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Digital payments, informality and economic growth

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Abstract

We examine the relationship between digital payment innovation, economic growth and informal activities in 101 economies over 2014–19. Following the economic growth literature, panel regressions relate growth rates of GDP per capita, total factor productivity (TFP) and the share of informal sector employment to lagged levels of these variables, the extent of digital payments use and various controls for endogeneity. We find that a one-percentage point increase in digital payments use is associated with increases in the growth of GDP per capita of 0.10 percentage points over a two-year period, and a decline in the share of informal sector employment of 0.06 percentage points over a two-year period. Insofar as the reported share of the population making digital payments ranges nearly from 0 to 100 percent, this is substantial. Digital payments do not appear to be significantly associated with rises in TFP, once controlling for general measures of digitalisation and government effectiveness, but they are linked to greater financial inclusion and credit access. Our results reinforce the case for government policies to encourage digital payments and, as complementary factors, access to the financial sector and information technology.

Keywords: digital innovation, informal economy, productivity, economic growth.

JEL classification: G21, G23, O32.

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Introduction

One of the most critical developments in global finance in recent years has been the adoption of cutting-edge information technology. Among the many applications of financial technology (fintech) has been the development of digital payment methods. Digital payments, also known as electronic payments, refer to any transfer of value using digital devices or channels, and include such means as bank transfers, mobile money, quick response (QR) codes and payment instruments such as credit or debit cards and help to avoid the use of cash. Digital payments also encompass the use of cryptocurrencies, such as bitcoin or so-called stablecoins,[2] and central bank digital currencies (CBDCs).[3]

Although the adoption of digital payments has become quite widespread in advanced economies (AEs), it is advancing as rapidly in emerging market and developing economies (EMDEs). Between 2014 and 2021, the share of adults in developing countries using digital payments rose from 35% to 57%, according to World Bank Findex data. In China, private digital payments platforms such as Alipay and WeChat Pay, based on digital wallets and QR codes, have made substantial inroads into retail cash payments (Klein, 2020). Similarly, the mobile money system M-Pesa, introduced in 2007, has revolutionised retail payments in Kenya, as has the Unified Payments Interface (UPI) in India (Prasad, 2021; Aurazo and Gasmi, 2024). Brazil's government has developed a retail fast payments system, Pix, that similarly has become widely adopted (Alfonso et al, 2020; Duarte et al, 2022). Finally, it is notable that all of the CBDCs that have become operational to date have been issued by EMDEs: the Bahamas, Eastern Caribbean, Jamaica and Nigeria (Alfonso et al, 2022).

Given the proliferation of digital payments in EMDEs, it is natural to ask what role these payments might play in the process of economic growth and development. This question is of more than purely academic interest. In particular, public policy can importantly affect the pace of adoption of digital payments, both through regulation or encouragement of private payments providers and through direct provision of payments services such as retail fast payment systems or CBDCs.[4]

Supporters of digital payments, including private providers, argue that their adoption can accelerate economic growth through a number of channels. First, digital payments are cheaper, faster and more efficient than cash or cheques, reducing the deadweight costs of payments to merchants and the economy more generally. As a related matter, they facilitate online purchases, enabling the development of e-commerce (IDB Lab and World Economic Forum, 2022). Second, for large subgroups of the population in many countries for whom banknotes and coins are their only financial assets, greater adoption of digital payments could be the gateway to the financial system, encouraging ownership of financial accounts. This could create greater opportunities for saving and credit (CPMI and World Bank, 2020). Third,

[2] Although popularly described as payments instruments, in practice, cryptocurrencies like Bitcoin are not used widely for payments. Stablecoins are a type of cryptocurrencies that aim to maintain a stable value relative to a specified asset, or a pool or basket of assets. See Arner et al (2020).

[3] CBDCs are a digital payment instrument, denominated in the national unit of account, that is a direct liability of the central bank. See Auer et al (2023).

[4] The aim of this study is to estimate the temporary contribution of digital payments to growth and not to provide a thorough explanation of the factors behind growth or informality. Digital payments use may eventually be close to universal, and thus this is unlikely to be a long-term source of growth.

widespread adoption of digital payments may create a "data trail" and encourage informal sector enterprises to move into the formal sector. This could lead to firms with greater scale, credit records (and access to credit) and investment (A.T. Kearney and Visa, 2018).[5] Fourth, and relatedly, the use of digital payments for payroll may help to formalise informally employed workers, again promoting financial inclusion for households and greater productivity for firms as they move into the formal sector. All these could create a virtuous circle where informal employers and employees enter the formal sector, encouraged by the convenience of digital payments and then by the benefit of using financial services. In principle, this could support growth and productivity by these firms.[6] Finally, digital payments could improve the administration of government finances, both by enabling better collection of revenues (including by reducing informality) and by facilitating transfer payments; stronger fiscal positions help to support public investment and increase debt sustainability, both of which support economic growth.

Although these advantages of digital payments are plausible, there is relatively little empirical analysis to support these claims and gauge the strength of the association between digital payments and economic growth. Much of the literature comes from non-peer reviewed, private sector sources. Deloitte (2019) develops econometric estimates of the impact of real-time payments on the use of existing payment instruments, and assesses how much this can reduce payment costs, enlarge payment volumes, increase the "float" available for working capital, and boost tax revenues. But it does not assess the impact on overall economic growth. Similarly, the Centre for Economics and Business Research (2022) measures the effect of real-time payments on GDP in a range of countries, again based on "bottom-up" estimates of the reduction in payments costs, increase in the float available to companies as working capital, and reduction in informality. Writing for Moody's, Zandi and Singh (2021) present panel regressions for 70 countries over 2015-2019 relating real consumption per capita to real disposable income, real interest rates and the use of payment (eg credit or debit) cards. They find a significant effect of card use on consumption, but its ultimate effect on productivity and output growth is not measured.[7]

To address the issues unresolved by the few previous studies, this paper examines the extent to which digital payment adoption has been associated with higher economic growth in up to 101 economies over 2014–19. Following the growth literature, panel regressions relate growth rates of GDP per capita, total factor productivity (TFP) and the share of informal sector employment to lagged levels of these variables, the extent of digital payments use and various controls for endogeneity. We are aware of only one prior analysis that empirically tests whether overall economic growth is linked to digital payments: Khera et al (2021), which uses

5 Levy (2018) provides a detailed description of the relationship between informality and low productivity in Mexico.

6 Alvarez and Ruane (2019) show how informal firms and employees with similar characteristics are smaller and less productive than formal ones. They also show that, for the case of Mexico, removing barriers to formalisation could be an important source of productivity gains.

7 There is also a growing literature with micro data for individual countries. For instance, Jack and Suri (2014) find that mobile money in Kenya helped users' resilience to shocks. Riley and Heath (2023) find in an experiment in Tanzania that women who are randomly assigned to repay loans with mobile money also gain increased control of their finances and experience less pressure to share money with others. For a randomised experiment in India, Mukherjee (2023) finds that firms that are offered more guidance on how to use digital finance technology significantly improve business management.

a cross-country regression approach to find that the growth of GDP per capita is significantly associated with a measure of digital financial inclusion. Our study goes beyond Khera et al (2021) by examining the impact of digital payments on productivity growth and the share of the informal sector as well as GDP growth. Moreover, we examine some of the channels through which digital payments enhance growth, and control for the tight correlation between digital payments and broader measures of information-technology proliferation.

We find that a one percentage-point rise in digital payments use is associated with increases in growth rates of GDP per capita of 0.10 percentage points (or 0.05 percentage points annually) over a two-year period. Digital payments are also associated with lower estimated informal employment, with a reduction by 0.06 percentage points (or 0.03 percentage points annually) over a two-year period. Insofar as the reported share of the population making digital payments ranges nearly from 0 to 100 percent, this indicates a substantial effect on growth and informality. Finally, digital payments are associated with greater access to credit and other financial services.

We also find a statistically significant association between digital payments and the growth of TFP. However, this association appears to reflect that digital payments are highly correlated with measures of internet penetration and government effectiveness, which themselves boost productivity growth. Nevertheless, TFP is difficult to estimate, and it would be premature to write off a positive effect of digital payments. Moreover, given the dependence of digital payments on the broader environment for information technology, distinguishing the separate effects of digital payments and internet penetration is difficult, particularly at the country level.

All told, our study underscores the link between digital payments and economic development. This argues for government policies to encourage the establishment of digital payment platforms in their jurisdictions. In our study, as indicated above, we also find strong correlations between digital payments, financial inclusion and internet penetration. This is unsurprising, as these factors all complement each other. Accordingly, government policies to promote growth and reduce informality should simultaneously address all three of these areas.

The rest of the paper is structured as follows. Section 1 describes the data used in the paper and the methodology of our econometric analysis. Section 2 provides an overview of the basic correlations between per capita income, growth, informality and digital payments in our data. Section 3 describes the econometric results, while Section 4 concludes.

1. Data and methodology

1.1 Data

The data source for our key explanatory variable, the extent of digital payments use, is the World Bank's Global Findex Database (Demirgüç-Kunt et al, 2022). This database uses the results of a comprehensive survey of financial development, inclusion and digital payments participation based on a survey of more than 128,000 adults in 123 economies around the world. As indicated by the summary table below, the Findex database covers the fraction of the population in each economy that have made or received digital payments, used a mobile service account, borrowed from financial institutions or had an account at a financial institution. The survey years are 2014, 2017 and 2021. Yet the 2021 survey coincides with the Covid-19 pandemic, which resulted in dramatic changes in payment behaviour and economic outcomes that may be hard to disentangle. As such, we limit our econometric analysis to the period 2014–19, using the 2014 and 2017 survey rounds.

Our analysis focuses on the impact of digital payments adoption on two broad measures of performance: economic growth and informality. As indicated in Table 1, we measure economic growth using two measures, both sourced from the Penn World Tables: GDP per capita and total factor productivity (TFP).

Variable description

Table 1

Variable	Definition and description
GDP per capita	Real GDP divided by population, in USD dollars per habitant. Variable in log, from 1950 to 2019. Source: Penn World Table.
Total factor productivity	Units where 1 is equal to US TFP, from 1950 to 2019. Source: Penn World Table
Informal labour	As proportion of employment in total employment (%) from 2010 to 2021. Source: International Labour Organization.
Digital payments	As percentage of population above 15 years for the years 2014, 2017 and 2021. The percentage of respondents who report using mobile money, a debit or credit card, or a mobile phone to make a payment from an account; or who report using the internet to pay bills or to buy something online or in a store in the past year. This includes respondents who report paying bills or sending remittances directly from a financial institution account or through a mobile money account in the past year. Source: Findex 2021.
Borrowing from formal financial institutions	The percentage of respondents who report borrowing any money from a bank or another type of financial institution or using a credit card in the past year for the years 2014, 2017 and 2021. Source: Findex 2021.
Financial institutions accounts	The percentage of respondents who report having an account (by themselves or together with someone else) at a bank or another type of financial institution for the years 2014, 2017 and 2021. Source: Findex 2021.
Fixed broadband subscriptions	Subscriptions per 100 habitants. Fixed wired broadband subscriptions include the total number of subscriptions to the following broadband technologies with download speeds of 256 kbit/s or greater: DSL, cable modem, fibre-to-the-home and other fixed technologies (such as broadband overpower lines and leased lines). Source: World Bank.
Trade openness	Sum of exports and imports as percentage of GDP. Source: IMF.
Inflation rate	Annual inflation rate. Source: IMF.
Population	Total population. Source: World Bank.
Human capital index	Index based on years of schooling and returns to education from 1950 to 2019. Source: Penn World Table.
Average annual hours worked by persons engaged	Measured in hours, from 1950 to 2019. Source: Penn World Table.
Government effectiveness	Government Effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. Estimate gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5. Source: World Bank.

Sources: Feenstra et al (2015); IMF; World Bank.

We measure the size of the informal sector using the share of informal employment in total employment, as estimated by the International Labour Organization (ILO).[8] Summary statistics for these and the other variables in our research are shown in Annex Table A1.1.

1.2 Econometric methodology

As will be illustrated in Section 2 below, a key problem in measuring the effects of digital payment adoption on growth is endogeneity: higher-income economies tend to have more developed financial sectors and smaller informal sectors, with multiple chains of inter-causation reinforcing these trends. To address this problem, we employ a standard growth framework in which the rate of economic growth is related to the prior level of digital adoption.[9] The rationale for this dynamic specification is described in Annex A2. Additionally, estimates of digital adoption for a given year are based on surveys in the prior year, providing further insulation against reverse causality.

Specifically, following on Vedia-Jerez and Chasco (2016), we estimate panel regressions based on the following equation:

$$\Delta y_{i,t:t+2} = \alpha_i + \beta_1 y_{i,t} + \beta_2 Digital_{i,t} + \beta_3 Development\ Controls_{i,t} + \gamma_t + \varepsilon_{i,t}$$

where:

- $\Delta y_{i,t:t+2}$ is the two-year change in the log of real GDP per capita, the log of TFP or the informal labour share, respectively, between the period *t+2* and t, for country i.
- $y_{i,t}$ is the level of the dependent variable.
- $Digital_{i,t}$ is a proxy of the use of digital payments. In this case, we used the percentage of population that made a digital payment in the past year.
- $Development\ Controls_{i,t}$ is a vector of controls that includes variables related to the stage of economic, financial, and technological development.
- α_i are random effects.
- γ_t are time fixed effects.

These equations are estimated for as many as 101 countries, depending on data availability. (The full list is given in Annex A3). Owing to constraints of data availability, observations from only two periods are used: (1) the growth of GDP per capita, TFP or informal labour from 2017 to 2019 is related to the levels of digital payments and control variables in 2017; and (2) the growth of GDP per capita, TFP or informal labour

[8] Other informality measures were considered for the analysis, such as the informal output share, but we decided against using these. For instance, Medina and Schneider (2019), estimate the size of the informal sector relative to formal output through various methods. Yet this is subject to substantial measurement error that makes it particularly difficult to use in a panel setting. Indeed, the definition of informal activities is that they are not recorded in official statistics.

[9] Of course, the growth literature is vast and finds many variables that correlate with growth (see Sala-i-Martin, 1997; Barro and Sala-i-Martin, 2003). Our ambition is not to add further indicators to this cannon. Instead, our estimates are a starting point to assess the specific impact of digital payments on growth and the channels through which this impact occurs.

from 2014 to 2016 is related to the level of digital payments and control variables in 2014. Both random and time fixed effects are included in the estimation.[10]

Finally, as indicated in Table 2 below, digital payments are highly correlated with several key financial and technological indicators: financial account ownership, broadband penetration and borrowing from financial institutions. This poses the likelihood of multicollinearity and difficulties in estimating the equation, a likelihood confirmed by our initial research. Accordingly, in the estimated equations shown below, we include the control variables one at a time rather than inserting them all into the same equation, and we separately analyse how control variables with higher correlations perform with our three main dependent variables in an attempt to disentangle the effects on economic development of payment systems, digitalisation and financial inclusion.

Pairwise correlations

Table 2

	TFP	GDP per capita	Informal labour	Digital payments	Borrow from FI	Fin. accounts	Fixed Broadband	Inflation	Popula-tion	Trade open.	Human capital index	Average hours worked	Gov effect
TFP	1.00												
GDP per capita	0.70	1.00											
Informal labour	-0.38	-0.69	1.00										
Dig. payments	0.47	0.83	-0.59	1.00									
Borrow from FI	0.41	0.65	-0.51	0.81	1.00								
Fin. account	0.42	0.79	-0.58	0.94	0.69	1.00							
Broadband	0.44	0.80	-0.77	0.84	0.72	0.82	1.00						
Inflation	-0.17	-0.32	-0.04	-0.21	-0.24	-0.29	-0.32	1.00					
Population	-0.17	-0.09	0.19	-0.07	-0.07	0.02	-0.07	0.00	1.00				
Trade openness	0.15	0.41	-0.09	0.32	0.20	0.33	0.30	-0.14	-0.19	1.00			
Human capital	0.46	0.74	-0.72	0.76	0.61	0.77	0.69	-0.24	-0.09	0.27	1.00		
Avg. hours	-0.51	-0.48	0.49	-0.59	-0.37	-0.49	-0.50	0.09	0.19	0.19	-0.56	1.00	
Gov effect	0.67	0.87	-0.58	0.81	0.67	0.81	0.72	-0.34	-0.03	0.37	0.75	-0.49	1.00

Sources: Feenstra et al (2015); World Bank; authors' calculations.

2. Simple correlations

Figure 1 presents a snapshot of the data on digital payments used in this study. The left panel shows a wide range of uptake of digital payments across the countries in

[10] Random effect models are well-suited for analysing unbalanced datasets with numerous countries and limited time periods, particularly when there are constraints on the degrees of freedom. Fixed effect models may suffer from biased estimates and reduced statistical power due to limited variation. In addition, random effect models capture country-specific heterogeneity, accounting for within-country and between-country variation. Finally, the theta estimator from baseline regressions supports the use of random effects. See Bell and McCaffrey (2002).

the sample, and uniformly large increases in that uptake between the survey dates of 2014 and 2017.

The right panel of Figure 1 compares digital payments uptake in the 2017 and 2021 surveys. As is evident, the pandemic further boosted the share of the surveyed population engaging in digital payments in some countries. However, as noted above, we will exclude the data from the 2021 survey from the analysis, as the economic disruptions associated with the pandemic would likely interfere with identification of the effect of digital payments on productivity, growth, and informality.

Figure 1. Left panel: level of digital payments in 2014 vs 2017. Right panel: level of digital payments in 2017 vs 2021

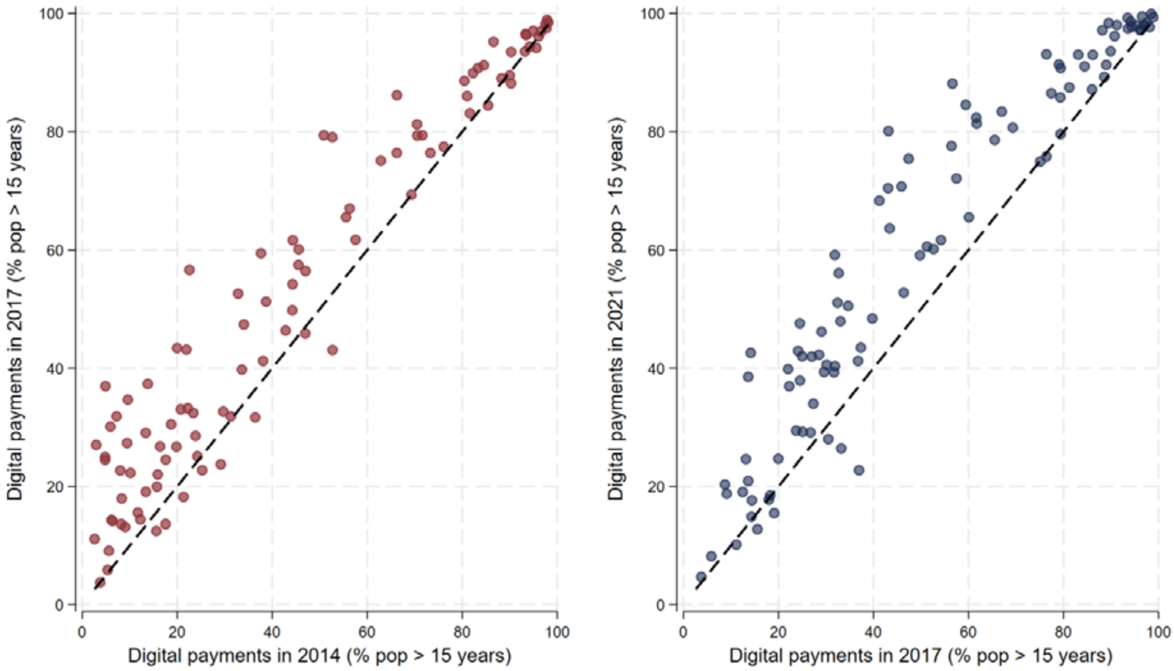
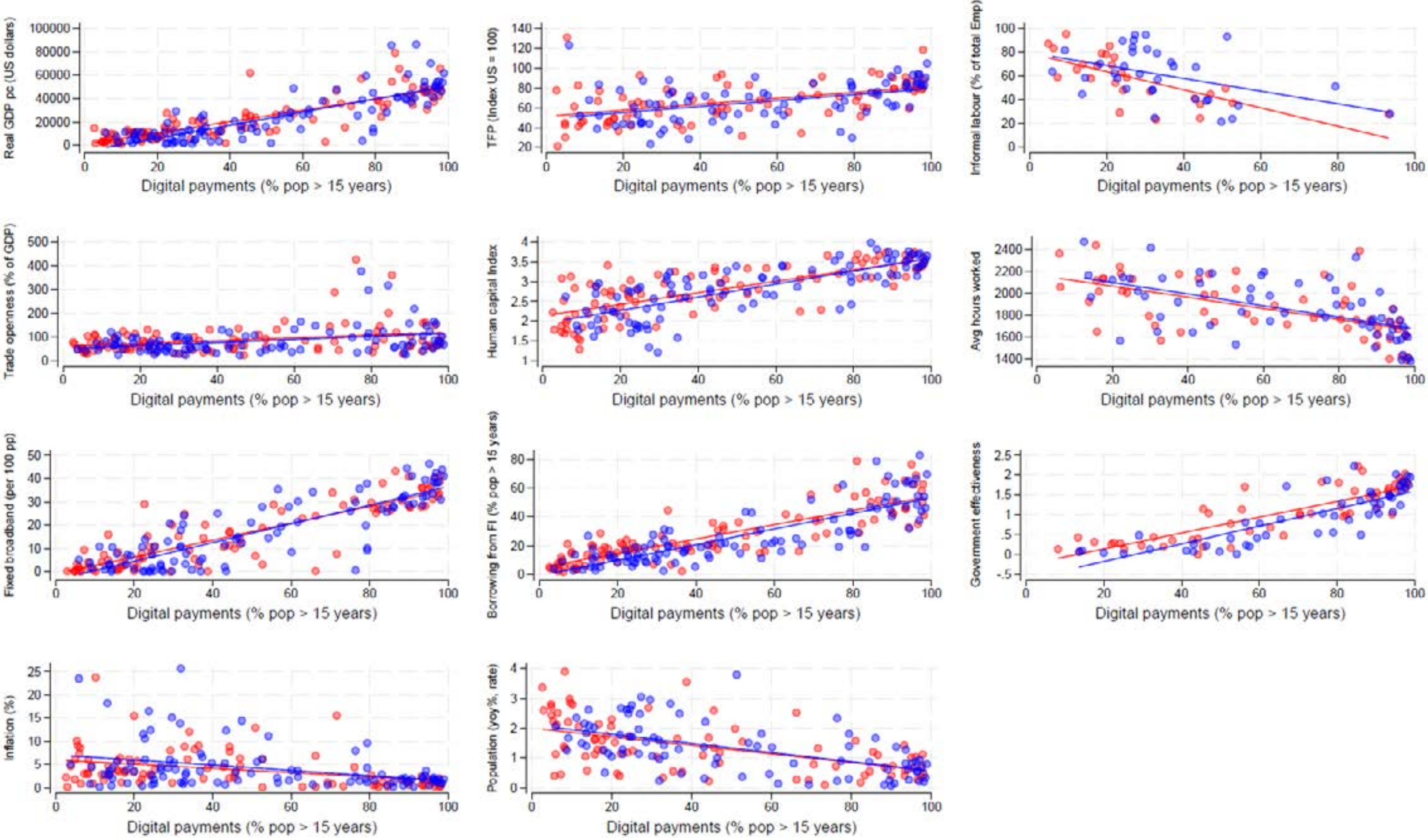


Figure 2 plots the correlations among the level of digital payments adoption, the size of the informal labour force and the level of GDP per capita and TFP. The correlations are quite strong: higher levels of digital payment adoption are associated with lower levels of informality and higher levels of per capita income and TFP. As indicated by the red and blue dots, the relationships held both in 2014 and in 2017, as well as across both periods. There is also considerable correlation between digital payments adoption and our five main control variables: human capital, trade openness, (with a negative sign) average annual hours worked by persons engaged, inflation and population growth. Finally, there is a strong correlation with fixed broadband internet access, borrowing from financial institutions and government effectiveness.[11]

[11] Other work finds an impact of broadband internet on economic growth. See Koutrompis (2009) and Czernich et al (2011). For work on financial inclusion and growth, see Kim et al (2018), Hu et al (2021) and Van et al (2021).

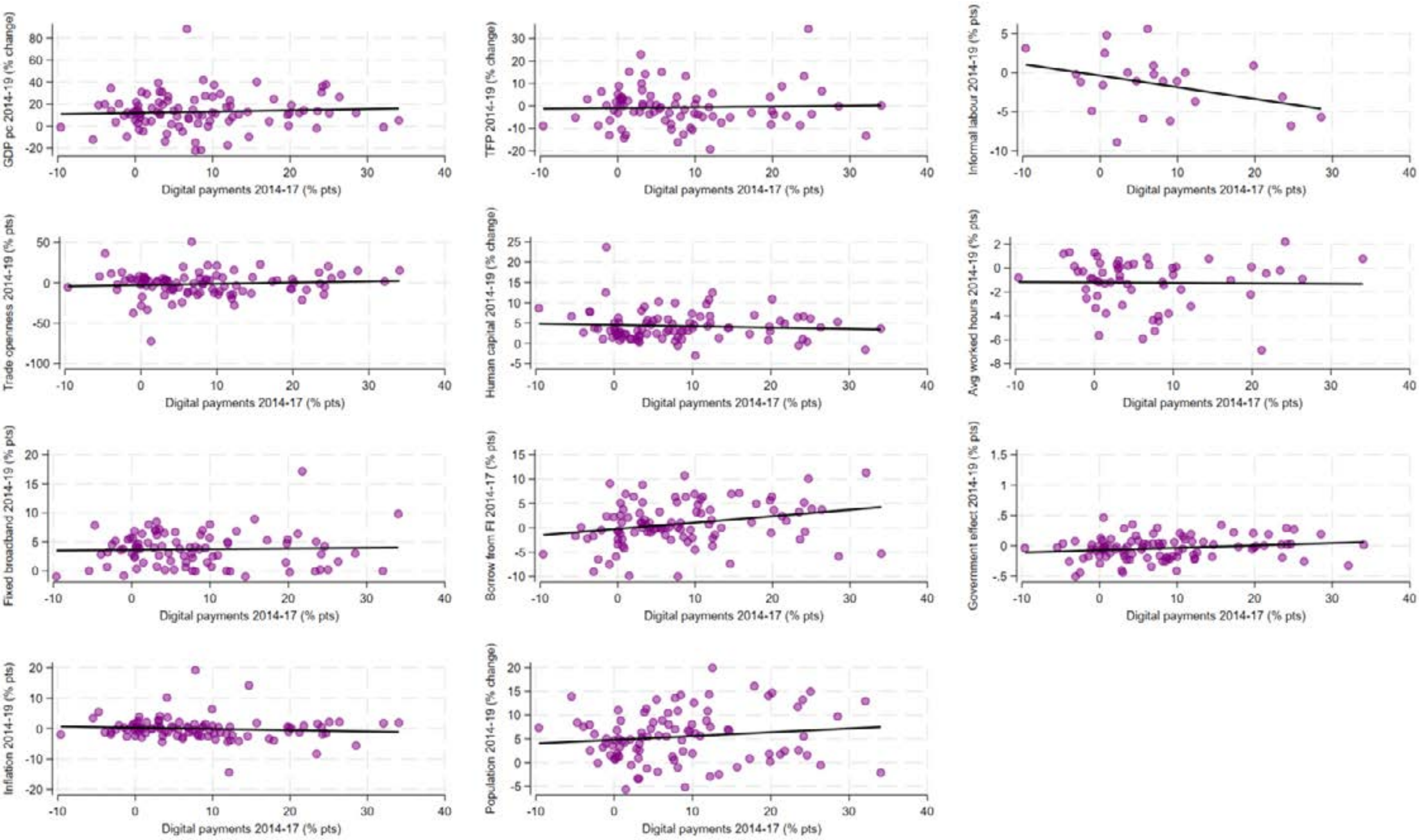
Figure 2. Relationship between use of digital payments with variables of interest. Dots in red denote figures for 2014 and dots in blue for 2017.



As noted above, the correlations in levels may well be spurious. Economic development and higher incomes may be encouraging digital payments rather than vice versa. Alternatively, both economic development and digital payments may be correlated with some third factor, such as greater educational attainment or technological sophistication. These issues are likely somewhat less concerning when looking at correlations among growth rates over relatively short periods than when looking at correlations among levels.

Accordingly, Figure 3 below compares growth rates or *changes* in our variables of interest (GDP per capita, TFP and informality) and in further indicators (trade openness, human capital, average hours worked, inflation, population growth, fixed broadband, borrowing from financial institutions and government effectiveness) with the *change* in digital payments uptake between 2014 and 2017. The charts show only a weak relationship between increases in digital payments and growth rates of TFP and of GDP per capita, perhaps because it takes longer for increases in digital payments to show through to growth. However, there is a stronger (and negative) relationship between digital payments and the share of informal labour. Correlations in changes between digital payments and human capital, hours worked, trade openness, inflation and fixed broadband are quite low. The correlation changes in borrowing from financial institutions and population is a little higher.

Figure 3. Change in digital payments from 2014 to 2017 in x axis and five-year growth rates in y axis. Three-year growth rate for borrowing from FI.



3. Empirical results

3.1 Main panel regressions

Tables 3 through 5 report our basic panel regression estimates for GDP per capita growth, TFP growth and the change in the share of informal labour. As noted in Section 1, the two-year growth rates for GDP per capita, TFP and informal labour (over 2014-2016, and 2017-2019) are related to the lagged levels (2014 and 2017) of the explanatory variables.

Starting with column (1) in Table 3, the level of digital payments is positively, and statistically significantly, associated with the subsequent growth rate of GDP per capita. The estimate indicates that a one percentage point rise in the share of the population making digital payments is linked to a 0.10 percentage point rise in the subsequent growth of GDP per capita over a two-year period. The average effect over a one-year period should be around 0.05 percentage points. Considering that the share of the population making digital payments ranges from zero to nearly 100 percent, as indicated in Figure 1, this is substantial.[12] The coefficient on the lagged level of GDP per capita is negative and statistically significant, consistent with the convergence hypothesis that countries with higher starting points for GDP per capita experience lower subsequent growth.

As noted in Section 1 above, we introduce the control variables one at a time, as indicated in columns (2) through (6). (Owing to their high correlation with digital payments, we do not include broadband penetration, borrowing from financial institutions or government effectiveness as control variables in these equations; those variables are discussed in Section 3.2 below.) In column (7) we include all these variables together. The coefficient on digital payments remains statistically significant and of similar size in all of these equations.

Digital payments are associated with higher GDP per capita

Table 3

	Two-year growth rate of GDP per capita, (%)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Digital payments$_{i,t}$	0.0986***	0.0948**	0.110***	0.119***	0.0906**	0.0959**	0.0817**
	(0.0377)	(0.0375)	(0.0368)	(0.0422)	(0.0368)	(0.0374)	(0.0415)
GDP pc$_{i,t}$	-2.672**	-3.002**	-4.575**	-5.643***	-3.199***	-2.689**	-7.457***
	(1.156)	(1.193)	(1.849)	(1.419)	(1.136)	(1.153)	(2.068)
Trade openness$_{i,t}$		0.0210					0.0126
		(0.0130)					(0.0111)
Human capital$_{i,t}$			6.790				2.712
			(4.698)				(5.798)
Average hours$_{i,t}$				0.00231			-0.000134
				(0.00270)			(0.00338)
Inflation$_{i,t}$					-0.425**		-0.559**
					(0.171)		(0.217)
Population$_{i,t}$						-0.00692	-0.00808**
						(0.00437)	(0.00348)
Random effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	196	196	190	117	195	196	116
Countries	101	101	98	59	101	101	59

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

12 As shown in Annex Table A1, the standard deviation of digital payments is 31 percentage points. Multiplied by the 0.10 coefficient, this implies that an increase in digital payments of one standard deviation might raise GDP growth by 3 percentage points. This may seem unrealistically high, but the standard deviation shown in the table is for the variation in digital payments across countries, not for countries over time; the median increase in digital payments between 2014 and 2017 was 8.1% percentage points, and that between 2017 and 2021 was 9.4% percentage points.

Digital payments are associated with higher total factor productivity

Table 4

	Two-year growth rate of TFP, (%)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Digital payments$_{i,t}$	0.0458***	0.0371**	0.0281	0.0592***	0.0292	0.0389**	0.0414
	(0.0149)	(0.0157)	(0.0217)	(0.0218)	(0.0182)	(0.0152)	(0.0380)
TFP$_{i,t}$	-5.176***	-4.951**	-6.414***	-8.212***	-4.706**	-4.946**	-6.794**
	(1.965)	(1.935)	(2.209)	(2.608)	(1.915)	(1.989)	(2.680)
Trade openness$_{i,t}$		0.0120*					0.00496
		(0.00664)					(0.00653)
Human capital$_{i,t}$			4.462				-7.115
			(3.418)				(6.049)
Average hours$_{i,t}$				-0.000522			-0.000947
				(0.00258)			(0.00285)
Inflation$_{i,t}$					-0.310*		-0.365*
					(0.178)		(0.196)
Population$_{i,t}$						-0.00746**	-0.00718***
						(0.00292)	(0.00278)
Random effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	162	162	162	111	161	162	110
Countries	83	83	83	56	83	83	56

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

Table 4 repeats the exercise for the growth of TFP. Column (1) indicates that, similar to Table 3, greater digital payments penetration is associated with faster productivity growth, whereas a higher starting point for TFP lowers subsequent growth (the convergence effect). A one percentage point rise in digital payments is associated with a 0.05 percentage point rise in subsequent two-year growth of productivity, lower than in the case of GDP per capita. The larger effect on GDP than on TFP may reflect that digital payments fuel the expansion of demand, and perhaps expanded use of factors of production (labour and capital), as well as productivity. The coefficient remains statistically significant in half of the equations with control variables.

Table 5 addresses the determination of the share of the labour force in the informal sector. As expected, a higher degree of digital payments penetration is associated with a decline in the informal labour share. A one-percentage point rise in digital payments goes with a fall in the informal labour share by 0.06–0.08 percentage points across different specifications. The coefficient is statistically significant in the presence of all control variables. As discussed above, digital payments could reflect the incentive for informal firms to enter the formal sector once their transactions start leaving a "data trail". This could also result from the greater use of digital payments (rather than cash) for payroll, which would tend to support a migration of workers to the formal sector. The reduction in informality could not only promote greater productivity, but also improvements in social welfare, since these workers become part of the social security system.

Digital payments are associated with lower informal labour

Table 5

	Two-year growth rate of informal labour, (%)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Digital payments$_{i,t}$	-0.0635*	-0.0716*	-0.0736**	-0.0781*	-0.0628*	-0.0722*	-0.0968*
	(0.0341)	(0.0402)	(0.0370)	(0.0426)	(0.0347)	(0.0379)	(0.0544)
Informal labour$_{i,t}$	-0.0632**	-0.0782***	-0.101***	-0.111***	-0.0620**	-0.0793***	-0.118**
	(0.0256)	(0.0289)	(0.0300)	(0.0414)	(0.0257)	(0.0282)	(0.0515)
Trade openness$_{i,t}$		-0.00830					0.0186
		(0.0192)					(0.0186)
Human capital$_{i,t}$			-3.117**				9.903*
			(1.492)				(5.194)
Average hours$_{i,t}$				0.00128			0.00117
				(0.00215)			(0.00196)
Inflation$_{i,t}$					0.0477		-0.0304
					(0.0524)		(0.0872)
Population$_{i,t}$						0.00194	-0.000846
						(0.00300)	(0.00278)
Random effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	50	50	48	27	50	50	27
Countries	29	29	28	15	29	29	15

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

3.2 Addressing spurious correlation with digital, financial and institutional variables

In this section, we describe estimations that include as control variables internet penetration, borrowing from financial institutions and government effectiveness. These are variables that are both highly correlated with digital payments and likely to influence economic growth in their own right. Accordingly, they could be sources of spurious correlation between digital payments and growth.

GDP per capita growth

The first column of Table 6 simply replicates the regression of GDP per capita growth on lagged digital payments and GDP per capita presented in Table 3. As before, the coefficient on lagged digital payments is highly significant. The second column adds the measure of broadband internet penetration. Its coefficient is not significantly different from zero, and the coefficient on digital payments drops into insignificance as well, suggesting that multicollinearity has diminished the precision of the estimates. Finally, the third column adds an interaction term between digital payments and broadband, as it may be the case that the two variables interact with each other in influencing GDP growth. Indeed, with addition of this interaction term, both digital payments and the broadband variable are shown to significantly boost GDP growth, while the coefficient on the interaction term is negative. This means that increases in digital payments have a greater impact on GDP growth when broadband is low than when it is high. We interpret this to suggest that digital payments are most likely to affect growth in less technologically developed economies, most likely because payments options are more limited in such an environment and thus adoption of digital payments is more transformative.

GDP per capita estimations with financial, digital and institutional controls

Table 6

	Two-year growth rate of real GDP per capita, (%)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Digital payments$_{i,t}$	0.0986***	0.0402	0.144**	0.102***	0.199***	0.0315	0.0643*
	(0.0377)	(0.0389)	(0.0610)	(0.0389)	(0.0551)	(0.0351)	(0.0388)
GDP pc$_{i,t}$	-2.672**	-2.240	-3.706**	-2.624**	-3.107**	-4.945***	-5.714***
	(1.156)	(1.404)	(1.596)	(1.270)	(1.278)	(1.692)	(1.685)
Broadband$_{i,t}$		0.112	0.634***				
		(0.112)	(0.225)				
Digital payments$_{i,t}$ * Broadband$_{i,t}$			-0.00682***				
			(0.00242)				
Borrowing from FI$_{i,t}$				-0.00920	0.358**		
				(0.0527)	(0.161)		
Digital payments$_{i,t}$ * Borrowing from FI$_{i,t}$					-0.00475***		
					(0.00173)		
Government effect$_{i,t}$						4.916***	10.65***
						(1.870)	(2.879)
Digital payments$_{i,t}$ * Government effect$_{i,t}$							-0.0911***
							(0.0318)
Random effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	196	185	185	196	196	194	194
Countries	101	98	98	101	101	100	100

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

Columns (4) and (5) include another control variable that is highly correlated with digital payments, namely borrowing from financial institutions. Despite the potential for multicollinearity, the coefficient on digital payments is significantly different from zero in both specifications. As with broadband, however, the coefficient on the interaction term is negative and significantly different from zero, suggesting that the support for growth provided by digital payments is greater in economies with less developed financial systems.

Finally, columns (6) and (7) include a measure of government effectiveness. As in the case of broadband, digital payments have a statistically significant association with GDP growth (albeit only at the 10% level of significance) when the interaction between government effectiveness and digital payments is controlled.

Summing up, we continue to find digital payments to exert a significant effect on growth of GDP per capita. The effect appears to be greatest when levels of development in technology, finance and government administration are relatively low.

Total factor productivity (TFP)

Table 7 repeats the exercises shown in Table 6, but with the growth of TFP, rather than GDP per capita, as the dependent variable. As indicated in column (4), the estimated effect of digital payments on TFP growth appears robust to the addition of borrowing from financial institutions as a control variable, although the standard error widens. However, both broadband and government effectiveness knock out the size and significance of the coefficient on digital payments. This suggests that the estimated effect of digital payments on TFP growth, when estimated without control variables, may reflect their spurious correlation with variables that more genuinely impact TFP growth, such as broadband and government effectiveness. However, it may also be that because TFP is difficult to measure, and because the effects of digital payments on productivity may be fairly small, our methodology simply fails to identify a positive effect, even if it truly exists.

TFP estimations with financial, digital and institutional controls

Table 7

	Two-year growth rate of total factor productivity, (%)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Digital payments$_{i,t}$	0.0458***	-0.0173	-0.000705	0.0429*	0.0431	-0.0171	-0.0141
	(0.0149)	(0.0254)	(0.0321)	(0.0247)	(0.0264)	(0.0255)	(0.0259)
TFP$_{i,t}$	-5.176***	-5.211***	-5.147**	-5.276**	-5.277**	-7.118***	-7.111***
	(1.965)	(1.960)	(2.024)	(2.203)	(2.208)	(2.171)	(2.215)
Broadband$_{i,t}$		0.162***	0.235**				
		(0.0619)	(0.114)				
Digital payments$_{i,t}$ * Broadband$_{i,t}$			-0.00111				
			(0.00139)				
Borrowing from FI$_{i,t}$				0.00653	0.00713		
				(0.0427)	(0.110)		
Digital payments$_{i,t}$ * Borrowing from FI$_{i,t}$					-7.54e-06		
					(0.00111)		
Government effect$_{i,t}$						2.868***	3.499**
						(1.051)	(1.669)
Digital payments$_{i,t}$ * Government effect$_{i,t}$							-0.0101
							(0.0201)
Random effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	162	154	154	162	162	160	160
Countries	83	80	80	83	83	82	82

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

Informality

Finally, Table 8 repeats the exercise for the share of labour in the informal sector. The results are broadly similar to those for GDP growth. In column (3), we find that both digital payment use and broadband are associated with lower levels of labour informality, but with a positive interaction term. In column (5), only digital payments are significant, while borrowing from financial institutions and the interaction term are not. In column (7), we find that digital payments are significant, as is the interaction with government effectiveness. Overall, thus, higher levels of digital payments are tied to less labour informality, and this association is strongest for low levels of internet penetration and government effectiveness.

Informality estimations with financial, digital and institutional controls							Table 8
	Two-year growth rate of informal labour, (%)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Digital payments$_{i,t}$	-0.0635*	-0.0566	-0.131***	-0.0708	-0.114*	-0.0720*	-0.0849**
	(0.0341)	(0.0402)	(0.0501)	(0.0482)	(0.0666)	(0.0369)	(0.0376)
Informal labour$_{i,t}$	-0.0632**	-0.114***	-0.134***	-0.0624**	-0.0704**	-0.0560**	-0.0661**
	(0.0256)	(0.0389)	(0.0337)	(0.0259)	(0.0279)	(0.0233)	(0.0260)
Broadband$_{i,t}$		-0.136	-0.382***				
		(0.0931)	(0.142)				
Digital payments$_{i,t}$ *			0.00464**				
Broadband$_{i,t}$			(0.00196)				
Borrowing from FI$_{i,t}$				0.0151	-0.0718		
				(0.0549)	(0.0663)		
Digital payments$_{i,t}$ *					0.00147		
Borrowing from FI$_{i,t}$					(0.000939)		
Government effect$_{i,t}$						0.792	-1.006
						(0.980)	(1.498)
Digital payments$_{i,t}$ *							0.0343*
Government effect$_{i,t}$							(0.0195)
Random effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	50	48	48	50	50	50	50
Countries	29	27	27	29	29	29	29

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

3.3 Controlling for endogeneity using instrumental variables

Khera et al. (2021) attempt to control for the endogeneity of digital payments by instrumenting for these payments with two variables: (1) the extent of internet penetration and (2) the share of mobile money agents in the population. These are found to be significant determinants of the extent of digital payments in first-stage regressions, and the instrumented value of digital payments are estimated to be significant determinants of GDP per capita growth in the second-stage regressions.

However, as indicated by the discussion above, internet penetration is unlikely to be a good instrument. While it is certainly correlated with digital payments, it is also likely to be correlated with the error term – that is, it is either likely to influence economic growth in its own right, or it is correlated with variables that influence growth, such as the digitalisation of the economy more broadly. The number of mobile money agents may be subject to similar concerns, but to a lesser extent. It is unlikely, for example, that the number of mobile money agents would directly influence subsequent economic growth.

To explore this issue further, Tables 9-12 re-estimate the relationship between digital payments and growth using instrumental variables (IV). Table 9 presents the first stage regression of digital payments on money market agents, broadband internet penetration and both, respectively. (Sample sizes differ based on data availability). Both instruments are significantly associated with digital payments. However, the R^2 associated with the use of broadband penetration is far higher than that of mobile money agents.

First stage: suggested instruments for digital payments

Table 9

	Digital payments$_{i,t}$, (% of pop > 15 years)		
	(1)	(2)	(3)
$MMA_{i,t}$	0.0179**		0.0328***
	(0.00686)		(0.00828)
Broadband penetration$_{i,t}$		1.829***	1.662***
		(0.0607)	(0.153)
R-squared	0.039	0.703	0.485
Observations	113	281	101

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

The remaining tables present the second-stage regressions for the IV procedure. Table 10 shows that digital payments remain a significant determinant of GDP growth, whether instrumented by money market agents alone (column (3)) or by both money market agents and broadband penetration (column (2)). (The OLS equation is shown in column (1), but re-estimated to use nearly the same observations as the equation in column (3)). Table 11 shows that with the IV procedure, digital payments are no longer estimated to be a significant determinant of TFP growth. This is consistent with the findings using control variables shown in Section 3.2 above. Finally, Table 12 shows the results for the informal share of the labour force. Although the coefficients on digital payments in the two IV estimations are not significantly different from zero, their magnitude is about as large as in the OLS equation, suggesting that the widening of the coefficients' standard errors results from imprecision in the second stage regression.

All told, the IV estimates, including those based on using as instruments mobile money agents alone, generally support the findings of the previous sub-sections: digital payments are associated with higher growth of per capita GDP and reduced informality, but they do not appear to influence TFP growth.

Instrumenting baseline estimations: GDP per capita

Table 10

	Two-year growth rate of GDP pc, (%)		
	(1)	(2)	(3)
Digital payments$_{i,t}$	0.0568		
	(0.0490)		
GDP pc$_{i,t}$	-1.923	-2.850**	-1.478*
	(1.237)	(1.123)	(0.826)
Digital payments$_{i,t}$		0.150*	
(MMA $_{i,t}$ and Broadband $_{i,t}$)		(0.0790)	
Digital payments$_{i,t}$			0.321*
(MMA $_{i,t}$)			(0.166)
Random effects	Yes	Yes	Yes
Time effects	Yes	Yes	Yes
Observations	109	106	114
Countries	57	55	57

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

Instrumenting baseline estimations: total factor productivity

Table 11

	Two-year growth rate of TFP, (%)		
	(1)	(2)	(3)
Digital payments$_{i,t}$	-0.00904		
	(0.0215)		
TFP$_{i,t}$	-4.284**	-4.022**	-4.389***
	(1.808)	(1.628)	(1.560)
Digital payments$_{i,t}$		0.0198	
(MMA $_{i,t}$ and Broadband $_{i,t}$)		(0.0358)	
Digital payments$_{i,t}$			-0.0969
(MMA $_{i,t}$)			(0.135)
Random effects	Yes	Yes	Yes
Time effects	Yes	Yes	Yes
Observations	82	81	86
Countries	43	41	43

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

Instrumenting baseline estimations: informality

Table 12

	Two-year growth rate of informal labour, (%)		
	(1)	(2)	(3)
Digital payments$_{i,t}$	-0.103**		
	(0.0507)		
Informal labour$_{i,t}$	-0.105***	-0.120**	-0.0618*
	(0.0358)	(0.0480)	(0.0335)
Digital payments$_{i,t}$		-0.163	
(MMA $_{i,t}$ and Broadband $_{i,t}$)		(0.103)	
Digital payments$_{i,t}$			-0.0781
(MMA $_{i,t}$)			(0.222)
Random effects	Yes	Yes	Yes
Time effects	Yes	Yes	Yes
Observations	40	40	42
Countries	24	23	25

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

3.4 Association with other financial services

As noted in the introduction, among the ways in which digital payments are believed to support economic growth and development is by encouraging financial inclusion and improving access to credit. More widespread use of digital payments may encourage households to open a bank account. Greater engagement with the formal financial sector may also facilitate borrowing by previously credit-constrained actors. In order to better evaluate this hypothesis, we now examine how digital payments affects measures of financial maturity. These are: the growth in the share of the adult population with a financial institution account and the share of the population that borrowed from financial institutions. These regressions are shown in Tables 13 and 14. Given that the Findex database shows figures for 2014, 2017 and 2021, we run the panel regressions with the three-year growth rate from 2014 to 2017 and the four-year growth rate from 2017 to 2021.[13]

Table 13 shows the impact of digital payments on the growth rate of financial accounts, while Table 14 shows the impact on the growth rate of individuals that borrow from formal financial institutions. Both sets of results indicate that higher levels of digital payments are associated with greater financial inclusion: a 1 percentage point increase in the share of the population using digital payments leads to a rise of 0.07 percentage point in the rise of the population share with financial accounts and 0.05 percentage point in the rise of the population share borrowing from formal financial institutions.

[1313] Unlike in the regressions described above, we use 2021 data here for the dependent variables. However, half of the four-year period of growth in the dependent variable occurs before the 2020 pandemic; moreover, financial accounts and borrowing may have been less impacted by the pandemic than TFP, GDP per capita and informality.

Digital payments are associated with higher financial institution accounts

Table 13

	Growth rate of financial institution accounts (% of population)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Digital payments$_{i,t}$	0.0670*	0.0669*	0.0905**	-0.0402	0.0795**	0.0733*	-0.0578
	(0.0379)	(0.0374)	(0.0380)	(0.0425)	(0.0388)	(0.0382)	(0.0410)
Financial Accounts$_{i,t}$	-0.218***	-0.224***	-0.279***	-0.115*	-0.233***	-0.235***	-0.137***
	(0.0486)	(0.0491)	(0.0495)	(0.0638)	(0.0524)	(0.0482)	(0.0524)
Trade openness$_{i,t}$		0.00615					0.00783
		(0.00527)					(0.00676)
Human capital$_{i,t}$			3.545*				12.49***
			(2.127)				(4.664)
Average hours$_{i,t}$				-0.00264			-0.00235
				(0.00188)			(0.00206)
Inflation$_{i,t}$					0.0611		0.546***
					(0.167)		(0.114)
Population$_{i,t}$						2.14e-05	0.00412
						(0.00359)	(0.00337)
Random effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	199	197	185	116	196	191	115
Countries	103	102	96	59	102	99	59

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

In additional regressions (not shown), we find that the size and significance of the estimated effect of digital payments on these measures of financial engagement decline in the presence of those control variables that are most highly correlated with digital payments, especially broadband internet penetration. However, considering that digital payments and the penetration of information technology are so interlinked, this is not surprising.

Digital payments are associated with higher borrowing from financial institutions — Table 14

	Growth rate of borrowing from financial institutions (% of population)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Digital payments$_{i,t}$	0.0473**	0.0474**	0.0514**	0.0460*	0.0475**	0.0549***	0.0206
	(0.0185)	(0.0202)	(0.0218)	(0.0270)	(0.0196)	(0.0205)	(0.0317)
Borrowing from F.I.$_{i,t}$	-0.0809***	-0.0849***	-0.0949***	-0.0822**	-0.0871***	-0.0923***	-0.0672*
	(0.0296)	(0.0300)	(0.0339)	(0.0392)	(0.0304)	(0.0318)	(0.0367)
Trade openness$_{i,t}$		0.00434					0.0175***
		(0.00547)					(0.00517)
Human capital$_{i,t}$			0.586				1.979
			(1.172)				(2.982)
Average hours$_{i,t}$				-0.000448			-0.00309
				(0.00232)			(0.00242)
Inflation$_{i,t}$					-0.0696		-0.0403
					(0.0876)		(0.169)
Population$_{i,t}$						0.00401*	0.0101***
						(0.00225)	(0.00282)
Random effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	200	198	186	117	197	192	116
Countries	103	102	96	59	102	99	59

Standard errors clustered by country; ***/**/* indicates statistical significance at the 1/5/10% level.

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

4. Conclusion

Digital payments are advancing in countries around the world, often substituting for cash transactions.

In this paper, we have shown that this could be associated with greater output and economic development. Specifically, we find that a one percentage-point increase in digital payments usage is associated with an increase in two-year growth of per capita GDP of 0.10 percentage points. Digital payments are also associated with lower estimated informal employment, by 0.06 percentage points. This may reflect that they create a data trail of transactions that encourages firms to formalise activities that were previously unrecorded. We do not find a significant association of digital payments and total factor productivity (TFP) growth, once measures of internet penetration and government effectiveness are controlled for. However, this may reflect difficulties in measuring TFP, as well as difficulties in disentangling the effects of such tightly intertwined factors. Finally, digital payments appear to boost access to accounts at financial institutions and credit. This likely is one of the ways in which digital payments supports economic growth and development.

There are necessarily caveats to these results. Countries with greater use of digital payments may be more developed and have higher productivity for other reasons. While we can control for the level of development and a number of factors, we cannot rule out all forms of reverse causality. Further work is needed, ideally with granular data for individual countries, to rule out spurious correlation and to assess whether this is a causal effect. Our contribution is to show cross-country evidence on these relationships, which can be assessed in more depth.

In this light, there are multiple avenues for future research. For instance, research could look into additional instrumental variables for the growth of digital payments, such as (exogenous) shocks or policy interventions that spur the adoption of digital payment methods. The Covid-19 pandemic could be a particularly useful test case, as it was unexpected and resulted in a major increase in adoption. There may be additional instruments in specific jurisdictions that could allow for better causal identification. It would be particularly relevant to look more deeply into the impact of retail fast payment systems, which could in principle speed up digitalisation and productivity. Finally, there are important questions about the impact of digitalisation in the economy more generally, including whether it may form a remedy for countries to escape from the middle-income trap.

Despite these caveats, our results support the desirability of government policies to encourage the use of digital payments. In our study, as noted above, we also find strong correlations among digital payments, access to financial accounts and internet penetration. Government policies to promote growth and reduce informality should simultaneously address all three of these complementary areas. As central banks embark on retail fast payment systems, CBDCs and other public infrastructures supporting such use, it will be important to assess their effects on macroeconomic outcomes.

References

Alfonso, V, S Kamin, and F Zampolli (2022), "Central bank digital currencies (CBDCs) in Latin America and the Caribbean", *BIS Working Papers*, No 989, January.

Alfonso, V, A Tombini and F Zampolli (2020), "Retail payments in Latin America and the Caribbean: present and future", *BIS Quarterly Review*, December.

Arner, D, R Auer and J Frost (2020), "Stablecoins: risks, potential and regulation", *Bank of Spain Financial Stability Review*, November.

A.T. Kearney and Visa (2018), "Digital payments and the global informal economy".

Auer, R, G Cornelli and J Frost (2023), "Rise of the central bank digital currencies", *International Journal of Central Banking*, vol 19, no 4, pp 185–214.

Aurazo, J and F Gasmi (2024), "Digital payment systems in emerging economies: Lessons from Kenya, India, Brazil, and Peru", mimeo.

Barro, R and X Sala-i-Martin (2003), Economic Growth, 2nd Edition, Cambridge: MIT Press Books, *The MIT Press*, edition 2, volume 1.

Bell, R M and D F McCaffrey (2002), "Bias reduction in standard error for linear regression with multi-stage samples", *Survey Methodology*, Vol 28, no 2, pp 169–182.

Centre for Economics and Business Research (Cebr) (2022), "The economic impact of real-time payments", April.

Committee on Payments and Market Infrastructures (CPMI) and the World Bank (WB) (2020): "Payment aspects of financial inclusion in the fintech era", April.

Czernich, N, O Falck, T Kretschmer and L Woessmann (2011), "Broadband infrastructure and economic growth", *The Economic Journal*, vol 121, no 552, pp 505–32, May 2011.

Deloitte (2019), "Economic impact of real-time payments", Research report, July.

Demirgüç-Kunt, A, L Klapper, D Singer and S Ansar (2022), "The Global Findex Database 2021: Financial Inclusion, Digital Payments, and Resilience in the Age of COVID-19", World Bank, June.

Duarte, A, J Frost, L Gambacorta, P Koo Wilkens and H S Shin (2022): "Central banks, the monetary system and public payment infrastructures: lessons from Brazil's Pix", BIS Bulletin, no 52, March.

Feenstra, R, R Inklaar and M Timmer (2015), "The next generation of the Penn World Table", *American Economic Review*, vol 105, no 10, pp 3150–82.

Hu, Y, C Liu and J Peng (2021), "Financial inclusion and agricultural total factor productivity growth in China", *Economic Modelling*, vol 96, pp 68–82, March 2011.

IDB Lab and World Economic Forum (2022), "Accelerating digital payments in Latin America and the Caribbean", White paper, May.

Jack, W and T Suri (2014), "Risk Sharing and Transactions Costs: Evidence from Kenya's Mobile Money Revolution", *American Economic Review*, vol 104, no 1, pp 183–223.

Khera, P, S Ng, S Ogawa and R Sahay (2021), "Is Digital Financial Inclusion Unlocking Growth?" *International Monetary Fund Working Paper*, WP/21/167, June.

Kim, D, J Yu and MK Hassan (2018), "Financial inclusion and economic growth in OIC countries", *Research in International Business and Finance*, vol 43, pp 1–14, January.

Klein, A (2020), "China's digital payments revolution", Brookings Institution, April.

Koutroumpis P (2009), "The economic impact of broadband on growth: a simultaneous approach", *Telecommunications Policy*, vol 33, no 9, pp 471–85.

Levy, S (2018), Under-Rewarded Efforts: The Elusive Quest for Prosperity in Mexico, Washington, DC: Inter-American Development Bank.

Medina, L and F Schneider (2019), "Shedding light on the shadow economy: a global database and the interaction with the official one", CESifo Working Papers, no 7981.

Mukherjee, S (2023), "Digital technology adoption: subsidizing learning costs for firms in India", mimeo.

Prasad, E (2021), The future of money: how the digital revolution is transforming currencies and finance, Harvard University Press.

Riley, E and R Heath (2023), "Repaying loans with mobile money: impacts on female microfinance clients in Tanzania", mimeo.

Sala-i-Martin, X (1997), "I Just Ran Two Million Regressions", American Economic Review, *American Economic Association*, vol 87, no 2, pp 178–83.

Van, L TH, A T Vo, NT Nguyen and D H Vo (2021), "Financial inclusion and economic growth: an international evidence", *Emerging Markets Finance and Trade*, vol 57, no 1, pp 239–63.

Vedia-Jerez, D and C Chasco Yrigoyen (2016), "Long-run determinants of economic growth in South America", *Journal of Applied Economics*, vol 19, no 1, pp 169–92.

Zandi, M and A Singh (2021), "The impact of payment cards on economic growth", Moody's Analytics, November.

Annex: additional tables and analysis

A1. Descriptive statistics

Summary statistics

Table A1.1

	Observations	Mean	Std dev	Min	Max
TFP (index)	1,680	67.4	23.3	16.7	145.0
GDP per capita (USD)	2,040	19,796.2	17,997.4	924.3	102,353.6
Informal labour (% total emp)	337	58.1	20.6	14.3	96.9
Dig. Payments (% of pop > 15 years)	306	52.3	31.4	2.6	99.9
Borrow FI (% of pop > 15 years)	406	23.2	18.6	1.5	82.8
Fin. Account (% of pop > 15 years)	405	63.2	29.6	2.5	100
Broadband (% of pop > 15 years)	1,949	12.3	13.3	0.1	48.8
Inflation rate (%)	2,610	5.6	9.0	-6.8	249.8
Population (annual growth)	1,938	1.17	1.1	-1.7	5.6
Trade openness (% of GDP)	2,615	84.1	56.6	19.6	442.6
Human capital index	1,980	2.7	0.7	1.1	4.3
Avg. hours worked	1,200	1,896.4	273.6	1,380.6	2,597.7
Government effectiveness	4,358	0.0	1.0	-2.4	2.5

Sources: Feenstra et al (2015); IMF; World Bank; authors' calculations.

A2. Dynamic specification of our equation derived from the fractional adjustment model

Let y be our dependent variable: the level of TFP, $GDP\ pc$, or $Informality$. $y*$ is its equilibrium value, which depends on digital payments DP and another control variable X:

$$(1) \qquad y_t = constant + \beta DP_t + \gamma X_t$$

Assume that the change in y between time $t-1$ and t depends negatively on the difference between its actual value in time $t-1$ and its current equilibrium value in time t:

$$(2) \qquad \mathrm{y_t} - \mathrm{y}_{t-1} = \Delta y_t = \lambda(y_{t-1} - y_t *) = \lambda(y_{t-1} - constant - \beta DP_t - \gamma X_t)$$

$$\lambda < 0$$

So this specification already provides a rational for relating the change in y to its previous level. Then, consider:

$$DP_t = DP_{t-1} + \Delta DP_t \ ; \ X_t = X_{t-1} + \Delta X_t$$

Then (2) can be expressed as:

$$(3) \qquad \Delta y_t = \lambda[y_{t-1} - constant - \beta(DP_{t-1} + \Delta DP_t) - \gamma(X_{t-1} + \Delta X_t)]$$

or

$$(4) \qquad \Delta y_t = \lambda y_{t-1} - \lambda constant - \lambda\beta DP_{t-1} - \lambda\beta\Delta DP_t - \lambda\gamma X_{t-1} - \lambda\gamma\Delta X_t$$

or

$$(5) \qquad \Delta y_t = \lambda y_{t-1} - \lambda constant - \lambda\beta DP_{t-1} - \lambda\gamma X_{t-1} - \lambda(\beta\Delta DP_t + \gamma\Delta X_t)$$

So, the first part of equation (5) is our basic estimating equation, relating the change in y to the previous levels of y, DP, and controls. (Remember that λ is negative, so the coefficients on lagged y are negative and those on DP and X are positive.)

The last two terms, in parentheses, are the contemporaneous changes in DP and X, and we leave them out because they could be subject to reverse causality from y. They are now in the error term, but since they come after the $t-1$ period, they should not be correlated with our lagged y, DP, or X.

A3. Country list

Table A3.1 gives a list of the countries used to study the impact of digital payments when data are available.

Country list — Table A3.1

Albania	Croatia	Iran, Islamic Rep.	New Zealand	Sri Lanka
Algeria	Cyprus	Iraq	Nicaragua	Switzerland
Argentina	Czech Republic	Ireland	Nigeria	Thailand
Armenia	Denmark	Israel	Pakistan	Togo
Australia	Dominican Republic	Italy	Panama	Tunisia
Austria	Ecuador	Jamaica	Paraguay	Türkiye
Bangladesh	Egypt, Arab Rep.	Japan	Peru	Uganda
Belgium	El Salvador	Jordan	Philippines	Ukraine
Belize	Estonia	Kenya	Poland	United Kingdom
Benin	Finland	Korea, Rep.	Romania	United States
Bolivia	France	Latvia	Russian Federation	Uruguay
Bosnia and Herzegovina	Georgia	Liberia	Saudi Arabia	Uzbekistan
Brazil	Germany	Malawi	Senegal	Zambia
Bulgaria	Ghana	Malaysia	Serbia	
Cambodia	Greece	Mali	Sierra Leone	
Cameroon	Guatemala	Malta	Singapore	
Canada	Haiti	Mexico	Slovenia	
Chile	Honduras	Mongolia	South Africa	
China	Hong Kong SAR, China	Morocco	Spain	
Colombia	Hungary	Mozambique	Sweden	
Congo, Rep.	India	Nepal	Taiwan, China	
Costa Rica	Indonesia	Netherlands	Tajikistan	

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