(In)Effective tax enforcement and demand for cash[1]

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Abstract

Cash holdings have increased worldwide in recent years. It is well known that a higher tax burden is typically an important factor for explaining a raise in cash holdings. However, the role of the quality of tax enforcement is less known. To explore the effect of tax enforcement quality on cash holdings, we study a fiscal reform carried out in a large, developing country. In mid-2013, Mexico tried to raise tax revenues by enrolling more taxpayers and introducing electronic invoices to counter a secondary market in illegal invoices. We use a Vector Error Correction (VEC) model to address this issue. The results suggest that a tax enforcement policy implemented under a weak institutional framework can exacerbate cash holdings.

JEL: E40, E41, E62, H26

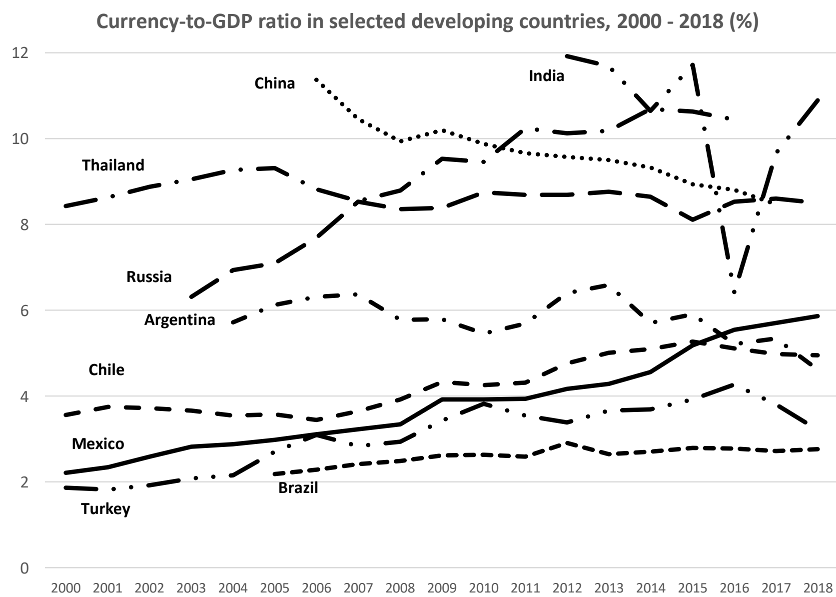
Keywords: Demand for cash, VEC, Tax enforcement, Mexico, Institutions.

1. Introduction

Despite the availability and expansion of different payment methods, cash is widely used among advanced countries (Amromin and Chakravorti, 2009; Bagnall et al., 2016). Contrary to claims about its death[2], cash holdings in some developed countries such as the United States (US) and the Euro Area have increased as a share of gross domestic product (GDP) in recent years (Rogoff, 2016; Jobst and Stix, 2017). Evidence in developing economies is mixed. Figure 1 reports cash holdings as a share of GDP for selected emerging economies from 2000 to 2018. There are countries where such ratio has remained relatively stable or diminished (Argentina and China); in others, it has increased over time. Mexico's cash-to-GDP ratio—2.2% in 2000—nearly tripled in a period of just 18 years; as a result, Mexico's cash-to-GDP ratio surpassed Argentina and Chile but is still well below India, China, Russia, and Thailand. However, Mexico's growth rate in cash holdings is the highest among the countries in the sample.

Figure 1

[2] There is also literature that argues that a currency ban might negatively affect overall welfare; see Lastrapes (2018).



Sources: National statistic offices, central banks and Federal Reserve Bank of St. Louis.

This paper identifies the factors behind significant increases in cash holdings in a large developing country such as Mexico. For that purpose, we exploit meaningful fiscal changes in the country to quantify the effect of stricter enforcement to explain its large increases in cash holdings. In 2013, the Mexican government implemented two important fiscal actions aimed at increasing tax enforcement. First, it introduced electronic invoices to counter a secondary market in illegal invoices used by the self-employed, firms, and micro entrepreneurs to reduce taxable earnings.[3] Likewise, it started a program to increase the number of taxpayers. These actions may have induced people to circumvent the regulation by conducting their transactions in cash. The argument about circumvention is old: regulations intended to bar one path to a goal—legitimate or not—create incentives to find alternate routes (Kane, 1981). Such is the case with fiscal measures in developing economies with weak institutions, which often causes a further jump in informal activities in the

[3] According to the Economic Census, 95% of firms in Mexico are small and micro firms. Also, nearly 80% of transactions in all establishments across the country are conducted with cash.

economy. As a result, demand for cash rises as monetary transactions become the way around fiscal structures. This study evaluates whether that phenomenon accounted for large increases in cash holdings in Mexico.

We modify Rogoff (1998)'s model to allow for the possibility of quality of tax enforcement. Based on this we estimate a relatively standard currency demand equation wherein real cash holdings per capita are a function of the nominal interest rate and a measure of economic activity.[4] In the spirit of Cagan (1958), Tanzi (1980, 1983), and Rogoff (1998), our model controls for the tax enforcement measures faced by people. The effect of stricter tax enforcement on cash holdings may depend upon the adequacy of the tax collection authority and the country's institutions in general, among other factors. One should expect a stricter tax enforcement to stimulate demand for cash in economies with low-quality institutions (such as the tax enforcement institute) as compared to developed economies. In this regard, Mexico spurs interest because it is frequently identified for weak rule of law.[5] It is important to emphasize at the outset that authors such as Cagan (1958), Tanzi (1980, 1983) and Rogoff (1998) are interested in capturing the effect of a higher tax burden on cash holdings. As we document later, the tax enforcement measures implemented in 2013 in Mexico did not translate into a higher tax burden for agents. Therefore, our focus on tax enforcement distinguishes our paper from previous studies.

We use a Vector Error Correction (VEC) model to evaluate relations between tax enforcement and cash holdings. VEC has advantages over a standard regression analysis.

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[4] To review literature concerning money demand, see Goldfeld and Sichel (1990), Sriram (2001), Duca and VanHoose (2004), and Alvarez (2017).

[5] Acemoglu and Robinson (2012) start their renowned book using Mexico as an example of a country with extractive institutions. The World Bank Worldwide Governance Indicators place Mexico in the bottom 30% in its Rule of Law ranking.

First, obtaining evidence of a cointegrated relationship diminishes risk of erroneous inference in the presence of non-stationarities, as is the case for variables we study (see the discussion below). Second, VEC distinguishes between short- and long-run relationships between variables, unlike standard regression analysis. This is important for understanding if tax enforcement can explain cash holdings in the short run. Third, VEC allows practitioners to infer which variable(s) adjust(s) whenever there is disequilibrium in a long-run relationship.

Our proxy for tax enforcement is the number of registered taxpayers as a percentage of the workforce. Arguably, this measure is misguided for examining developed economies, where substantially all workers are registered taxpayers, but not for developing economies. In May 2018, only 49% of Mexico's workforce was registered by the tax authority, reflecting the country's weak institutions for tax collection and its inability to reduce high levels of informality.

Our findings suggest that Mexico's significant increase in cash holdings may be explained partly by the heavier tax enforcement measures imposed in 2013. Our results indicate that a 1.2% increase in cash holdings followed a 10% increase in tax enforcement during the period studied. We test our main result with alternative specifications and confirm its robustness. With the notable exception of Stix (2013), the relationship between tax enforcement and cash holdings has not been addressed previously in the literature. Stix (2013) uses data for 10 Central, Eastern, and Southeastern European countries and find that households in environments with weak tax enforcement present average larger cash holdings. Importantly, the data do not include changes in tax enforcement policies in any country under the period of analysis. To the best of our knowledge, our paper is the first to specifically address the effect of a change in tax enforcement policies on cash holdings.

The study proceeds as follows. Section 2 reviews the literature. Section 3 discusses cash holdings in Mexico and the tax changes of 2013. Section 4 presents our primary results. Robustness analysis confirms our original findings. Section 5 concludes.

2. Literature review[6]

Since the seminal work of Cagan (1958), the relation between taxes and cash holdings has been a subject of interest for economists. Based on Cagan (1958), Tanzi (1980, 1983) studies the relation between the underground economy and the use of cash, positing that high taxes prompt underground transactions that occur strictly in cash. In turn, demand for currency rises. Tanzi uses the tax rate to proxy changes in size of the underground economy. Adopting further assumptions, he uses the estimated equation as an input to calculate its size.[7] Our paper differs from the approach of Tanzi (1980, 1983) and his followers in the sense that we only want to understand how tax enforcement affect cash holdings in an environment of weak institutional framework. We do not seek to measure either the effects of a higher tax burden on cash holdings or the size of the underground economy.

Our paper is closely related to the work of Rogoff (1998), Herwartz et al. (2016), and Jobst and Stix (2017). Rogoff (1998) estimates determinants of currency velocity for 16 OECD countries using annual data spanning 1980–1994 and finds that the ratio of taxes to GDP relates negatively to currency velocity in 14. In contrast, Herwartz et al. (2016) reports that the share of direct and indirect taxes plus social security contributions to GDP did not affect demand for currency in 11 OECD economies for 1970–2012. None of these studies

[6] We concentrate only on studies related to tax burden and cash demand. Footnote 1 references a complete survey of the literature of money demand.

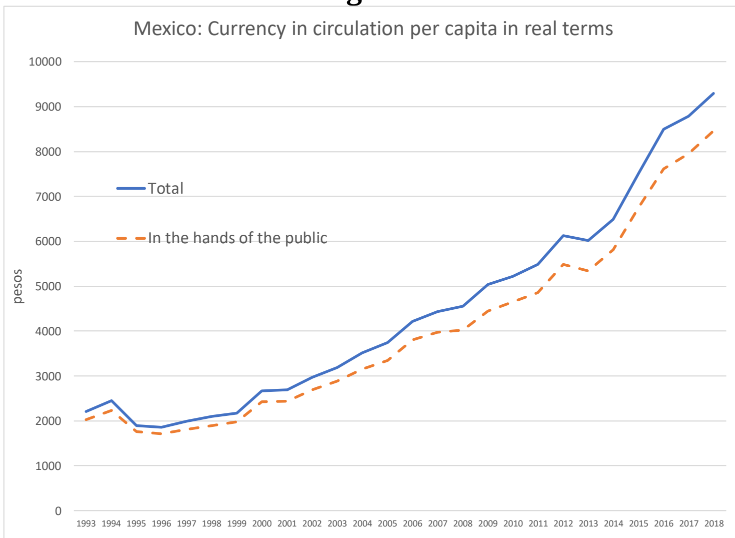
[7] This method is usually known as the currency demand approach for measuring underground activities (Schneider and Enste, 2000). For recent refinements of this method, see Ahumada et al. (2007) and Ardizzi et al. (2014).

examines the effect of tax enforcement on cash holdings. Jobst and Stix (2017) evaluate whether increased cash holdings are attributable to changes in magnitude of the shadow economy in a panel of 70 countries for 2001–2014 and find no significant effects. Results in such a framework portray effects of the shadow economy on demand for currency across economies *on average*. Therefore, country-specific studies like ours add insights into relations between tax policies and demand for cash. In relation to country-specific studies, Lahiri (2020) suggests that it is hard to argue that demonetization in India induced an increase in the collection of tax revenues, highlighting that India is a very informal economy (44 million people are registered before fiscal authorities out of 600 million people as labor force). However, a formal testing of the relationship between tax enforcement and cash holdings is missing.

3. Demand for cash in Mexico

Mexico has experienced a secular uptrend in cash holdings for nearly 20 years. Figure 2 shows total cash and cash in public hands per capita over 1993–2018. Maximum holdings were slightly above 2,200 pesos in 1994 and were below that level for five years after the Tequila Crisis. Ever since, cash holdings have increased almost yearly in real terms. The Mexican public in 2018 carried 3.5 times more pesos on average than in 2000. The series exhibits an increasing trend between 2013 and 2014.

Figure 2

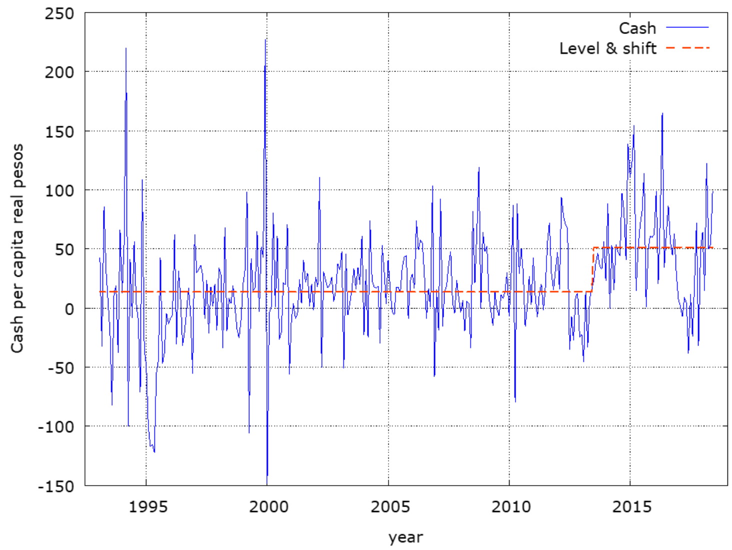


Sources: Central Bank of Mexico and National Statistics Office.

Formally, we check for a structural break in seasonally-adjusted cash holdings per capita using the Bai–Perron (BP) test. The test requires stationary series, so we take the first difference in the series. The results are shown in Figure 3.[8] As shown, the test identifies one upward break in the series in August, 2013 (dashed line).

Figure 3
First difference in cash holdings per capita (seasonally adjusted)

[8] From the global optimization stage, the Bayesian Information Criterion (BIC) indicates two breaks. UD_{max} and WD_{max} (36.318) indicate the evidence of an unknown number of breaks. The sequential procedure (the one we prefer) indicates the evidence of one break at 1% confidence (August 2013).



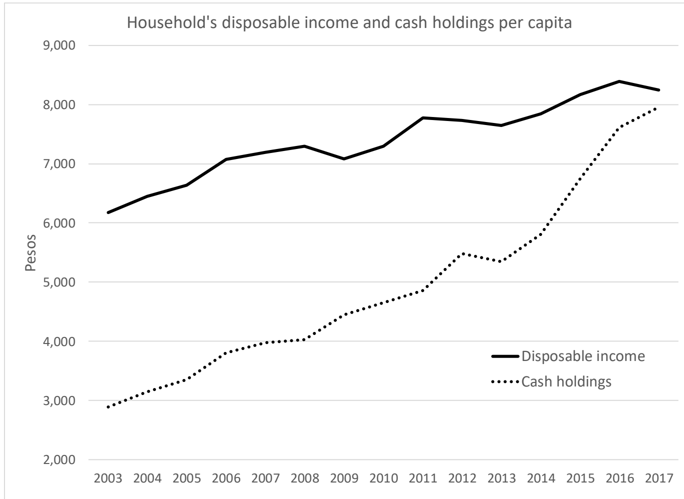
Source: own elaboration.

Figure 4 depicts disposable household income and demand for cash per capita for 2003–2017.[9] It confirms that a significant increase in income around the same date does not explain that structural break. In fact, the gap between these variables closes over time: The sharp rise in cash holdings since 2013 is not paralleled by a similar rise in disposable income. Something else triggered demand for cash around August, 2013.[10]

Figure 4

[9] Data for disposable income are available only since 2003.

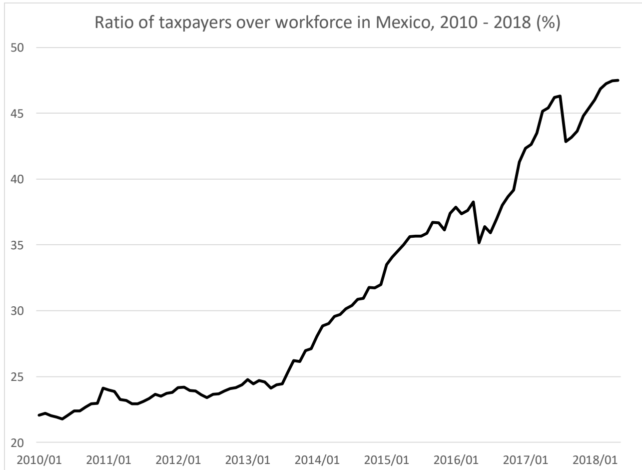
[10] The nominal interest rate is another suspect for the structural break in cash holdings. This variable (measured as the ninety-day interest rate on Mexican Treasury debt) exhibits a downward trend before August 2013. The interest rate fell smoothly during the next two years with no abrupt changes around August 2013. In our specification for demand for cash in Section 4, we formally control for both a measure of economic activity and nominal interest rate.



Sources: Central Bank of Mexico and National Statistics Office.

We consider that the government's tougher tax enforcement and increased numbers of registered taxpayers underpin the 2013 break in cash holdings. In 2013, the Mexican government introduced universal electronic invoicing to assure registration of all taxable transactions and thus reduce tax evasion. The increase in the number of registered taxpayers as a percentage of the workforce for 2010–2018 is shown in Figure 5. The series starts in 2010 because data for number of taxpayers were available only since January that year. From 2010 to mid- 2013, the series increases slowly from 22%. It trends upward from the second half of 2013. The ratio of taxpayers in the workforce increased 23 percentage points in five years.

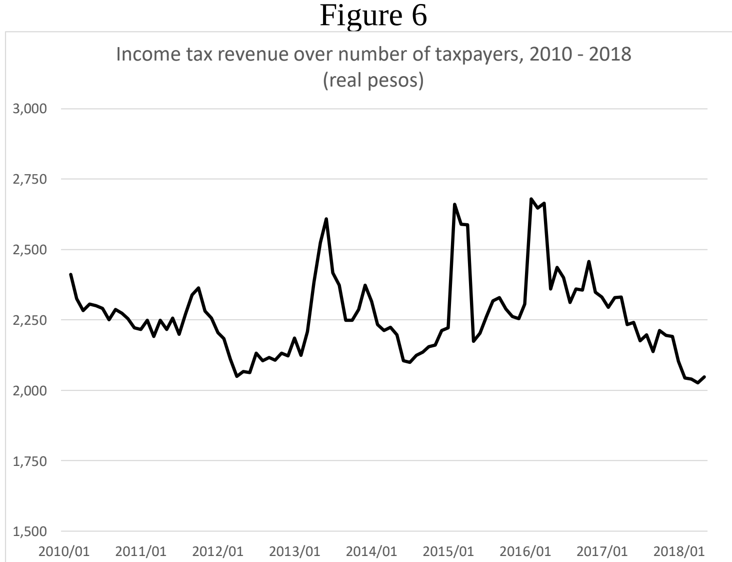
Figure 5



Sources: Ministry of Finance and National Statistics Office.

To illustrate that the tougher enforcement policies of 2013 did not imply a higher tax burden for taxpayers, Figure 6 shows the 3-month centered moving average of income tax revenue per taxpayer in real pesos for the period 2010-2018. The spike registered in 2013 illustrates the tax policy changes implemented in that year. However, the tougher enforcement did not translate into a higher income tax revenue per taxpayer on average for subsequent periods.

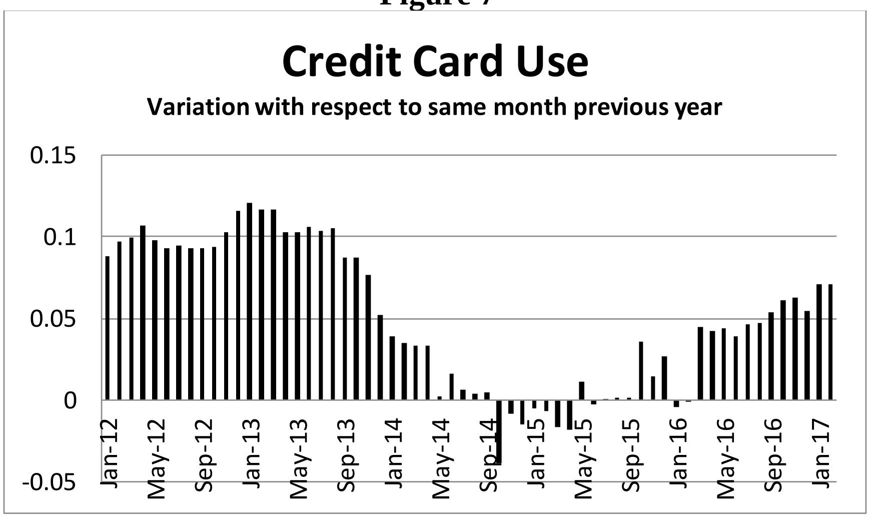
Figure 6



Source: Ministry of Finance and Tax Revenue Administration.

To examine if tougher tax enforcement in 2013 altered behavior, we examined use of credit cards. We did so because electronic invoicing allowed Mexico's tax authority trace transactions and thus payment of consumption and personal income taxes. People might curtail payments by credit and switch to cash to hide transactions Figure 7 presents annual growth rates in credit card balances in Mexico from January 2012 to February 2017. There is a clear decline around mid-2013. This period corresponds to the structural break in cash holdings, suggesting people started to transact with cash instead of credit cards.

Figure 7



Source: National Banking and Securities Commission.

To verify that, we tested for the presence of a structural break in the ratio of credit card balances to cash holdings using unit root and BP tests for January 2011 to February 2017. In Table 1 both tests identify a break in the series at yearend 2013. This finding suggests a shift from credit cards to cash around that date, as illustrated in Figure 8.

Table 1
Structural break tests in ratio of credit card balances to cash holdings

Test	**Credit card balances/ Cash holdings**
Unit root tests	
ADF-GLS (constant + trend)	-1.335

Phillips-Perron (constant + trend)	-2.311
Whittle	0.900***
GPH Estimator	0.999***
Kapetanios (Breaks + constant + trend)	
Test statistic	-6.796***
Breaks (2)	Nov 2011 & Nov 2013
Bai–Perron test	
Evidence of breaks	
BIC	-23.222 (5)
LWZ	-22.180 (3)
UD_{max}	844.862***
WD_{max}	1289.560***
Number of breaks and location (Sequential procedure)	Dec 2011 & Dec 2013

Source: own elaboration.

Figure 8
Structural breaks in the ratio of credit card balances to cash holdings (Bai–Perron test)

Source: own elaboration.

In sum, this evidence shows that Mexican authorities in mid-2013 tried to raise tax revenues by enrolling more taxpayers and toughening tax enforcement. People responded by conducting more cash transactions to avoid tracking by the tax authority. This suggests cash holdings are directly linked to tax enforcement, especially when it was inadequate. Section 4 develops a cash demand model to obtain how this mechanism works. Later, in section 5 we test this hypothesis.

4. The model

This section constructs a model to obtain the condition under which tax enforcement may affect cash demand. First, consider a small, open economy where the infinitely-lived agent has a utility function with elastic labor supply:

$$\sum_{t=0}^{\infty} \beta^t [u(c_t) + h(1 - l_t)], \qquad (1)$$

where c_t is consumption, l_t is labor, and $\beta \in (0,1)$ is the time discount factor. The representative agent is endowed with one unit of time, so that $1 - l_t$ is leisure. Functions $u(\cdot)$ and $h(\cdot)$ satisfy the usual properties, namely $u_c > 0, u_{cc} < 0, h_{1-l} \equiv h_L > 0$ and $h_{LL} < 0$.

For simplicity, the production function is linear in the labor factor: $y_t = l_t$. In addition, the agent derives income from one-period real bond holdings b_t that pay a real interest rate r, money holdings from the previous period M_{t-1}, and nominal transfers T_t from the government. This income is allocated to consumption, real bonds and money. In this framework, there are trading frictions that are wasteful in terms of output, and money holdings are used to save on transaction costs. Using the fact that $y_t = l_t$, pre-tax income in period t may be written as $l_t[1 - v(M_t/P_t l_t)]$, where P_t is the price level. The function $v(M_t/P_t l_t)$ has the properties that $v(0) < 1, v_m < 0, v_{mm} > 0$, and $\lim_{M/Pl \to \infty} v(M/Pl) = 0$, where $m \equiv M/Pl$.

The representative agent must pay a tax on income at the statutory rate τ. However, money may be used to reduce the agent's tax burden, as in Rogoff (1998). We model this through a tax evasion technology represented by a function g. The novel feature here is that this function depends on the quality of tax enforcement, which we denote it by the parameter $E > 0$:

$$g\left(\frac{M_t}{P_t l_t}, E\right) \geq 0 \ .$$

.This function has the following properties: $g(0, E) = 1, g_m < 0, g_{mm} > 0$ and $\lim_{M/Pl \to \infty} g\left(\frac{M}{Pl}, E\right) \geq 0$. In addition and in contrast with Rogoff, we assume $g\left(\frac{M}{Pl}, 0\right) = 0$, $g_E > 0, g_{EE} < 0$ and $\lim_{E \to \infty} g\left(\frac{M}{Pl}, E\right) = 1$. The term $g_E > 0$ means that a higher enforcement by the authority increases the agent's tax compliance, as expected. The key assumption in the model is the expression $g_{Em} \leq 0$. If $g_{Em} < 0$, the effect of a better-quality tax enforcement is weaker if households simultaneously increase their cash demand. This reflects the idea that tax evasion is facilitated by the use of cash in the presence of enforcement. On the other hand, if $g_{Em} = 0$, cash is useless to weaken the effects of an improvement in tax enforcement.

Given the above information, the budget constraint of the representative agent in nominal terms is given by:

$$P_t c_t + P_t b_{t+1} + M_t = P_t l_t \left[1 - v\left(\frac{M_t}{P_t l_t}\right) - \tau g\left(\frac{M_t}{P_t l_t}, E\right)\right] + P_t(1+r)b_t + M_{t-1} + T_t. \qquad (2)$$

Accordingly, the problem of the representative agent is to choose sequences $\{c_t, l_t, b_{t+1}, M_t\}_{t=0}^{\infty}$ to maximize (1) subject to (2).

From the FOCs, it may be shown that optimality conditions are given by the following equations:

$$u_c(c_t) = \beta(1+r)u_c(c_{t+1}), \qquad (3)$$

$$\frac{h_L(1-l_t)}{u_c(c_t)} = 1 - v\left(\frac{M_t}{P_t l_t}\right) - \tau g\left(\frac{M_t}{P_t l_t}, E\right) + \left(\frac{M_t}{P_t l_t}\right)(v_m + \tau g_m), \qquad (4)$$

$$-v_m\left(\frac{M_t}{P_t l_t}\right) - \tau g_m\left(\frac{M_t}{P_t l_t}, E\right) = \frac{i}{1+i}, \qquad (5)$$

where i is the nominal interest rate, defined by $1 + i = (1+r)P_{t+1}/P_t$. Equation (5) implicitly defines the demand for real cash holdings $\frac{M_t}{P_t}$.

We are interested in finding an expression for the term $\frac{\partial(M_t/P_t)}{\partial E}$. For that purpose, we apply the implicit function theorem in the equation system given by (3), (4) and (5), after defining $c_t, l_t, M_t/P_t$ as the endogenous variables of the system. Then, we may show that:

$$\frac{\partial(M_t/P_t)}{\partial E} = \frac{\frac{h_{LL}\tau g_{Em}}{u_c} - \left(\frac{M_t}{P_t l_t}\right)\left(\frac{1}{l_t}\right)(v_{mm} + \tau g_{mm})\tau g_E}{-\left(\frac{1}{l_t}\right)\left(\frac{h_{LL}}{u_c}\right)(v_{mm} + \tau g_{mm})}. \qquad (6)$$

Given that $v_{mm} > 0, g_{mm} > 0, u_c > 0$ and $h_{LL} < 0$, the denominator in equation (6) is unambiguously positive. Hence, the sign of $\frac{\partial(M_t/P_t)}{\partial E}$ depends on the sign of the expression in the numerator. Provided that $g_E > 0$ and the fact that $\frac{h_{LL}\tau g_{Em}}{u_c} \geq 0$, it is clear that the sign of the derivative in (6) is ambiguous in general. This is precisely the key result of the model.

Consider first the particular case in which $g_{Em} = 0$. Here, an increase in cash holdings is ineffective to curb tax enforcement. Arguably, this is a situation resembling countries with strong and efficient institutions. In this case, $\frac{\partial(M_t/P_t)}{\partial E} < 0$. Now consider the second case in which $g_{Em} < 0$. If institutions are ineffective and deficient, an increase in tax enforcement should have a small effect on tax compliance, namely $g_E > 0$ should be small. Under this scenario, the first term in the numerator of equation (6) dominates the second one, thus implying $\frac{\partial(M_t/P_t)}{\partial E} > 0$.

In sum, we argue that in developing countries with weak institutions such as Mexico and most in the Latin American Region, g_E is relatively small and hence, an attempt to better enforce tax collection brings about an increase in household's cash holdings. We next turn our attention to the empirical exercise.

5. Cash holdings and tax enforcement: The estimation

5.1 Baseline specification

Our starting point is the classical specification wherein demand for cash is a function of economic activity and the nominal interest rate.[11] To test whether tax policy affects demand for cash, we include a variable for tax enforcement. This approach is captured in Eq. (1):

$$m_t = \beta_0 + \beta_1 E_t + \gamma T_t + \delta i_t, \tag{1}$$

[11] Holding cash incurs the opportunity cost of holding currency, i.e., foregone returns from asset yielding. It is a standard procedure to measure the latter via the nominal interest rate (see, inter alia, Bates, Kahle and Stulz, 2009; Huynh, Schmidt-Dengler, and Stix, 2014; Judson, 2017; and Arango-Arango and Suárez-Ariza, 2019, among others).

where m_t is per capita cash holdings in real terms, E_t measures economic activity (defined below), T_t denotes tax enforcement, and i_t is the nominal interest rate. To estimate Eq. (1), we propose a VEC model wherein β_0 and β_1 are the parameters of the cointegrated vector under a restricted constant specification, whereas γ and δ are associated with the $I(1)$ restricted variables. The standard theory suggests $\beta_1 > 0$ and $\delta < 0$. In addition, we test the hypothesis that γ is positive and significant.

Our data set is built using information from official sources. Data for our tax enforcement measure as described below are available only since January 2010. Given the brief time span, we collected monthly information. Data for remaining variables (m_t, E_t and i_t) are available over a longer period. To search for breaks in the series attributable to the Great Recession, the starting period for the remaining variables is September 2008. In all cases the sample period ends May 2018.

Nominal cash holdings are banknotes and coins held by the public, as reported by Banco de México. We use the Consumer Price Index published by the National Statistics Office (INEGI) to compute real cash holdings. INEGI reports total population quarterly. Linear interpolation constructs the corresponding monthly series. Given lack of monthly GDP data, our measure of economic activity is total employment as a percentage of the workforce from INEGI. The nominal interest rate is the ninety-day rate on Mexican Treasury debt as reported by the Banco de México. Our proxy for tax enforcement is number of registered taxpayers as a percentage of the workforce reported by the Ministry of Finance monthly. All variables are in logs (except nominal interest rate) and are seasonally adjusted using Census X-12-ARIMA.

A glance suggests these variables do not behave as stationary processes, so we applied several unit root tests for a formal proof (Table 2). They suggest all variables behave as unit-root processes. Details of the tests appear in Table A1 of the Appendix.[12]

Table 2
Unit-root and stability test

Variable	UR Tests	Breaks (sequential Bai–Perron)	VSG Drift	VSG Break
m_t	I(1)	2012:07, 2015:04	Yes	No
E_t	I(1)	2009:10	No	--
T_t	I(1)	--	Yes	2012:12
i_t	I(1)	--	No	--

Notes: All variables except interest rate are logs. BP is applied to first-differenced variables. VSG: Ventosa-Santaulària and Gómez (2010) test, a sequential test for evidence of a drift and break in drift.

Given the stochastic trending mechanism that seems pervasive among all variables, the search for breaks (besides that identified by Ventosa-Santaulària and Gómez (2010) test in T_t) must follow a more convoluted path. The BP procedure requires stationary variables to identify the number, location, and timing of structural breaks. We therefore apply the procedure to first differences of all variables. Results are indicated in Table 3. BP identifies breaks in demand for cash (July 2012 and April 2015) and employment (October 2009). BP finds no evidence of structural breaks for tax enforcement and nominal interest rate under a sequential procedure.

Table 3
Bai and Perron structural break procedure results

Variable	Evidence of breaks: UD_{max}	Evidence of breaks: WD_{max}	Evidence of breaks: $BIC^{\dagger}$	Number and location of breaks: Sequential procedure (at 1%)	Number and location of breaks: 95% confidence interval
Δm_t	39.81***	52.57***	2	2012:07 2015:04	2012:02–2012:08 2015:02–2015:05
ΔE_t	13.95**	13.95**	0	2009:10	2008:11–2010:07

[12] We include a unit root test robust to structural breaks (Kapetanios, 2005).

ΔT_t	6.90	7.59	0	--	--
Δi_t	10.46	11.51	2	--	--

Notes: Robust standard errors; trimming: 0.1 (except for m_t, where trimming = 0.2 for coherence); maximum number of breaks: 2. † number of breaks per the Bayesian Information Criterion (BIC). *,**, and *** denote rejection of the null at the 10%, 5%, and 1% levels, respectively.

Given the evidence of non-stationarity among these variables, it is natural to investigate a possible cointegrated VEC process to estimate the relation between demand for cash and variables on the right side of equation (1). We use a small-sample adjusted Johansen test, which forces specification of the model. Our model is described in Appendix B.

Once the model is fully specified, the following expression gives the long-run estimate of equation (1):

$$\underset{}{m_t} = -\underset{(13.365)}{119.300} + \underset{(2.986)}{28.030}\, E_t + \underset{(0.069)}{0.119}\, T_t - \underset{(0.006).}{0.038}\, i_t,$$

Standard errors are in parenthesis. All coefficients are significant and bear expected signs. The result suggests a positive effect of tax enforcement on real cash holdings and confirms our hypothesis that the large increase in cash holdings in Mexico is partly attributable to stricter tax enforcement.

We also present evidence concerning stability of the cointegrating vector and the long-run relationship. We use the Hansen and Johansen (1999) test for parameter constancy in VECs. Table 4 provides results for fluctuation tests of recursive eigenvalues and of beta parameters. Neither test provides evidence of instability, so we infer none (i.e., instability is statistically undetectable).

Table 4

Hansen and Johansen VEC stability tests

Test	Test statistic	Interpretation
Fluctuation test of recursive eigenvalue	0.47	No evidence of instability in the eigenvalue
Fluctuation test of Beta parameters	2.30*	No evidence of instability in the parameters

Source: own elaboration. * denotes rejection at the 10% level.

Despite the evidence of structural breaks found in the individual series (Table 3), there are no signs that such breaks do not affect the relationship. In other words, the breaks identified in the marginal distributions do not affect the conditional distribution.-

Figure B3 in the Appendix depicts these results. We execute these tests with two restricted exogenous variables that may affect their validity, so we test stability by ignoring both variables. Results remain unchanged.

5.2 Robustness analysis

This section considers alternative specifications of Mexican data to check robustness of results. First, we select the three-month CD rate ($\hat{\imath}_t$) as an alternative to the nominal interest rate (i_t). Data are from Banco de México. We add to Eq. (1) a variable to control for informality. We propose three alternative measures for this purpose: (a) share of employment without social insurance (L_{1t}); (b) share of employment in the informal sector (L_{2t}); and (c) share of own-account workers (L_{3t}). Data are collected from INEGI.[13]

[13] It is important to mention that the informality time series L_1, L_2 and L_3 seem non-stable (i.e., not I(0)). We first-differenced the series to avoid potential spurious inference. We also controlled for alternative payment methods in the demand for cash equation. In particular, we considered average credit card balance per capita in real terms. The corresponding coefficient was insignificant and results are excluded in Table 6.

Results appear in Table 6. The column under Specification 0 reports the results under the baseline case. The first robustness check adds a restricted constant to the cointegration vector. The column under Specification 1 declares that baseline findings are robust to this modification. Specification 2 reports a traditional estimate of cash holdings as a function of economic activity and nominal interest rate only. Coefficients bear the expected signs and are significant. Also, estimates remain substantially unchanged versus the baseline. The next specification estimates demand for cash under the alternative definition of nominal interest rate. Once again, the coefficient estimates barely change with respect to the baseline.

Specifications 4, 5, and 6 show the three alternative measures to control for informality. On the one hand, their effect on cash demand is negative but non-significant. On the other, its effect on employment is negative and statistically significant. This implies that an increase in informality has an indirect but nonetheless positive relation to demand for cash through employment.[14]

6. Conclusion

This paper showed that tougher tax enforcement may explain large increases in cash holdings in Mexico. Mexico undertook significant fiscal changes in 2013 and simultaneously experienced significant increases in cash holdings. Our VEC approach found that the jump in cash holdings was partly attributable to those changes. These results may suggest that, as the tax enforcement strengthened in Mexico, agents sought tax-evading activities that are

[14] Clearly, after enduring tax enforcement, returns on tax evasion became higher. Lopez (2017) find that reducing the returns to tax evasion by formal firms increases tax revenues by up to 68%. However, economies where such returns are too high face a trade-off between tax collection and aggregate efficiency, as cracking down on formal tax-evading firms pushes some firms into informality. This is consistent with our results.

facilitated by use of cash, and demand for currency increased. Furthermore, the effect of tougher tax enforcement measures on cash holdings seems to depend on the quality and efficiency of the tax collection authority and the country's institutions in general, among other factors. That stands as our main contribution to the literature concerning estimation of cash demand.

Table 6
Robustness analysis

	Variable	Specification 0	1	2	3	4	5	6
Cointegrated	m_t	1	1	1	1	1	1	1
	E_t	28.030 (2.986)	28.075 (2.987)	33.025 (1.276)	27.030 (2.039)	28.035 (3.032)	28.706 (3.203)	27.902 (3.107)
Exogenous	T_t	0.119 (0.069)	0.117 (0.069)	--	0.119 (0.049)	0.104 (0.092)	0.087 (0.086)	0.108 (0.072)
	i_t	-0.038 (0.006)	-0.038 (0.006)	-0.046 (0.007)	--	-0.037 (0.006)	-0.038 (0.006)	-0.037 (0.006)
	$\hat{\imath}_t$	--	--	--	-0.066 (0.007)	--	--	--
	ΔL_{1t}	--	--	--	--	-0.004 0.006***	--	--
	ΔL_{2t}	--	--	--	--	--	-0.003 0.006***	--
	ΔL_{3t}	--	--	--	--	--	--	-0.007 0.013***
ECM	1	-0.029	-0.027	0.012	-0.045	-0.030	-0.027	-0.020
	2	0.036***	0.036***	0.031***	0.050***	0.036***	0.035***	0.035***
	Specification	RC	UC	RC	RC	RC	RC	RC
Test statistics	Trace with exog. random variable							
	Ho1: no coint. vector	44.65***	40.87**	44.15***	50.73***	44.24***	41.44***	45.04***
	Ho2: 1 coint. vector	12.78	9.01	11.24*	12.83	12.30	9.13	9.32
	Normality	5.477	4.898	16.372**	4.797	4.739	4.740	4.823
	Joint autocorr. (4)	2.106***	1.891**	1.661*	2.026**	2.262***	2.337***	1.750**
	Joint heterosc. (4)	44.545	48.103*	58.991***	47.054	47.877*	46.213	48.849*
	Stability eigenvalue	0.47	0.47	0.19	0.47	0.47	0.47	0.47
	Stability param.	2.30	2.30	1.32	1.82	2.30**	2.30**	2.30**

Note: *, **, and *** denote rejection of the null hypothesis of statistical significance at the 10%, 5%, and 1% levels, respectively.

Appendix A: Unit roots

Table A1
Unit-root tests (detailed results)

Variable	ADF	ADF-GLS†	Phillips-Perron‡	Kapetanios	VSG			Persistence	
					R^2	t-ratio	Obs.	Whittle	GPH
m_t	3.26	-1.80	0.19	-5.74*	0.98**	1.21	--	0.99	0.99
E_t	0.66	-0.76	-0.99	-6.34*	0.86	--	--	1.13	1.25
T_t	4.36*	-1.29	0.68	-5.05	0.98**	1.53**	2012:12	0.99	0.99
i_t	-0.44	-0.17	-1.64	-6.20	0.83	--	--	1.53	1.69

Notes: † constant and trend; maximum number of lags; lag selection criterion: Perron and Qu (2007) modified-BIC (BIC for the aforementioned variables). ‡ constant and trend; Bartlett window = $[4(T/100)^{2/9}]$. Kapetanios test: 5 breaks allowed, 12 lags max, 0.15 trimming, only DU_t breaks. VSG: Ventosa-Santaulària and Gómez (2010) test. Interest rates not in logs.

Appendix B: VEC and stability

We obtained VEC specification under these criteria:

1. There should be sound evidence of cointegration. We address this issue through the Johansen cointegration test plus the statistical significance and expected sign of at least one adjustment parameter. The number of lags and the specification of the long-run equation are thus allowed to vary. Many modified specifications yield evidence favoring cointegration, but only a few generate well-behaved residuals. For that reason, we apply a second specification criterion.
2. VEC residuals should be well behaved. That is, the stationary short-run equation must have residuals that show no autocorrelation, heteroscedasticity, and—most important—non-normality. This finding makes us confident in drawing inferences, especially for the adjustment parameters.

Results of the Johansen cointegration test appear in Table B1. They clearly reject the null hypothesis of no cointegration (p-value<0.01), and fail to reject the null of one cointegration vector (p-value>0.10).

Table B1
Johansen cointegration tests

Null hypothesis	Eigenvalue	Trace test[1]	p-value
0 cointegration vectors	0.271	44.647***	0.001
1 cointegration vectors	0.119	12.783	0.122

[1] p-value is conditional on two I(1) variables and controls for (small) sample size. Specification: restricted constant; lag order: 6.
*** denotes rejection of the null at 1%.

Table B2 reports the corresponding normality, autocorrelation, and homoscedasticity tests on residuals. VEC residuals seem to behave as normal random variables with no evident heteroscedasticity. Evidence for autocorrelation is mixed. Univariate tests fail to reject the null of no autocorrelation, although there is some supporting evidence in the multivariate test.

Table B2
Normality, autocorrelation, and homoscedasticity tests

Modality	Normality†		Autocorrelation‡		Heteroscedasticity°	
	Eq. 1	Eq. 2	Eq. 1	Eq. 2	Eq. 1	Eq. 2
Univariate (a)	-	-	0.124	0.749	3.410	3.265
Univariate (b)	-	-	11.817	3.753	3.823	4.926
Multivariate (a)	5.478		2.106**		44.545	
Multivariate (b)			1.526**		96.877	

Notes: Eq. 1: Δm_t, Eq. 2: ΔE_t. (a) four lags, (b) twelve lags. † Doornik-Hansen multivariate test. ‡ univariate: Ljung-Box Q; multivariate Rao $\mathcal{F}$ test. ° uni/multivariate: ARCH LM test. * denotes rejection of the null at 10%.

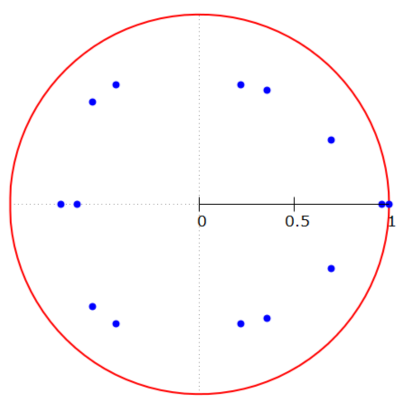
The VEC includes 6 lags with no unrestricted variables. All VEC estimates are in Table B3, and the inverted roots of the VEC appear in Figure B1.

Table B3
VEC equation estimates

Parameter	Eq. 1: Δm_t	Eq. 2: ΔE_t
Δm_{t-1}	0.1607	0.0022
Δm_{t-2}	0.4073 ***	0.0349
Δm_{t-3}	0.0999	0.0595 **
Δm_{t-4}	0.1422	−0.0022
Δm_{t-5}	0.1931 *	−0.0397
Δm_{t-6}	0.1731	0.0007
ΔE_{t-1}	0.3065	0.0129
ΔE_{t-2}	0.3943	0.1543
ΔE_{t-3}	−0.1143	0.2450 *
ΔE_{t-4}	−0.1745	0.1722
ΔE_{t-5}	−0.2157	0.1039
ΔE_{t-6}	−0.2689	0.1213
ECM_1	−0.0289	0.0365***
R^2	0.5488	0.5559
$\bar{R}^2$	0.4754	0.4836
$\mathcal{DW}$	1.9634	1.9244

*,**, and *** denote rejection of the null at the 10%, 5%, and 1% levels, respectively.

Figure B1
Inverse VAR roots depicted in the unit circle



Note that all roots lie within the unit circle.

Table B4 presents the corresponding adjustment velocities. Note that only the Error-Correction Mechanism in the employment equation is statistically significant, which implies that the parameter associated with m_t is weakly exogenous to E_t. In other words, when a shock deviates variables from its long-run equilibrium relationship, the adjustments occur through changes in employment.

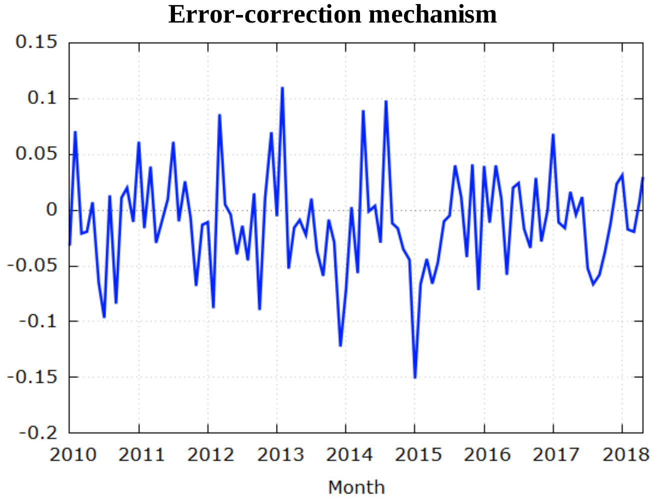
Table B4
Adjustment velocities

ECM (α's) in VECS		
ECM_i	Δm_t	ΔE_t
	-0.029	0.036***

*** denotes rejection of the null at 1%.

Figure B2 depicts temporal evolution of the ECM. At yearend 2013 and 2014, ECM has important effects, and relevant corrections occur via employment. Observe that these dates again coincide with national fiscal changes. Results suggest that demand for cash rises with tougher tax enforcement.

Figure B2
Error-correction mechanism

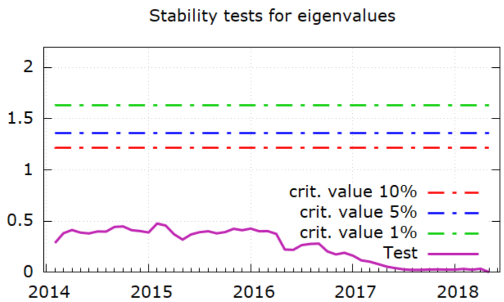


Source: own elaboration.

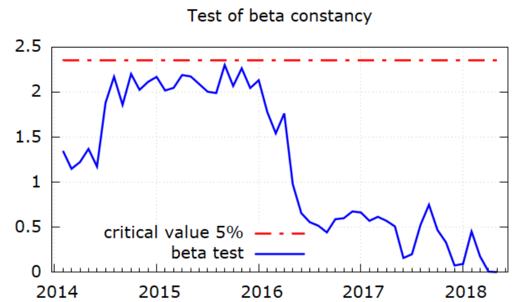
Figure B3 illustrates the results reported in Table 3 in the main text.

Figure B3
Stability tests

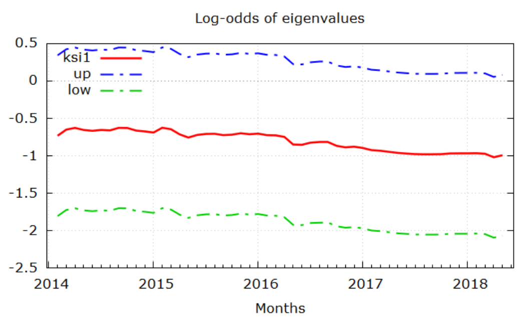
(a)



(b)



(c)



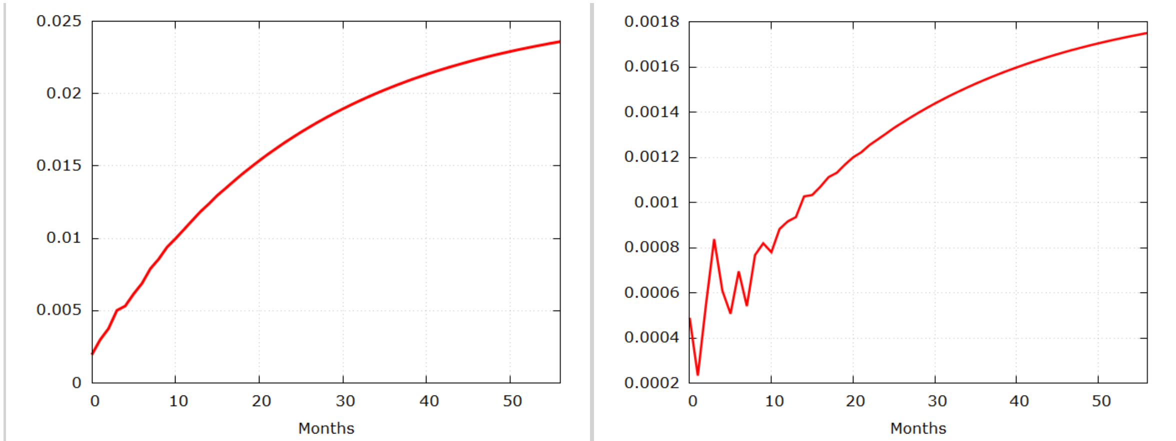
Source: own elaboration.

Appendix C: Impulse response functions and Granger causality test

Impulse response functions illustrated in Figure C1 reveal that systemic shocks are hard-dying: it takes more than four years for them to cease impacting the series. Note also that shocks have a positive effect on the dynamics of both variables.

Figure C1
Impulse response functions

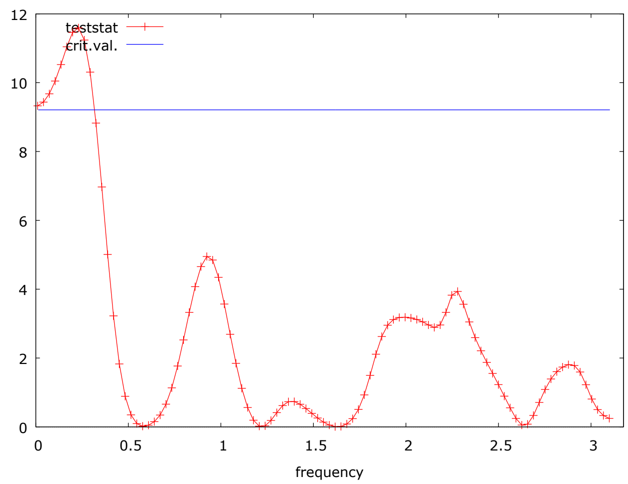
(a) Shock in E_t, response in m_t (b) Shock in m_t, response in E_t



Source: own elaboration.

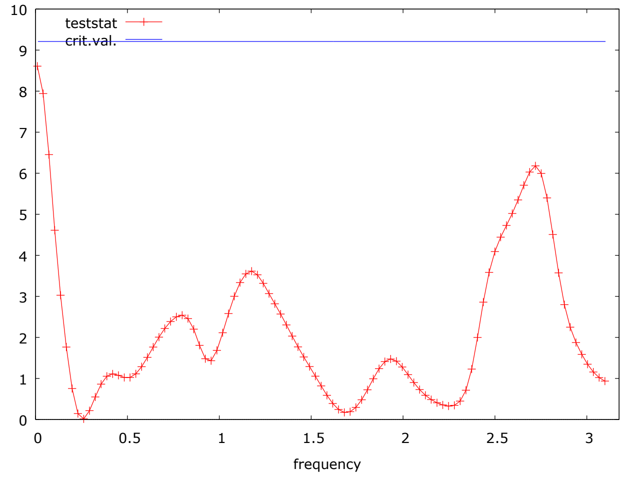
We also performed a Granger causality (GC) test à la Breitung-Candelon (2006) between cash holdings and employment. The test assumes 20 lags with a critical value of 1% without controls. It reveals that cash demand is Granger-caused by employment, but employment is not Granger-caused by cash. Results appear in Figs. C2 and C3 (test details available upon request).

Figure C2
Granger causality from employment to demand for cash



Source: own elaboration.

Figure C3
Granger causality from demand for cash to employment



Source: own elaboration.

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