domestic credit to the private sector to GDP ratios to equity market capitalization, bond market turnover, and the number of commercial bank branches per 100,000 adults, among others. Virtually all of these indicators, except those relating to equity market development, are significantly correlated with a range of informality measures (Capasso, Ohnsorge, and Yu 2022).

Here, for our purpose, we focus on banking sector development and, specifically, access to banking services. Informal workers tend to be lower-income and lower-skilled, and informal firms tend to be smaller, less productive, and active in less capital-intensive sectors (Ohnsorge and Yu 2021). Hence, the main point of interaction of informal workers and firms with the financial system is likely to be banks, not equity or bond markets. Their transactions with banks, if any, are likely to be small in magnitude and founded on relationship banking since relationship banking, which can also be measured by a denser branch network, can decrease the probability of credit rationing despite higher screening and monitoring costs (Presbiter and Rebelotti 2014). This is the reason why, in the presence of a larger number of opaquer borrowers, banks can grant more credit by employing relationship lending technologies. One study for India, for example, showed that greater banking system access, including branch density, was associated with significant increases in enterprises in the informal sector (Raj, Sen, and Kathuria 2014).

As such, we deliberately avoid using domestic credit to the private sector— a measure of banking sector depth rather than access— since aggregate credit tends to be dominated by large loans to large firms (Čihák et al. 2013). One study for the United States, for example, showed that the largest 8 percent of firms account for 68 percent of bank credit (Chorodow-Reich et al. forthcoming). Domestic credit to the private sector also tends to be highly cyclical for reasons unrelated to financial development (Claessens, Kose, and Terrones 2012). In contrast, our interest here is in financial development, stripped of its cyclical component to the extent possible and focused on the financial services relevant to informal workers and firms. That said, in Section 4.2, we test the robustness of our results by using domestic credit to the private sector as an alternative measure of financial development.

Specifically, our proxy for financial development is the number of commercial bank

branches per 100,000 adults. The data are available in the *World Development Indicators* (WDI) for 183 countries from 2004-2018 (Table 1). Our proxy for financial development is significantly and positively correlated with other financial development measures commonly used in the literature, such as domestic credit to the private sector, the number of automated teller machines, account ownership, or the IMF's financial development indices (Table 2).

While there are many dimensions of informality, we focus on one for the purposes of this study: output informality (Elgin et al. 2021). For our analysis, output measures of informality are preferable to employment measures since finance is typically accessed to fund working capital or investment in physical or human capital, not employment. Specifically, output informality is proxied by Dynamic General Equilibrium (DGE) model-based estimates of informal output in percent of official GDP, as detailed in Elgin and Öztunalı (2012) and Elgin et al. (2021). DGE-based informal output as a share of GDP is available for up to 156 economies for 1990-2018. This measure of informality has been used in several previous studies of informality, including Elgin, Elveren, and Bourgeois (2021); Elgin and Iyidost (2021); Elgin, Williams, Oz-Yalaman and Yalaman (2022); and Granda-Carvajal and García-Callejas (2022). As a measure for the purposes of this study, it is preferable to the MIMIC measure of informality since the MIMIC measure includes, in its construction, indicators of financial development (specifically, cash demand). There are, however, limitations of the DGE-based estimates on informal output, such as reliance on a specific functional form or the choice of benchmarking (Elgin et al. 2021). In section 4.2, we run a series of robustness checks to address some of these limitations.

2.2 Correlation between informality and banking sector development

The scatter plot in Figure 1 indicates a negative relationship between the average level of output informality and the average number of commercial bank branches (per 100,000 adults) over the period 2004-2018. A large group of emerging market and developing economies are concentrated in the upper left corner where output informality is high, but the number of commercial bank branches is limited.

This negative relationship is further confirmed by t-tests where the sample is split into country-year pairs with above-median and below-median shares of informality. We test for statistically significant differences in the simple average of the number of commercial bank branches for country-year pairs with above-median informality and those with below-median informality. On average, every 100,000 adults in countries with above-median informality have access to about 11 commercial bank branches— about half the number in countries with below-median informality. The t-test suggests that these differences are statistically significant.

Of course, this association between informality and financial development could simply be driven by a set of confounding factors, such as per capita incomes or the quality of

institutions.⁶ To avoid results being biased by omitted variables, we run the following panel fixed-effect estimation:

$$INF_{it} = \alpha + \beta FD_{it} + \gamma X_{it} + c_i + y_t + \varepsilon_{it} \quad (1)$$

where INF_{it} is the extent of informality in country i and year t , FD_{it} captures the level of banking sector development, and c_i and y_t control for country fixed effects and year fixed effects. The estimation includes a range of controls (X_{it}) that can influence both informality and financial development. In particular, these are real GDP per capita (in constant 2010 U.S. dollars, in logarithms) and indicators of institutional quality (control of corruption, regulatory quality, and the rule of law). Data on real GDP per capita are drawn from the World Bank's WDI. The indicators of institutional quality are obtained from the World Bank's *Worldwide Governance Indicators*, with higher values corresponding to better institutional quality.

As shown in Table 3, greater banking sector development is associated with less output informality in a statistically significant manner, even when controlling for other aspects of underdevelopment (such as poor institutions and low per capita incomes). This relationship remains statistically significant when using lagged financial development.

While this establishes a correlation between financial development and informality, it does not establish causality. As discussed in the introduction, several studies argue for causality running in either direction. To establish causality, we next turn to an instrumental variable approach.

3. Causal link from financial development to informality

We conduct the two-stage least squares estimation with a novel instrumental variable that has not yet been used in the literature on informality but that captures a well-established, quantitatively important driver of domestic financial development: financial development in other (neighboring) countries.⁷ This approach provides us with a time-variant external instrumental variable to take advantage of our panel setting (Madsen, Islam, and Doucouliagos 2018; Davidson and MacKinnon 2006).⁸ In the next subsection, we

⁶ See Ohnsorge, Okawa, and Yu (2021), Medina and Schneider (2018), and Ulyssea (2020) for recent reviews on determinants of informality. See Fergusson (2006) and Voghouei, Azali, and Jamali (2011) for reviews of factors contributing to financial development. Both informality and financial development are associated with institutional quality and economic development (typically captured by per capita incomes).

⁷ Distance-discounted financial development in foreign countries was used as an instrumental variable (IV) for domestic financial development in studies such as De Haan et al. (2021) and Pleninger and Sturm (2020) in different contexts, but our study is the first to use it to establish a causal link between financial development and informality

⁸ As suggested by Madsen, Islam, and Doucouliagos (2018) and Davidson and MacKinnon (2006), the benefits of using long panel data are that the fixed effects estimator becomes more consistent

demonstrate the validity of our instrumental variable and, in the subsequent subsection, detail our empirical strategy.

3.1 Instrumental variable: Foreign banking sector development

International banking links are sizeable and have grown over the past two decades. They have grown particularly rapidly in emerging markets and developing economies (EMDEs; Aldasoro and Ehlers 2019; Feyen et al. 2020). In one-quarter of EMDEs, international claims— both cross-border (by foreign parent banks) and local (by local branches and subsidiaries of foreign parent banks)— on the nonfinancial private sector amounted to 11 percent of banking system assets and 12 percent of GDP in 2020. Foreign banks have contributed to domestic financial development, with studies showing that they introduce new banking technologies (Kumar and Ang 2014), spur competition and improve efficiency (Klein and Olivei 1999; Levine 2001), and expand access to banking services (IMF 2015). Foreign bank presence and other cross-border banking links have contributed to the convergence in cross-country banking sector development over time (Bahadir and Valev 2015).

International banking links tend to thrive with geographical proximity. For instance, during 2003-08, foreign banks operating in Central, Eastern and Southeastern Europe were largely headquartered in Western Europe (IMF 2013). Gravity models applied to bilateral financial flows suggest that financial flows grow with geographic proximity (see, e.g., Head and Ries 2008; de Sousa and Lochar 2011; and Okawa and van Wincoop 2012). In one sample of 14 reporting countries and 186 partner countries, shorter distance was associated with greater international banking integration during 1995-2017 (Bouvatier and Delatte 2015). The importance of geographic proximity may reflect the trade and multinational corporate activities that tend to deepen with proximity as banks follow their clients to provide finance (see Floy and Manova 2015, for a review). It may also reflect similar operating environments, especially in economic or monetary unions. The significant commercial banking links between countries in the Eastern Caribbean Currency Union (ECCU) have in part been attributed to the joint operating environment with a single currency and a shared central bank (Csonto et al. 2018). The predominance of such regional banking links may account for the decline of convergence in banking sector developments as geographic distances grow (Bouvatier and Delatte 2015). Therefore, we expect the link between domestic financial development and financial development in other countries to be stronger for neighboring countries.

At the same time, there is no reason to suspect that banking sector development in other (neighboring) countries would be directly associated with domestic informal economic activity. There is ample evidence that the informal sector is largely excluded from the domestic formal financial system (Farazi 2014; Perry et al. 2007). A domestic informal

as the sample grows, whereas the instrumental variable parameter estimates can be severely biased in small samples.

sector that is largely excluded from the domestic formal banking system is even more likely also to be excluded from formal banking systems in other (neighboring) countries. Therefore, banking sector development in other (neighboring) countries is unlikely to directly affect, or be affected by, the extent of domestic informal economic activity.

Of course, the possibility remains that financial development abroad correlates with something abroad that has cross-country spillovers to something at home that correlates with informality at home. Through this indirect channel, the exclusion restriction condition for our selected instrumental variable could be violated. However, two factors mitigate these concerns. First, we do not use the measures of financial development (such as credit to GDP) that are most strongly correlated with output. Instead, we use bank branches per person abroad as the baseline measure of financial development— a measure that is likely to be less strongly associated with output abroad than some other measures of financial development. Second, we use two distance-weighted measures for banking sector development abroad (detailed in the next section). As argued in Pleninger and Sturm (2020) and the sources cited therein, the exclusion restriction for such instrument is satisfied if two assumptions hold: (i) distance is exogenous (which it is) and (ii) any bias stemming from the endogeneity of financial development is independent of distance (which is also the case here).⁹

Indeed, as expected, there is a statistically significant, positive correlation between domestic banking sector development and regional banking sector development, at least in the dimension that matters for our purposes as discussed above: the number of commercial bank branches per 100,000 adults. Figures 2 A and B show, in scatter plots, the correlation between the home country’s number of bank branches and the distance-discounted average of bank branches in other countries in the region (A) or the distance-discounted average of bank branches in all other countries in the world (B).

The strength of the correlation between domestic banking sector development and banking sector development in other (neighboring) countries, at least in the dimension that is relevant for our purposes (bank branches), is also apparent in the panel regression that constitutes the first stage of the instrumental variable estimation.

3.2 Empirical strategy

Formally, we establish the causal effect of financial development on informality in the following two-stage least squares instrumental variable approach:

$$INF_{it} = \alpha + \beta \widehat{Branches}_{it} + \gamma X_{it} + \delta c_i + \varphi y_t + \varepsilon_{it} \quad (\text{second stage})$$

$$Branches_{it} = \alpha + \beta Branches^*_{-it} + \gamma X_{it} + \delta c_i + \varphi y_t + \varepsilon_{it} \quad (\text{first stage})$$

⁹ In future work, additional robustness tests could control for regional or distance-weighted GDP abroad to test the validity of our instruments, following the approach of Acemoglu et al. (2019).

In the first stage, we regress the level of banking sector development— proxied by the number of commercial bank branches per 100,000 adults— in country i and year t against three variants of banking sector development in other (neighboring) countries ($Branches_{-it}^*$): (i) the unweighted average of the number of bank branches in all countries with common borders to country i , (ii) the geographic distance-discounted average of the number of bank branches in all countries in the same region excluding country i , and (iii) the geographic distance-discounted average of the number of bank branches in all countries excluding country i .¹⁰ The three variants of our instrumental variable both capture foreign financial development as well as the fact that the link between domestic and foreign financial sector development is stronger for neighboring countries. Both the regional and global distance-discounted averages are defined in this equation:

$$Branches_{dist,-it}^* = \sum_{j \neq i} \left(\frac{2}{n} - \frac{dist_{ji}}{\sum_{j \neq i} dist_{ji}} \right) * Branches_{jt}$$

The proxy for geographic proximity (i.e., geodesic distance) is obtained from the CEPII database. Common regions are defined as in World Bank (2021). In both the first and second-stage regressions, we control for the same set of control variables as in equation (1), including the level of per capita income (in 2010 U.S. dollars) and the three institutional quality measures taken from WGI (i.e., control of corruption, regulatory quality, and rule of law). All regressions include year fixed effects (y_t) and country fixed effects (c_i).

Table 4 shows the results of the first-stage regression for an unconstrained sample for 2004-2018 (some of these observations will be dropped for the full estimation due to the lack of data on informal activity). Banking sector development in country i is significantly positively correlated with banking sector development in countries that are geographically close or in the same region. This supports our hypothesis that a well-developed banking system in one country “spills over” into a better developed banking system— of the type that would be accessed by informal firms and workers— in geographically close countries. Hence, we take this as an indication that banking sector development in other (neighboring) countries is a suitable instrumental variable for domestic banking sector development.

4. Empirical results

As expected, the results of this exercise point to a causal impact of banking sector development on informal activity. The following subsection summarizes the main results. These are subjected to a battery of robustness tests in the subsequent subsection.

¹⁰ Similar distance-discounted instruments have been used in studies such as De Haan et al. (2021) and Pleninger and Sturm (2020).

4.1 Baseline results

Table 5 presents the estimated causal impact of banking sector development on the share of informal output. The estimated coefficients for our variable of interest, $\widehat{Branches}_{it}$, are of the expected signs and statistically significant.

In the first-stage regressions (this time with the matching sample to the second-stage regression), the number of bank branches in geographically close countries is statistically significantly associated with respect to a larger number of domestic bank branches, regardless of the precise definition of banking sector development in other (neighboring) countries. Ten more bank branches on average in the rest of the region are associated with 8-9 more domestic bank branches (all per 100,000 adults). The post-estimation test statistics confirm that the proposed instrumental variables are strong instruments.

The second stage results document the statistically significant negative effect of banking sector development, as instrumented with the average number of bank branches in other (neighboring) countries, on the share of informal output in percent of GDP. Ten more bank branches per 100,000 adults reduce informal output by 1-2 percentage points of GDP. This is statistically significant, but also economically meaningful: it is equivalent to the median annual decline in the share of informal output between 2000 and 2018.

4.2 Robustness tests

The above baseline results are robust to a series of alternative exercises, including the use of lagged independent variables, restricting the samples to subsamples that differ by relevant country characteristics, and employing domestic credit to GDP as a measure of financial development.

4.2.1 Lagged dependent variables

The first-stage regression is open to concerns about endogeneity since the domestic banking system itself, especially if it is large, may affect foreign banking systems, especially if they are small. Hence, in the first-stage regression, the contemporaneous value of foreign bank branches is replaced with the lagged value of foreign bank branches. Table 6 shows that the main results are robust: greater banking sector development, as instrumented here, reduces the informal share of output.

4.2.2 Trade openness and capital account openness

Our choice of instrumental variable— foreign banking sector development— rests crucially on two assumptions: first, that banking systems can transact easily across borders, including setting up foreign branches and subsidiaries, and second, that there are powerful incentives for banking systems to transact, including strong international trade or multinational corporate activity. In countries that are closed to foreign capital flows, such transactions should be severely impaired; in countries that are closed to international trade, there may be little incentive for foreign banks to follow their clients

abroad. Hence, in both cases, our choice of instrument should be less relevant. We would therefore expect the 2SLS regression to yield largely insignificant results in countries that allow limited trade or international capital flows.

Tables 7 and 8 show that this is indeed the case. Our approach yields a significant effect of banking sector development on informality only in countries that are highly open to foreign trade (Table 7) and capital flows (Table 8). In these two tables, we split the sample into countries with above-median trade openness (defined as trade in percent of GDP) or capital account openness (defined as in Chinn-Ito 2006) and those with below-median trade openness or capital account openness. In the first-stage regression, the coefficient estimates are indeed somewhat smaller in countries that are less open to trade and capital flows than in those that are more open. In the second-stage regression, banking sector development, as instrumented here, has no statistically significant effect on informality in countries that are less open to trade and capital flows but does have a statistically significant effect in countries that are more open to trade and capital flows.

4.2.3 Alternative indicators of financial development

We have deliberately chosen the number of commercial bank branches per 100,000 adults for the reasons laid out in Section 2. That said, an alternative indicator of financial development that has often been used in the literature is domestic credit to the private sector in percent of GDP. While this indicator is less suitable than the number of bank branches for our purposes, because it is “polluted” by cyclical movements and because it is mainly driven by formal-sector firms, Table 9 shows the results using domestic credit to the private sector (in percent of GDP) as a measure of financial development. The main results are robust: greater financial sector development leads to a lower share of informal output.

4.2.4 Alternative indicators of informality

For our baseline results, we deliberately chose the share of informal output in GDP, for the reasons laid out in Section 2. That said, while conceptually less appropriate for the exercise conducted here, the DGE-based estimates on output informality of Elgin and Oztunali (2012) have some limitations. First, they rely on strong assumptions about the functional form of activity in the informal and formal sectors and about the relationship between formal and informal productivity (Orsi, Raggi, and Turino 2014; Schneider and Buehn, 2016). Second, like the MIMIC approach, they require base-year estimates of the informal economy from another independent study to calibrate the size of the informal economy (Ihrig and Moe 2004).¹¹

¹¹ In the case of Elgin and Oztunali (2012), productivity in the informal economy was assumed to grow at the average of the growth rates of formal sector productivity and the capital stock (Solis-Garcia and Xie 2018). The model was calibrated by matching the productivity in the informal sector to the size of the informal sector in 2007 of the series reported in Schneider, Buehn, and Montenegro (2010).

Therefore, we conduct a series of robustness checks using alternative measures of informality, including the survey-based share of self-employed in total employment, the MIMIC measure of informality, and a DGE-based measure of informality that is benchmarked to survey-based estimates of self-employment. The survey-based share of self-employment does not rely on strong assumptions but is more tenuously linked to credit than output-based measures. It is available for 160 economies over 2000-18. The MIMIC-based estimates cover a wider range of indicators associated with informality but include a measure of financial size in its construction. Estimates are taken from Medina and Schneider (2019) and are available for 155 economies over the period 2000-17. The model of Elgin and Oztunali (2012) benchmarked to survey-based estimates of self-employment is decoupled from MIMIC-based estimates of informality and does not require ad-hoc assumptions regarding the relationship between formal and informal productivity.¹² It is available for up to 155 economies during 2000-18.

Table 10 shows that the baseline results are largely robust to the use of alternative informality measures. All regressions that instrument the informal economy with commercial bank branches in the region or with distance-discounted commercial bank branches continue to indicate that greater financial development reduces the share of the informal economy.

5. Conclusion

It is well-established in the literature that widespread informal economic activity is associated with underdeveloped financial systems through a wide range of mechanisms. What has not been well-established is the direction of causality, at least in a multi-country setting. In this paper, we use an instrumental variable approach to establish such a causal link. Using a novel instrument— financial sector development in other (neighboring) countries— we show that greater financial sector development, here proxied by access to banking services, reduces the share of informal output to GDP. The impact is stronger in countries with greater trade openness and capital account openness. These findings are robust to the use of alternative informality measures and various indicators for financial development.

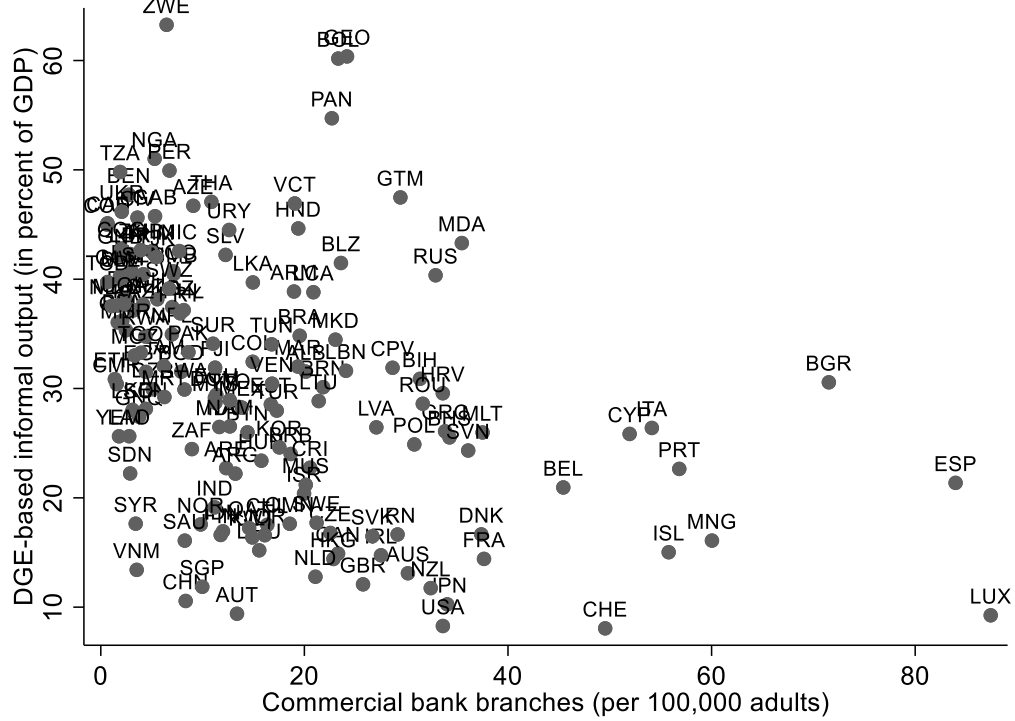
Confidence in a causal effect of financial development supplies policy makers with the information needed to direct policy action. It suggests that efforts to broaden access to the financial system can help reduce informal activity. This is likely to be particularly helpful when combined with other policies.

¹² See the Appendix for details regarding calibrating the model of Elgin and Oztunali (2012) to survey-based estimates of self-employment.

Future research could broaden this analysis to other measures of financial sector development. Here, we focus our exercise on banking sector development and specifically the extent of commercial bank branch networks. This choice reflected the theoretical and empirical support for a link between domestic and foreign banking sectors. However, other such links may exist in other parts of the financial systems and could be further explored. For example, in some regions (such as Sub-Saharan Africa), the use of mobile money and digital payments has grown rapidly in recent years (World Bank 2022; Yermack 2018). On average in EMDEs, the share of adults with a mobile money account has more than doubled from 6.5 percent of the people aged 15 years or older in 2014 to 14.8 percent only three years later, in 2017, and to 24 percent in 2021. That said, this is still well below the share of adults with an account at a financial institution (52.3 percent of the population aged 15 years or above in 2021). During our sample period of 1990-2018, data on mobile money use is only available for 2014 and 2017, too limited to yield meaningful econometric results. Future research, drawing on additional data, could explore the link between mobile money and informality further.

Tables and Figures

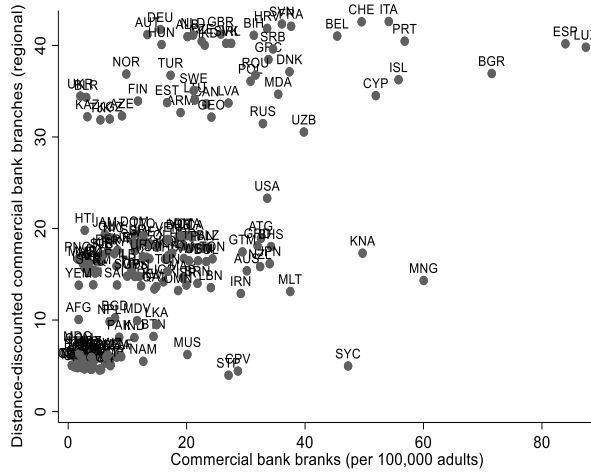
Figure 1. Output informality and bank sector development (2004-18)



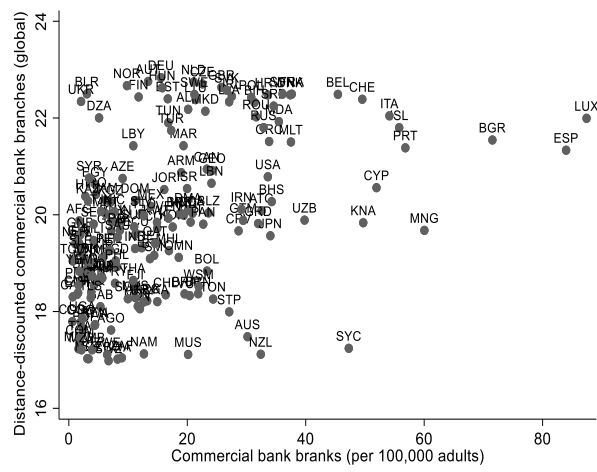
Notes: Output informality is proxied by DGE-based estimates on informal output in percent of GDP. Financial development is measured as the number of commercial bank branches per 100,000 adults. Both measures are averaged over the period 2004-18 here. See section 2 for detailed data description.

Figure 2. Alternative measures of financial development spillover

A. Distance-discounted commercial bank branches in the rest of the region



B. Distance-discounted commercial bank branches in the rest of the world



Notes: Financial development is measured as the number of commercial bank branches per 100,000 adults. All measures are averaged over the period 2004-18 here. See section 2 for detailed data descriptions.

Table 1. Data description

Variable	Description	Source	#ctry	Period	Obs	Mean	SD.
Domestic credit to private sector	Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations, such as through loans, purchases of nonequity securities, and trade credits and other accounts receivable, that establish a claim for repayment. Expressed in percent of GDP.	World Development Indicators (WDI)	183	2000-18	3,009	50.39	44.26
Commercial bank branches	The number of commercial bank branches per 100,000 adults	WDI	183	2004-18	2,591	17.44	16.41
Real GDP per capita (in logs)	GDP per capita (constant 2010 U.S. dollars; in logs).	WDI	188	2000-18	3,525	8.47	1.45
Control of Corruption	Perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. A higher value corresponds to better governance outcomes.	World Governance Indicators (WGI)	189	2000-18	3,564	-0.07	0.99
Rule of Law	Perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. A higher value corresponds to better governance outcomes.	WGI	189	2000-18	3,580	-0.08	0.99
Regulatory quality	It captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. A higher value corresponds to better governance outcomes.	WGI	189	2000-18	3,551	-0.06	0.97

DGE-based output informality	Dynamic General Equilibrium (DGE) model-based estimates on informal output in percent of official GDP, calibrated as in Elgin and Oztunali (2012).	Elgin et al. (2021)	156	2000-18	2,924	30.86	12.02
Share of self-employment	Survey-based self-employment in percent of totalemployment.	Elgin et al. (2021)	163	2000-18	1,906	31.88	21.67
MIMIC-based output informality	Multiple Indicators Multiple Causes (MIMIC) model-based estimates of informal output in percent of official GDP.	Medina and Schneider (2019)	155	2000-17	2,790	29.67	12.38
DGE-based output informality, calibrated to survey-based self-employment	Dynamic General Equilibrium model-based estimates on informal output in percent of official GDP, calibrated using survey-based self-employment (see Appendix for details).	Authors	155	2000-18	2,283	43.55	31.11

Table 2. Correlations among various proxies for financial development

	[1] Commercial bank branches	[2] Domestic credit to priv. sect.	[3] ATMs	[4] Account ownership	[5] Financial development	[6] Financial institutions	[7] Financial markets
Commercial bank branches (per 100,000 adults)	1						
Domestic credit to private sector (% of GDP)	0.476***	1					
Automated teller machines (ATMs; per 100,000 adults)	0.541***	0.578***	1				
Account ownership (percent of age 15+)	0.529***	0.677***	0.682***	1			
IMF's "financial development" index	0.539***	0.809***	0.754***	0.799***	1		
IMF's "financial institutions" development index	0.689***	0.802***	0.792***	0.827***	0.928***	1	
IMF's "financial markets" development index	0.366***	0.733***	0.648***	0.696***	0.956***	0.777***	1

Notes: Global Financial Development Database=GFDD. * p < 0.05, ** p < 0.01, *** p < 0.001. "Account ownership" is the percentage of survey respondents (aged 15 or above) who report having an account (by themselves or together with someone else) at a bank or another type of financial institution or report personally using a mobile money service in the past 12 months. The IMF's "financial development" index has the following two components: "financial markets" development and "financial institutions" development". The IMF's "financial markets" development index captures access to, and depth and efficiency of, a country's stock and debt markets. The IMF's "financial institutions" development index measures how developed financial institutions are in terms of their depth (size and liquidity), access (the ability of individuals and companies to access financial services), and efficiency (the ability of institutions to provide financial services at low cost and with sustainable revenues). Data on financial development over the period 2000-18 are available from the World Bank's Global Financial Development Database, the World Development Indicators, the Global Findex Database, and the IMF's Financial Development Index Database.

Table 3. Fixed-effect estimator: output informality and financial development

	[1]	[2]	[3]	[4]
Real GDP pc (in logs)	-5.58*** (1.64)	-5.48*** (1.35)	-3.68*** (1.07)	-2.52*** (0.95)
Commercial bank branches (t)	-0.04** (0.02)	-0.04** (0.02)		
Commercial bank branches (t-3)			-0.05*** (0.02)	
Commercial bank branches (t-7)				-0.03* (0.02)
Control of Corruption		-0.33 (0.51)	-0.82 (0.59)	-0.59 (0.40)
Regulatory Quality		-0.06 (0.64)	-0.26 (0.86)	0.14 (0.62)
Rule of Law		0.22 (0.56)	0.47 (0.70)	-0.56 (0.53)
Observations	2,157	2,157	1,736	1,130
Number of countries	154	154	154	153
R-squared	0.56	0.56	0.52	0.46
Adj R-sq	0.55	0.55	0.51	0.45

Notes: Standard errors clustered at the country level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. All fixed-effect regressions also control for year-fixed effects. See section 2 for detailed data descriptions. The sample covers up to 154 economies over the period 2004-2018, due to the data availability of commercial bank branches. Commercial bank branches are in per 100,000 adults. GDP per capita is in constant 2010 U.S. dollars. “Commercial bank branches (t -n)” capture “commercial bank branches” lagged by n years.

Table 4. The linkage between domestic and foreign banking development

Dep var=Commercial bank branches	[1]	[2]	[3]
Real GDP per capita (in logs)	9.59*** (2.64)	8.58*** (2.62)	9.63*** (2.92)
Control of Corruption	3.13** (1.24)	2.74** (1.16)	3.23** (1.29)
Regulatory Quality	1.51 (0.93)	1.24 (0.87)	0.49 (0.92)
Rule of Law	-0.44 (1.20)	-0.25 (1.20)	-0.67 (1.21)
Commercial bank branches in the region	0.83*** (0.15)		
Distance-discounted commercial bank branches (regional)		0.82*** (0.13)	
Distance-discounted commercial bank branches (global)			2.95*** (0.63)
Observations	2,526	2,495	2,497
Number of countries	180	177	177
R-squared	0.26	0.30	0.20
Adj R-sq	0.26	0.30	0.19

Notes: Standard errors clustered at the country level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Fixed-effect models are estimated here. All regressions include year dummies. The data are for the period 2004-18. Commercial bank branches are in per 100,000 adults. GDP per capita is in constant 2010 U.S. dollars. See section 2 for detailed data descriptions. Data are between 2004 and 2018.

Table 5. Baseline results: Two-stage least squares estimation

	[1]	[2]	[3]
2nd stage: Output informality			
Real GDP per capita (in logs)	-3.86*** (1.49)	-3.89*** (1.51)	-3.28* (1.68)
Control of Corruption	-0.09 (0.56)	-0.10 (0.57)	-0.04 (0.60)
Regulatory Quality	0.09 (0.65)	0.09 (0.65)	0.14 (0.66)
Rule of Law	0.17 (0.57)	0.17 (0.57)	0.19 (0.58)
Commercial bank branches	-0.16*** (0.05)	-0.15*** (0.04)	-0.20*** (0.07)
1st stage: Banking sector development			
Commercial bank branches in the region	0.88*** (0.17)		
Distance-discounted commercial bank branches (regional)		0.81*** (0.15)	
Distance-discounted commercial bank branches (global)			2.99*** (0.70)
Observations	2,155	2,155	2,157
R-squared	0.99	0.99	0.99
Kleibergen-Paap rk LM statistic	22.59***	23.70***	17.66***
Cragg-Donald Wald F statistic	26.31	31.17	18.29

Notes: Standard errors clustered at the country level in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Here common controls and constant terms are omitted for brevity. All regressions include both country fixed effects and year fixed effects. The data are for the period 2004-18. Commercial bank branches are in per 100,000 adults. GDP per capita is in constant 2010 U.S. dollars. The dependent variable at the second stage is DGE-based output informality (in percent of GDP). See sections 2 and 3 for detailed data descriptions and empirical methods. Data are for 2004-18.

Table 6. Robustness test: Lagged dependent variables in first-stage regression

	[1]	[2]	[3]
2nd stage: Output informality			
Real GDP per capita (in logs)	-3.33** (1.43)	-3.31** (1.40)	-2.70* (1.53)
Control of Corruption	-0.16 (0.62)	-0.14 (0.63)	-0.05 (0.67)
Regulatory Quality	-0.05 (0.66)	-0.06 (0.65)	-0.03 (0.66)
Rule of Law	0.35 (0.59)	0.37 (0.58)	0.41 (0.60)
Commercial bank branches	-0.16*** (0.04)	-0.16*** (0.04)	-0.21*** (0.06)
1st stage: Banking sector development			
Commercial bank branches in the region (t-1)	0.94*** (0.17)		
Distance-discounted commercial bank branches (regional; t-1)		0.86*** (0.15)	
Distance-discounted commercial bank branches (global; t-1)			3.36*** (0.72)
Observations	2,000	2,021	2,023
R-squared	0.99	0.99	0.99
Kleibergen-Paap rk LM statistic	24.47***	25.67***	20.89***
Cragg-Donald Wald F statistic	29.29	35.16	22.02

Notes: Standard errors clustered at the country level in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Here common controls and constant terms are omitted for brevity. All regressions include both country fixed effects and year fixed effects. The dependent variable at the second stage is DGE-based output informality (in percent of GDP). The data are for the period 2004-18. Commercial bank branches are per 100,000 adults. GDP per capita is in constant 2010 U.S. dollars. See sections 2 and 3 for detailed data descriptions and empirical methods. Data are between 2004 and 2018.

Table 7. Robustness test: Trade openness

	[1]	[2]	[3]	[4]	[5]	[6]
	High trade openness			Low trade openness		
2nd stage: Output informality						
Real GDP per capita (in logs)	-0.70 (1.51)	-0.58 (1.51)	-0.17 (1.85)	-8.86*** (2.91)	-8.83*** (2.89)	-9.16*** (3.43)
Control of Corruption	0.34 (0.49)	0.34 (0.50)	0.34 (0.55)	-0.77 (0.86)	-0.76 (0.85)	-0.83 (0.92)
Regulatory Quality	0.86* (0.49)	0.87* (0.50)	0.88* (0.53)	-1.12 (0.96)	-1.12 (0.96)	-1.14 (0.94)
Rule of Law	-0.68 (0.65)	-0.67 (0.66)	-0.65 (0.69)	1.55* (0.84)	1.55* (0.84)	1.61* (0.89)
Commercial bank branches	-0.18*** (0.06)	-0.19*** (0.05)	-0.23*** (0.08)	-0.04 (0.10)	-0.04 (0.09)	-0.02 (0.15)
1st stage: Banking sector development						
Commercial bank branches in the region	0.93*** (0.21)			0.64** (0.29)		
Distance-discounted commercial bank branches (regional)	0.54** (0.22)			0.51*** (0.18)		
Distance-discounted commercial bank branches (global)	3.21*** (0.86)			1.76 (1.11)		
Observations	1,122	1,122	1,122	1,033	1,033	1,035
R-squared	0.99	0.99	0.99	0.99	0.99	0.99
Kleibergen-Paap rk LM statistic	16.63***	18.66***	13.86***	4.61**	4.47***	2.78*
Cragg-Donald Wald F statistic	18.83	23.62	13.78	4.7	5.11	2.52

Notes: Standard errors clustered at the country level in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Here common controls and constant terms are omitted for brevity. All regressions include both country fixed effects and year fixed effects. The dependent variable at the second stage is DGE-based output informality (in percent of GDP). “High (low) trade openness” are countries where trade flow (i.e., imports plus exports) as a share of GDP is above (below) median. Commercial bank branches are per 100,000 adults. GDP per capita is in constant 2010 U.S. dollars. See sections 2 and 3 for detailed data descriptions and empirical methods. Data are between 2004 and 2018.

Table 8. Robustness check: Capital account openness

	[1]	[2]	[3]	[4]	[5]	[6]
	High capital account openness			Low capital account openness		
2nd stage: Output informality						
Real GDP per capita (in logs)	-2.07 (1.57)	-1.84 (1.62)	-0.72 (2.20)	-5.75** (2.24)	-5.88*** (2.26)	-4.24 (6.83)
Control of Corruption	0.90 (0.62)	0.90 (0.64)	0.80 (0.79)	-0.73 (0.81)	-0.77 (0.80)	-0.28 (2.31)
Regulatory Quality	1.20** (0.52)	1.22** (0.52)	1.33** (0.52)	-0.81 (1.09)	-0.83 (1.08)	-0.61 (1.70)
Rule of Law	-1.07 (0.65)	-1.04 (0.67)	-0.77 (0.74)	1.56* (0.90)	1.52* (0.87)	2.03 (2.36)
Commercial bank branches	-0.14*** (0.04)	-0.16*** (0.04)	-0.22*** (0.07)	-0.33 (0.26)	-0.29 (0.20)	-0.81 (2.17)
1st stage: Banking sector development						
Commercial bank branches in the region	1.01*** (0.23)			0.35** (0.16)		
Distance-discounted commercial bank branches (regional)		0.88*** (0.18)			0.38** (0.16)	
Distance-discounted commercial bank branches (global)			3.45*** (0.96)			0.30 (0.71)
Observations	1,087	1,087	1,089	1,068	1,068	1,068
R-squared	0.99	0.99	0.99	0.98	0.98	0.95
Kleibergen-Paap rk LM statistic	17.35***	18.59***	14.08***	4.37**	5.26**	0.20
Cragg-Donald Wald F statistic	19.85	22.94	12.91	4.80	5.39	0.18

Notes: Standard errors clustered at the country level in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Here common controls and constant terms are omitted for brevity. All regressions include both country fixed effects and year fixed effects. The dependent variable at the second stage is DGE-based output informality (in percent of GDP). “High (low) capital account openness” are countries where Chinn-Ito index is above (below) median. Commercial bank branches are per 100,000 adults. GDP per capita is in constant 2010 U.S. dollars. See sections 2 and 3 for detailed data descriptions and empirical methods. Data are between 2004 and 2018.

Table 9. Robustness check: Domestic credit to private sector

	[1]	[2]	[3]
2nd stage: Output informality			
Real GDP per capita (in logs)	-6.90*** (1.66)	-6.98*** (1.62)	-6.86*** (1.70)
Control of Corruption	-0.38 (0.47)	-0.36 (0.46)	-0.41 (0.47)
Regulatory Quality	-0.21 (0.57)	-0.21 (0.56)	-0.22 (0.57)
Rule of Law	0.58 (0.61)	0.51 (0.61)	0.64 (0.64)
Domestic credit to private sector	-0.04** (0.02)	-0.04* (0.02)	-0.05* (0.03)
1st stage: Domestic credit			
Domestic credit to private sector in the region	0.53*** (0.15)		
Distance-discounted domestic credit to private sector (regional)		0.70*** (0.18)	
Distance-discounted domestic credit to private sector (global)			2.21*** (0.65)
Observations	2,511	2,511	2,521
R-squared	0.99	0.99	0.99
Kleibergen-Paap rk LM statistic	11.90***	12.55***	11.47***
Cragg-Donald Wald F statistic	12.37	14.48	11.63

Notes: Standard errors clustered at the country level in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Here common controls and constant terms are omitted for brevity. All regressions include both country fixed effects and year fixed effects. The dependent variable at the second stage is DGE-based output informality (in percent of GDP). Domestic credit to private sector is in percent of GDP (taken from WDI). See sections 3 and 4 for detailed data descriptions and empirical methods. GDP per capita is in constant 2010 U.S. dollars. Data are between 2000 and 2018.

Table 10. Robustness check: Alternative measures of informality ^{2nd stage:}	Share of self-employment			MIMIC-based output informality			DGE-output informality, calibrated to self-employment		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Real GDP pc (in logs)	-2.52 (3.15)	-2.70 (2.99)	2.53 (4.75)	-8.86*** (1.10)	-8.81*** (1.09)	-7.91*** (1.54)	2.58 (4.24)	3.06 (4.08)	7.85 (6.47)
Control of Corruption	-1.23 (1.40)	-1.42 (1.37)	-0.93 (1.66)	0.39 (0.51)	0.40 (0.51)	0.48 (0.58)	-1.35 (1.63)	-1.45 (1.62)	-1.10 (1.90)
Regulatory Quality	1.25 (1.56)	1.07 (1.54)	1.61 (1.69)	0.03 (0.53)	0.04 (0.53)	0.11 (0.53)	-1.69 (2.55)	-1.95 (2.47)	-1.40 (2.52)
Rule of Law	-0.15 (1.67)	0.01 (1.68)	0.34 (1.88)	-2.82*** (0.57)	-2.82*** (0.57)	-2.84*** (0.61)	0.91 (2.11)	1.09 (2.13)	1.30 (2.32)
Commercial bank branches	-0.22* (0.13)	-0.21** (0.10)	-0.45** (0.21)	-0.08** (0.04)	-0.09** (0.04)	-0.16** (0.08)	-0.37** (0.17)	-0.39*** (0.14)	-0.63** (0.26)
1st stage: Banking sector development									
Commercial bank branches in the region	0.82*** (0.20)			0.89*** (0.18)			0.80*** (0.19)		
Distance-discounted commercial bank branches (regional)	0.80*** (0.17)			0.83*** (0.15)			0.78*** (0.16)		
Distance-discounted commercial bank branches (global)	2.84*** (0.81)			2.84*** (0.70)			2.77*** (0.80)		
Observations	1,419	1,399	1,401	2,051	2,051	2,053	1,530	1,517	1,519
R-squared	0.97	0.97	0.97	0.99	0.99	0.98	0.97	0.97	0.96
Kleibergen-Paap rk LM stat.	16.98***	20.65***	12.27***	21.87***	23.15***	15.87***	16.83***	20.24***	11.73***
Cragg-Donald Wald F statistic	17.44	22.95	12.42	25.44	31.18	16.26	17.67	23.17	11.91

Notes: Standard errors clustered at the country level in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Here common controls and constant terms are omitted for brevity. All regressions include both country fixed effects and year fixed effects. The dependent variable at the second stage are different measures of informality: share of self-employment (in percent of total employment; survey-based), MIMIC-based output informality (in percent of GDP), and DGE-based output informality, calibrated to the share of self-employment (percent of total employment). Commercial bank branches are per 100,000 adults. GDP per capita is in constant 2010 U.S. dollars. See sections 3 and 4 for detailed data descriptions and empirical methods. Data are between 2000 and 2018.

Appendix: Calibrating DGE estimates using survey-based self-employment data

This appendix explains the benchmarking of the DGE model of Elgin and Oztunali (2012) to survey-based self-employment data. In Elgin and Oztunali (2012), employment in the informal sector, N_{It} has the following form:

$$N_{It} = \left\{ \frac{\gamma A_{It}}{(1-\tau_t)(1-\alpha)A_{Ft}} \left[\frac{\frac{1}{\beta} - 1 + \delta}{\alpha(1-\tau_t)A_{Ft}} \right]^{\frac{\alpha}{1-\alpha}} \right\}^{\frac{1}{1-\gamma}} \quad Eq(1).$$

After transforming equation (1), A_{It} can be expressed as follows:

$$A_{It} = \frac{N_{It}^{1-\gamma} (1-\tau_t)(1-\alpha)A_{Ft}}{\gamma \left[\frac{\frac{1}{\beta} - 1 + \delta}{\alpha(1-\tau_t)A_{Ft}} \right]^{\frac{\alpha}{1-\alpha}}} \quad Eq(2).$$

Following Loayza and Rigolini (2011) and Fiess et al. (2010), data on self-employment provided by Elgin et al. (2021) can be used to define N_{It} and calculate A_{It} using equation (2). Following the earlier literature, α is assumed to be equal to 0.36 while δ takes the country average of the depreciation rates reported in Penn World Tables 9.1 (PWT). Following Ihrig and Moe (2004), γ is assumed to be 0.425. Capital stock (K_t) and formal employment (N_{Ft}) are obtained from PWT 9.1 and updated using the *World Development Indicators*. Assuming a balanced budget for the government, τ_t is obtained as government spending in percent of GDP reported in PWT 9.1.

Rewriting the production function of the informal sector (Y_{It}) using equation (2), we find Y_{It} to be a function of A_{Ft} and N_{It} :

$$Y_{It} = N_{It} * \frac{(1-\tau_t)(1-\alpha)}{\gamma \left[\frac{\frac{1}{\beta} - 1 + \delta}{\alpha(1-\tau_t)} \right]^{\frac{\alpha}{1-\alpha}}} * (A_{Ft})^{\frac{1}{1-\alpha}}$$

which gives $\frac{\partial Y_{It}}{\partial A_{Ft}} > 0$. Since $\frac{\partial Y_{Ft}}{\partial A_{Ft}} > 0$, it is possible that the DGE estimates will move procyclically in the presence of large shocks in formal productivity. However, when other types of shocks occur at the same time, Y_{It} may not move procyclically. For instance, if N_{It}

and N_{Ft} experienced simultaneous shocks in different directions , Y_{It} might move countercyclically.

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