

Adoption of inflation targeting and tax revenue performance in emerging market economies: An empirical investigation

Abstract

This paper investigates whether the adoption of inflation targeting (IT), by strengthening the central bank independence and by maintaining inflation at low levels, has encouraged the governments of emerging economies to improve the collection of domestic tax revenue in order to recoup the loss of seigniorage revenue. Using the propensity score matching methodology, a micro-econometric methodology recently used in macroeconomics, we evaluate the ‘treatment effect’ of IT on fiscal mobilization in emerging countries that have adopted this monetary policy framework. Our empirical analysis, conducted on a sample of 59 countries (19 IT and 40 non-IT countries) for the period from 1980 to 2009, shows that on average IT adoption has had a large and significant positive effect on public revenue collection. Our results are confirmed by extensive robustness tests.

Keywords: Inflation targeting, public revenue, treatment effect, propensity score matching, emerging countries.

JEL Codes: E5, E6, H2.

1. Introduction

Since its adoption by Chile in 1990, the monetary policy framework known as inflation targeting (hereafter IT) has been implemented by an increasing number of other emerging countries. Thus, by the end of 2009, there were eighteen emerging market economies which have adopted this monetary policy strategy, predominantly Latin American and Central and Eastern European countries¹. Moreover, beside these countries, several other emerging countries have expressed the wish to switch to IT at short-medium term².

According to Amato and Gerlach (2002), this evolution of monetary policy constitutes the most important change in the framework of monetary policy since the collapse of the Bretton Woods system. Two main arguments can be advanced to explain the high popularity of IT in emerging economies. First, the choice of IT constitutes a pragmatic response to difficulties of central banks in conducting their monetary policy using exchange rate pegs or monetary aggregates as intermediate targets. Second, this choice can be explained by the relative benefits of this monetary policy framework on economic performances observed in industrialized and emerging economies that have adopted IT, and corroborated by a significant body of empirical literature. For instance, Lin and Ye (2009) and de Mendonça and de Guimarães e Souza (2011) find evidence for a large sample of developing and emerging countries that IT improves economic performance as measured by the level and variability of inflation³.

IT is defined as a framework for monetary policy characterized by the public announcement of official quantitative targets and by a commitment that low and stable inflation is the primary long-run goal of monetary policy (Bernanke *et al.*, 1999). More precisely, Mishkin (2000) lists five components to an IT framework: (i) a public announcement of a medium-term numerical inflation target; (ii) an institutional commitment to price stability as the primary monetary policy objective; (iii) an information-inclusive strategy to set monetary policy instruments; (iv) an increased level of transparency for the conduct of monetary policy;

¹ Note that Slovakia, which adopted IT in 2005, has joined the European Monetary Union (EMU) in 2009.

² These countries are: Albania, Angola, Armenia, Azerbaijan, Belarus, Bolivia, Botswana, China, Costa Rica, Dominican Republic, Egypt, Georgia, Guinea, Honduras, Kenya, Kyrgyz Republic, Mauritius, Moldova, Morocco, Nigeria, Pakistan, Papua New Guinea, Paraguay, Serbia, Sri Lanka, Sudan, Tunisia, Uganda, Ukraine, Uruguay, Venezuela, Vietnam, Zambia (IMF, 2006).

³ Note however that Brito and Bystedt (2010) find no evidence that IT improves economic performances in emerging countries.

(v) and, an increased accountability of central bank for attaining its inflation objectives. Thus, this monetary policy strategy requires much more than a public announcement of numerical inflation targets. The main advantage of an IT framework is the increase of monetary policy discipline, transparency and coherence (Bernanke *et al.*, 1999; Faust and Henderson, 2004). Furthermore, according to Bernanke *et al.* (1999), IT offers a framework of ‘constrained discretion’ where the official target imposes the constraint, and the discretion is the scope for monetary authorities to take into account short-term disturbances to output or financial stability. This flexibility in the conduct of monetary policy is particularly important for emerging economies that are often adversely affected by external shocks (Fraga *et al.*, 2003).

These considerations suggest therefore that the success and the sustainability over the medium term of IT entail the fulfillment of several economic and institutional conditions. The literature has identified some preconditions that countries should theoretically satisfy before adopting IT⁴. However, the experience of emerging countries shows that the non fulfillment is not in itself an impediment to the adoption and success of this monetary policy framework. This emphasizes especially that the implementation of IT is a gradual process with economic and institutional reforms before and after the official adoption of this monetary policy framework. Indeed, as illustrated in Batini and Laxton (2006), we observed in some emerging countries that the adoption of IT has been associated with rapid improvements in institutional and technical structures.

Besides these post-IT technical and institutional changes, we think that the adoption of IT by emerging market economies could also affect the design of fiscal policy, and more particularly the design of tax policy. Indeed, by strengthening the central bank independence and by giving the monetary authority a clear mandate for low inflation, the IT regime deprives the government of seigniorage revenue which is an important source of public revenue in developing and emerging countries. Consequently, we can expect that the government will attempt to enhance its tax revenue collection in order to recoup the loss of inflation tax revenue. In a recent theoretical paper, Minea and Villieu (2009) address this question and

⁴ These preconditions have been especially underlined in the literature on IT in emerging market economies, such as Masson *et al.* (1997), Mishkin (2000), Amato and Gerlach (2002), and Carare *et al.* (2002). These requirements include in particular an independent, transparent and accountable central bank with a clear price stability mandate, a sound fiscal policy, a well-developed financial market, a flexible exchange rate regime, relatively low inflation rates, and well-developed statistic and econometric models to understand monetary policy transmission mechanisms and to forecast inflation.

show that a tighter monetary policy, characterized by a low inflation target, encourages the government to enhance the performance of its tax administration.

Therefore, the aim of this paper is to empirically test this theoretical prediction by investigating whether the adoption of IT has encouraged the governments of emerging countries to raise domestic tax revenue. To the best of our knowledge, no previous empirical study has tried to investigate this question.

The remainder of the paper is organized as follows. Section 2 discusses briefly the literature and outlines the channels through which IT could affect tax policy in emerging economies. The econometric model and the data are described in section 3. Section 4 discusses our econometric results and reports the robustness checks. Section 5 concludes, highlighting the main policy implications of our empirical findings.

2. Inflation targeting and tax policy design in emerging economies

Over the past three decades, a large academic literature has studied the strategic interactions between monetary policy making institutions and the fiscal stance. A first, mostly theoretical strand of the literature focused on the impact of fiscal policy on monetary policy. Characterizing the interaction between monetary and fiscal policy as a non-cooperative game between the government and its central bank, this strand of the literature shows that monetary policy can be constrained by fiscal policy if the government runs large budget deficits that will force sooner or later the monetary authority to create money and tolerate additional inflation, i.e. monetize the public debt. This scheme, formally introduced by the seminal paper of Sargent and Wallace (1981), is commonly known as the “unpleasant monetarist arithmetic”. The argument of inflationary fiscal effects was afterwards taken up by the “fiscal theory of the price level”, which argues that in a non-Ricardian regime the fiscal policy is the primary determinant of the price level (see, e.g., Leeper, 1991; Sims, 1994; Woodford, 1994; Christiano and Fitzgerald, 2000; Cochrane, 2001).

A second strand of the literature explored the inverse causality linkage, by studying whether monetary policy can affect the design of fiscal policy. The results of this literature suggest in particular that the delegation of monetary policy to an independent and more conservative central bank, by depriving the government of future inflation tax revenue, will constrain it to fiscal discipline (see, e.g., Masciandaro and Tabellini, 1987; Castellani and Debrun, 2001;

and, Montiel, 2003). Indeed, according to Burdekin and Lane (1988, p. 648), “if the fiscal authority faces an independent central bank committed to anti-inflationary policy, then the expectation that the deficit will not be accommodated tomorrow may deter the government from running a deficit today”. This argument, based on the implicit assumption that the monetary authority always prevails in a ‘game of chicken’ vis-à-vis the fiscal authority (Sargent and Wallace, 1981), was supported by an extensive empirical literature. This latter shows that central bank independence exerts a negative effect not only on the size of monetized deficit, but also on the size of the public deficit (see, e.g., Burdekin and Laney, 1988; Parkin, 1987; De Haan and Sturm, 1992; Lucotte, 2009).

This problematic of the influence of central bank independence on fiscal discipline refers to the question of the sources of financing of public imbalances and, consequently, is particularly important when we study the linkage between IT adoption and tax policy in emerging economies for two reasons. First, seigniorage represents an important source of revenue for governments in developing and emerging countries, since compared to other revenue sources which impose high collection costs, it tends to be easier to collect and enforce (IMF, 2001). Second, as argued by Gerlach (1999), by giving the monetary authority a legislated and clearly objective of price stability, IT can be viewed as a substitute for central bank autonomy. Accordingly, under an IT framework, government’s revenue from seigniorage is expected to decrease.

More precisely, three main channels can be advanced to explain why the adoption of IT should induce a government to conduct a more responsible fiscal policy and, to enhance its tax revenue collection in order to recoup the loss of seigniorage revenue. First, in many IT countries, the adoption of this monetary policy strategy has been associated with major institutional reforms granting notably central banks greater independence from the political policymakers. Indeed, as underlined by the literature (see, e.g. Bernanke *et al.*, 1999; Amato and Gerlach, 2002), central bank independence is an essential precondition for the adoption and the viability of IT since it protects the monetary authority against electoral cycles and hence reduces the inflation bias. More particularly, the success of IT requires a large degree of instrument independence, which refers to the ability of the central bank to set monetary policy instruments and to achieve its inflation objective without substantial government interference. From a legislative point of view, instrument independence implies to prohibit the government to have recourse to central bank financing, either directly or indirectly, to cover public deficits. This means that the monetary authority cannot extend credits to the government and,

intervene in the bond market to influence long-term interest rates. Although such intervention may sometimes be guided by inflation and output considerations, we have observed many central banks in emerging countries directly intervene in the bond market to stabilize long-term yields, especially when the government had to issue large amounts of bonds to finance its fiscal deficit (Mohanty, 2002; Reddy, 2002). Consequently, if a government expects that the central bank will not help it to manage its debt by intervening in the bond market to stabilize bond prices, since such intervention can be counterproductive for monetary policy, it will be less inclined to run large budget deficits (Sargent, 1993).

Second, by giving the central bank a clear objective of price stability and by holding it accountable for achieving that one, IT leads to tighter monetary policies. Thus, adoption of IT may initially induce higher debt/GDP ratios by increasing the debt service cost, since a tighter monetary policy is associated with higher real interest rates. This is particularly true when the share of domestic debt to total public debt is high and the average maturity is short, which makes the public finances more vulnerable to interest-rate shocks (Aktas *et al.*, 2010). As argued by de Mendonça and da Silva (2009) in the case of Brazil, this rise of the debt ratio might require an increase in the primary surplus to offset it. This argument can therefore explain why inflation targeting can encourage the governments that have adopted this monetary policy framework to enhance their tax revenue collection. Nonetheless, to avoid such public debt trajectory and not undermine the success of IT, it is important to note that some countries have made the choice to implement fiscal reforms before the adoption of IT, not only to reduce the level of public debt, but also to increase the average debt maturity. This is for instance the case of New Zealand, the first country which has switched to an IT regime in 1990, when it adopted the Public Finance Act in 1989, consolidated in 1994 with the Fiscal Responsibility Act. The *raison d'être* of these legislative reforms was to consolidate legislation regarding public finance after a long period of structural fiscal deficits, in order to promote long-term fiscal sustainability. Among other things, this legislative framework required public debt to be reduced and maintained at prudent levels, and a high degree of transparency of government about its fiscal strategy by setting out long-term fiscal objectives for total operating expenses, total operating revenues, the operating balance, total debt, and total net worth (see, e.g., Reddell, 1999; Sherwin, 1999; Bollard and Karagedikli, 2006). Thus, after two decades of persistent deficits that ran as high as 5% of GDP, the New Zealand's central government deficit returned approximately to balance in 1993-1994. More recently, the Turkey has also supported significant fiscal adjustment efforts before officially

adopting IT in 2006. Indeed, after the 2001 crisis, this emerging country faced high levels of public debt. In 2000, the public debt rose to around 78% of GDP and became Turkey's main source of macroeconomic vulnerability (Sahinbeyoglu, 2008). Especially, the average maturity of the public debt was short, less than 6 months, while real Treasury bill rate was very high, around 50%. To address these debt problems, the government of Turkey relied on extensive emergency financing from international institutions and increased its primary surplus target, with the objective to reduce the debt service burden. The strict commitment of the Turkey to these reforms has allowed to improve substantially the government's fiscal position and the debt sustainability, and finally to adopt IT without being in a situation of fiscal dominance. On the basis of these countries' experiences, the prospect of IT adoption seems to be a strong signal for fiscal discipline and tax revenue performance.

Finally, as shown by the empirical literature, IT adoption in emerging economies has been associated with reductions in both the average level and the volatility of inflation (see, e.g., IMF, 2005; Lin and Ye, 2009; de Mendonça and de Guimarães e Souza, 2011). This decrease of inflation implies a sizable loss of inflation tax revenue for governments, which face an increase of the real value of their public debts⁵. As developed above, this rise in the cost of debt service due to higher real Treasury bill rates will require that governments increase durably their primary surplus. Concretely, to increase durably its primary surplus, a fiscal authority has two complementary options: restrain its spending and increase its revenue. On the expenditure side, the government can undertake measures to reduce its structural spending and enhance the allocative efficiency of public expenditure. In emerging markets, over the last two decades, a common measure to consolidate fiscal accounts consisted of privatizing or reforming state-owned firms (Montiel, 2003). On the revenue side, the government can implement reforms to improve the performance of its tax administration, i.e. its capability to impose and collect taxes efficiently. Thus, the implementation of such tax reforms is likely to generate more revenues at a given level of economic activity and so, to recoup the loss of inflation tax revenue. Following this, Minea and Villieu (2009) have recently developed a theoretical model which shows that a tighter monetary policy, characterized by a low inflation target, should induce the government to improve institutional quality in order to limit the

⁵ Note however that a significant and rapid decrease of inflation rate can theoretically affect positively the real value of tax revenue. This effect, so-called Olivera-Tanzi effect (Tanzi, 1992), means that the real value of tax revenue can be eroded by inflation, since there exists for some tax categories a time-lag between the date of imposition and the effective collection of these taxes. Nonetheless, we expect that the 'inverse' Olivera-Tanzi effect is relatively marginal in emerging countries that have adopted IT, since this latter was adopted after a disinflation process for the majority of them.

erosion of tax revenue⁶. Extending the model developed by Huang and Wei (2006), Minea and Villieu (2009) find more precisely that, conditionally to the cost of institutional reforms⁷, the lower the inflation target is, the higher the government's effort in implementing a more efficient tax-collecting administration is. This interesting result joints the arguments outlined above which show that the adoption of IT in emerging countries, characterized by a tighter and more independent monetary policy, is expected to exert a positive effect on tax revenue collection.

In this section, we have tried to describe through which channels the adoption and the conduct of an IT strategy can impact tax policy design in emerging economies, strongly dependent on seigniorage revenue. This short theoretical excursion was particularly important since there exists a large debate in the literature, both theoretical and empirical, about the ability of IT, as opposed to fixed exchange rates to encourage fiscal discipline. Thus, Hamman (1999) viewed in hard pegs a better nominal anchor than inflation target to strengthen fiscal discipline, especially during disinflation process: "The argument is that a credible commitment to a highly visible variable such as the exchange rate (as opposed to an inflation or money target) will be a relatively more effective way to eliminate 'inflation bias' [...], and would provide a better incentive to produce the fiscal adjustment needed for the sustainability of low inflation and the viability of the peg itself" (Hamman, 1999, p. 9). This argument is empirically supported by Edwards (1993) and Fatas and Rose (2001), whose results indicate that countries that have adopted hard pegs, such as currency union or currency board, exhibit on average greater fiscal accountability than countries with floating exchange rates. On the contrary, Tornell and Velasco (1995, 1998, 2000) find no theoretical and empirical evidence on the ability of hard-peg regimes to strengthen fiscal discipline. The effect of IT on fiscal policy design is thus an empirical question that we will test in the next section.

⁶ The literature identifies many causes of poor tax administration in developing countries. These causes are principally: (i) a high level of taxpayers' noncompliance and tax evasion because the tax system is perceived as unfair, and there is a lack of transparency in the use of public funds; (ii) a high corruption in the tax administration due to low wages in the public sector compared to the private sector, and a low probability of detection and punishment for corruption; and, (iii) a large informal sector.

⁷ According to Huang and Wei (2006, p. 248), '*the cost could be in the form of a loss of economic rents that officials enjoy, or a stiffened resistance from powerful special interest groups that have been benefiting from corruption and lost tax revenue*'.

3. Data and methodology

To investigate whether the adoption of IT in emerging economies has encouraged the governments to increase domestic tax revenue, we implement the propensity score matching (hereafter PSM) methodology developed by Rosenbaum and Rubin (1983) and Heckman *et al.* (1998). This method is becoming increasingly popular in microeconometrics in order to assess the performance of development programs, such as school or health programs. Although still little used in macroeconomic studies, the PSM approach has nevertheless been recently used by Vega and Winkelried (2005), Lin and Ye (2007, 2009) and de Mendonça and de Guimarães e Souza (2011) to assess the impact of IT adoption on the level and variability of inflation in developed and emerging economies.

Our panel dataset consists of fifty-nine emerging market countries, inflation targeters and non-inflation targeters, over the period of 1980-2009⁸. The data are drawn from various sources, including in particular World Development Indicators (WDI) and the Database of Political Institutions (DPI)⁹.

3.1. Data

Independent variable and sample countries. The independent variable of interest is a binary variable taking the value 1 if a country operates with an IT framework at the year t , and 0 otherwise. In this paper, following Levya (2008), we consider two IT adoption dates for each country having adopted this monetary policy framework: one corresponding to a partial adoption (IT_PA) and the second to a fully-fledged adoption (IT_FF)¹⁰. Our sample of IT emerging economies is composed of Brazil, Chile, Colombia, Czech Republic, Ghana, Guatemala, Hungary, Indonesia, Israel, Mexico, Peru, Philippines, Poland, Romania, Slovakia, South Africa, South Korea, Thailand and Turkey. Concerning our control group, we follow Lin and Ye (2009) by including only non-targeting emerging countries that have a real GDP per capita at least as large as that of the poorest targeting country and with a population size at least as large as that of the smallest targeting country. This choice aims to ensure that the treatment group and the control group are reasonably comparable. According to these criteria, our control group is composed of forty countries. Table 1 lists the nineteen targeting

⁸ The data are not available for all countries on the whole period, so we use an unbalanced panel data. The list of countries that constitute our sample is given in Table 1.

⁹ See Appendix A for variables definitions and sources.

¹⁰ Note that Levya (2008) adopts the ‘half-year rule’: if IT is adopted in the second half of any year t , the year $t+1$ is considered as the adoption year.

and the forty non targeting countries considered in this study, and the years in which IT countries have adopted this monetary policy framework¹¹.

Table 1: Country samples and dates of IT adoption

<i>IT countries</i>			<i>Non-IT countries</i>	
	<i>Partial adoption</i>	<i>Fully-fledged adoption</i>		
Brazil	1999	1999	Algeria	Kazakhstan
Chile	1991	2000	Angola	Kenya
Colombia	2000	2000	Argentina	Lao PDR
Czech Republic	1998	1998	Bangladesh	Malaysia
Ghana	2007	2007	Belarus	Morocco
Guatemala	2005	2005	Benin	Nigeria
Hungary	2001	2001	Bolivia	Pakistan
Indonesia	2005	2005	Bulgaria	Russia
Israel	1992	1997	Cambodia	Senegal
Mexico	1995	2001	Cameroon	Sri Lanka
Peru	1994	2002	China	Sudan
Philippines	2002	2002	Côte d'Ivoire	Syria
Poland	1999	1999	Dominican Rep.	Tanzania
Romania	2005	2005	Ecuador	Tunisia
Slovakia	2005	2005	Egypt	Ukraine
South Africa	2000	2000	El Salvador	Venezuela
South Korea	1998	1998	Haiti	Vietnam
Thailand	2000	2000	Honduras	Yemen
Turkey	2006	2006	India	Zambia
			Iran	Zimbabwe

As shown in Table 1, four countries (Chile, Israel, Mexico, and Peru) started using a partial IT framework before switching to a full-fledged IT. In fact, during this transition period, central banks of these countries have maintained an additional nominal anchor for monetary policy (typically an exchange rate band). Moreover, according to Mishkin and Schmidt-Hebbel (2007), a partial IT is also characterized by the non-fulfillment of key preconditions for IT and the non-establishment of operational features of IT (such as publishing inflation reports that contain inflation projections).

Dependent variable. The endogenous variable considered in our study is the total public revenue (excluding grants) as share of GDP compiled by the Center for Studies and Research on International Development on the base of International Financial Statistics (IFS) and

¹¹ Slovakia is considered as an IT country until 2008 since it joined EMU in 2009. Furthermore, note that we have taken the year 2000 as reference to apply the criteria defined by Lin and Ye (2009), this year corresponding to the mean of the adoption dates (*IT_PA*) in the targeters group. Azerbaijan, Guinea, Serbia, and Uzbekistan satisfy the criteria of GDP per capita and population size, but are not included in the control group since many data are not available for these countries.

Government Finance Statistics (GFS) databases, and national statistics. Although most studies use tax revenue, we measure taxation revenue as total public revenue (*TAX_REV*). Three arguments can be advanced to explain our choice. First, availability of relevant data on domestic tax revenue for developing and emerging countries is relatively limited. Second, in developing and emerging economies, public revenue is principally composed of direct taxes (taxes on income and profit) and indirect taxes (taxes on international trade and domestic taxes on consumption – sales tax, Value-Added tax and excise tax), while non-tax revenue represents a small part of the public revenue¹². Third, total public revenue is less sensitive to the substitution effect between the different components of public revenue, i.e. tax revenue and non-tax revenue (Chambas, 2005).

Figure 1a presents a comparison of average total public revenues between IT countries and non-IT countries over different time periods, while figure 1b presents a comparison of average total public revenues between pre and post-IT periods for inflation targeters. In figure 1a, we compare firstly average total public revenue in IT and non-IT economies on the overall period (1980-2009), while for the two other specifications we follow Ball and Sheridan (2003) suggestion to make a comparison between inflation and non-inflation targeters after the adoption (partial and fully-fledged respectively) of this monetary policy framework¹³. The two specifications in figure 1b correspond to a comparison of average public revenue between pre and post-IT periods, respectively in the case of a partial adoption (*IT_PA*) and a fully-fledged adoption (*IT_FF*). Two preliminary results emerge from figures 1a and 1b. First, on average, IT countries have higher levels of public revenue than non-IT economies. Second, in IT countries, average total public revenue tends to increase after the adoption of IT. Hence, this latter result seems to indicate that IT countries have intensified their efforts to collect more public revenue after the implementation of IT.

¹² The non-tax revenues include in particular social security contributions, dividends from state firms, rents from government property, fines, penalties, and sales of goods and services.

¹³ Ball and Sheridan (2003) suggest to take as the ‘year of adoption’ for non-targeters the mean of the adoption dates in the targeters group. This date is so the same for all non-IT countries, respectively 2000 if we consider partial adoption (specification 2) and 2001 in the case of fully-fledged adoption (specification 3).

Figure 1a: Average total public revenue (% of GDP): IT vs. Non-IT countries

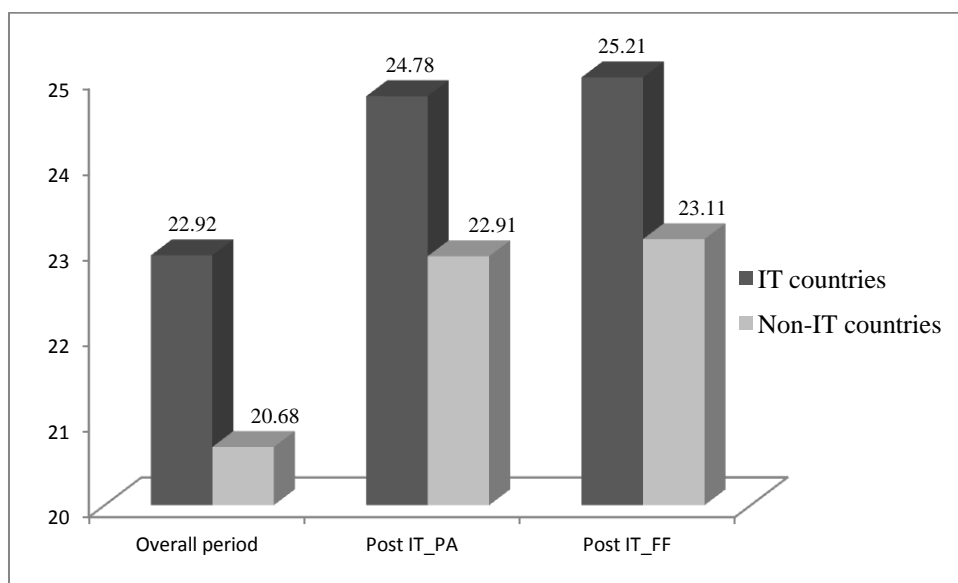
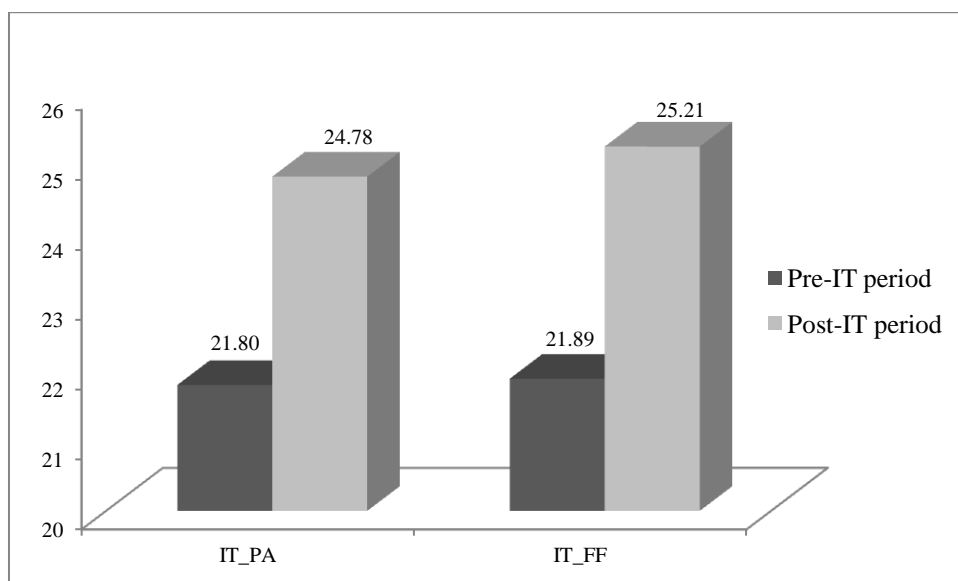


Figure 1b: Average total public revenue (% of GDP): pre-IT vs. post-IT periods



Finally, the other variables of the model are variables that could explain the probability that an emerging country adopts an IT framework. Following Lin and Ye (2009) and the empirical literature devoted to the determinants driving the choice of IT¹⁴, we consider the following variables: the lagged inflation rate¹⁵ (*INF_I*), the five-year central bank governors turnover

¹⁴ See notably Pétursson (2004) for a detailed survey of empirical literature.

¹⁵ The inflation rate is lagged one period to avoid a potential simultaneity bias between IT adoption and inflation level.

rate (*TOR_5*), the real per capita GDP growth (*GDPPCG*), the domestic credit to private sector to GDP (*PCRED*), the *de facto* exchange rate regime (*EXCH*), and the trade openness (*OPEN*). Furthermore, contrary to previous empirical studies, we include also as potential determinant of IT adoption in emerging economies the number of countries (industrialized and emerging) that have adopted IT at the year t (*NUM_IT*). This variable is introduced to account for a potential ‘popularity effect’ of IT. Indeed, although they do not satisfy most of the preconditions theoretically required for adopting IT, a growing number of emerging countries has adopted this monetary policy framework over the last decade and, as emphasized in introduction, many other have expressed an interest in moving to IT at short-medium term. This increasing popularity of IT among emerging economies can nonetheless be explained by the relative good macroeconomic performance of inflation targeters, and by ‘promotion’ efforts made by the IMF to support and encourage emerging countries to adopt IT (Epstein, 2006). Following the literature on the preconditions for adopting IT and the results of previous empirical papers, we expect the first two covariates to be negatively correlated with the likelihood of adopting IT, while the financial development, the exchange rate flexibility and the trade openness are expected to have a positive effect on this probability. Concerning the real per capita GDP growth, the expected sign is ambiguous since some papers found a positive but insignificant sign (see, e.g., Lin and Ye, 2009), while others found a negative effect of GDP growth on the likelihood of adopting IT (Truman, 2003).

3.2. Econometric methodology

The main challenge of our econometric analysis is to deal with the nature of the independent variable. Indeed, as specified above, the independent variable of interest is binary, and takes the value 1 if a country pursues an IT policy at the year t and 0 otherwise. In the case of our study, the difficulty of evaluating the impact of IT adoption on domestic tax revenue resides in the fact that we cannot observe what would have been this revenue if an inflation targeter has made the choice to not adopt this monetary policy framework. Conversely, it is impossible to observe what would have been domestic tax revenue if a non-inflation targeter has switched to IT.

A simple solution to assess this causal effect, by definition unobservable, would consist in comparing average public tax revenue of IT countries with those of a comparison group of countries which have not adopted IT (canonical model introduced by Rubin, 1974). In doing so, we suppose that our two groups of economies are very similar, such that countries which

adopted IT would have had domestic tax revenue similar to those in the comparison group in the absence of IT. However, as we know, emerging countries constitute a relatively heterogeneous group. Thus, such a statistical approach raises the question of selection bias, which can lead to an overestimation of the impact of IT adoption on tax revenue¹⁶.

In response to this selectivity bias problem, Rosenbaum and Rubin (1983) have developed the PSM methodology. This latter is a non experimental method which consists of matching treated observations with untreated observations on the basis of observed characteristics unaffected by the treatment. The average treatment effect is then calculated as the mean difference in outcomes across these two groups, i.e. treated and untreated. In our case, the treatment corresponds to the adoption of IT and the outcome is the domestic tax revenue. Indeed, a country is considered as ‘treated’ if it pursues an IT strategy at the year t , and as ‘untreated’ if it does not operate with this monetary policy framework at the same period. Finally, concerning the matching, it is conducted on a set of potential determinants associated with a country’s choice of IT.

Therefore, the average treatment effect on treated (hereafter ATT) can be written as:

$$\Delta_{ATT}^{PSM} = E[Y_{it}^1 | T_{it} = 1, p(X_{it})] - E[Y_{it}^0 | T_{it} = 0, p(X_{it})] \quad (1)$$

where T is the independent variable corresponding to the adoption of IT and Y is the domestic tax revenue. Thus, $Y_{it}^1 | T_{it} = 1$ represents the domestic tax revenue observed in a country having adopting IT at the year t ($T = 1$) and $Y_{it}^0 | T_{it} = 0$ the domestic tax revenue observed in the counterfactual. $p(X_{it})$ corresponds to the propensity score, i.e. the probability that conditionally to a set of observable covariates X , a country i adopts an IT framework at the period t . The propensity score is noted as:

$$p(X_{it}) = Pr(T_{it} = 1 | X_{it}) \quad (2)$$

The propensity score is estimated using a binary outcome model (probit or logit) where X_{it} is a vector of variables corresponding to observed country’s characteristics theoretically associated with the choice of adopting IT.

¹⁶ In theory, a selection bias can lead to an either underestimation or overestimation. Nonetheless, in our case study, an overestimation of the impact of IT adoption on domestic tax revenue could be expected since to adopt such a monetary policy framework, a country should theoretically fulfill several preconditions. One of them is a sound fiscal policy. So, we can expect that IT emerging countries are also those with a relatively developed tax administration.

Nevertheless, the PSM approach provides a sound impact assessment only if two assumptions are satisfied. The first is the conditional independence assumption, which means that given a set of observed covariates X unaffected by the treatment, the potential outcomes Y is independent of treatment assignment T . In other words, this means that the choice of adopting IT is independent of the potential outcomes in both situations, adoption or no adoption. Consequently, this implies that the choice of switching to an IT strategy is solely based on observable countries' characteristics and not on unobservable characteristics. Furthermore, in practical terms, this assumption implies that we must observe and include in the vector X all variables that influence simultaneously treatment assignment and potential outcomes. Formally, this hypothesis can be written as:

$$(Y_i^0, Y_i^1) \perp T_i | X_i \quad (3)$$

As shown by Rosenbaum and Rubin (1983), the fulfillment of this assumption is fundamental since it allows matching observations on the basis of their propensity score $p(X_{it})$ rather than on the whole conditioning variables. The propensity score constitutes then an unidimensionnal 'summary' of the covariates. According to Rubin (2007), the fact that the propensity score is independent of the potential outcomes constitutes the main advantage of matching estimators compared with other non experimental methodologies.

The second assumption is the common support condition whose importance has been emphasized by Heckman *et al.* (1998, 1999). In the case of our study, this condition ensures that we can find for each IT country at the period t a counterfactual in the comparison group of non-IT economies, i.e. an observation with the same or nearby propensity score. Formally, the common support condition means that observations with the same X values have a positive probability of being treated or untreated. Thus, this condition can be written as:

$$0 < p(X_{it}) < 1 \quad (4)$$

This condition implies that the propensity score distribution is not very different in the treatment and the control group. Consequently, the common support condition rules out the phenomenon of perfect predictability of T given X (i.e. the perfect predictability of IT adoption) and so, paradoxically, implies that the binary outcome model must not be 'too good' (Brodaty *et al.*, 2007).

By presenting in details the propensity score matching methodology and its relevance for our study, we have seen that the quality of impact analysis depends mainly on the 'robustness' of

propensity score estimates. Furthermore, the resulting estimate is also affected by the matching criterion used to assign treated and untreated on the basis of the propensity score. For this reason, most of papers use different matching algorithms to assess the effect of treatment¹⁷. In this paper, following Lin and Ye (2007, 2009), we use three PSM algorithms commonly used in the literature:

- (i) Nearest-neighbor matching estimator consists of matching each treated observation with an untreated observation that is the closest in terms of propensity score. We consider the one-to-one matching with no replacement ($n = 1$), the three nearest-neighbor matching ($n = 3$), and the five nearest-neighbor matching ($n = 5$);
- (ii) Radius matching estimator imposes a threshold on the maximum propensity score distance. We consider three calipers, i.e. three values for maximum distance of untreated observations: a wide radius ($r = 0.04$), a medium radius ($r = 0.02$), and tight radius ($r = 0.01$);
- (iii) Kernel matching estimator proposed by Heckman *et al.* (1998) consists of using a weighted average of all untreated observations to construct the counterfactual match for each treated observation. The weight given to each untreated observation depends on the distance from the treated observation in terms of propensity score. Logically, this weight increases with the convergence in terms of propensity score of untreated observations to the considered treated observation¹⁸.

4. Results

As implicitly shown in the previous section, the estimation process of the average treatment effect of IT on the level of domestic tax revenue includes two steps. The first step consists of estimating the propensity scores with a binary outcome model, while the second step consists of matching treated and untreated observations to estimate the average treatment effect on the treated.

¹⁷ See notably Caliendo and Kopeinig (2008) and Khandker *et al.* (2010) for detailed discussions concerning these algorithms.

¹⁸ The weights for kernel matching are given by: $(i, j) = \frac{K\left(\frac{P_j - P_i}{a_n}\right)}{\sum K\left(\frac{P_j - P_i}{a_n}\right)}$, where P_i is the propensity score for treated observation i , P_j is the propensity score for untreated observation j , $K(\cdot)$ is a kernel function, and a_n is a bandwidth parameter.

4.1. Estimating the propensity scores

To estimate the propensity scores, we use a probit model. The dependent variable is the IT variable. The results are reported in table 2, in which we distinguish the partial adoption and the fully-fledged adoption of IT. All significant estimated coefficients have the expected signs. We find that the *de facto* exchange rate flexibility, the domestic credit and the number of inflation targeters in the world are positively associated with a greater likelihood of adopting IT, while the turnover rate of central bank governors and the lagged inflation rate are significantly and negatively related with this probability. Furthermore, we find that the real GDP per capita growth is significantly and positively associated with the probability that a country adopts IT. This result is nonetheless consistent with those found by Truman (2003), who argued that poor macroeconomic performances increase the probability of IT adoption. Finally, as Gerlach (1999), we find a negative effect of openness on the probability of moving to IT, but this result is on the borderline of the statistical significance. The pseudo-R² is equal to 0.40 and 0.48 in the case of partial adoption and fully-fledged adoption, respectively.

Table 2: Probit estimates of propensity scores

	IT (<i>partial adoption</i>) (1)	IT (<i>fully-fledged adoption</i>) (2)
GDPPCG	-0.041** (0.02)	-0.073*** (0.02)
INF_1	-0.021*** (0.01)	-0.067*** (0.02)
PCRED	0.009*** (0.00)	0.009*** (0.00)
TOR_5	-0.974** (0.41)	-0.999** (0.47)
EXCH	0.225*** (0.03)	0.232*** (0.03)
OPEN	-0.003* (0.00)	-0.002 (0.00)
NUM_IT	0.069*** (0.01)	0.103*** (0.01)
Nb. of observations	1197	1197
Pseudo-R ²	0.40	0.48

Note: Constant terms are included but not reported. Standard errors are reported in parentheses. *, **, *** refer to statistical significance at the 10%, 5% and 1% respectively.

4.2. Results from matching

Before turning to the matching estimates¹⁹, we implement the common support condition which ensures that treated and untreated observations share the same support. In this paper, we use the methodology suggested by Dehejia and Wahba (1999) which consists of dropping treated observations whose the propensity score is higher than the maximum or smaller than the minimum in the control group. The estimated ATTs on the level of public revenue are reported in table 3. The first three columns show the results from nearest-neighbor matching, the columns (4) (5) and (6) report the results from radius matching, and the last column presents the results from kernel matching. The estimated ATTs are all found to be positive and statistically significant. This suggests that, on average, IT countries have higher levels of public revenue than non-IT countries. Our results support the theoretical arguments presented in section 2 and confirm that the adoption of IT has encouraged the governments of emerging countries to improve the collection of tax revenue. The average estimated ATT on the level of public revenue across different matching algorithms is about 4.46 in the case of partial adoption and is about 4.17 in the case of fully-fledged adoption.

Table 3: Matching estimates of treatment effect on the level of public revenue

	Matching algorithms						
	Nearest-neighbor matching			Radius matching			Kernel matching
	n = 1	n = 3	n = 5	r = 0.04	r = 0.02	r = 0.01	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
	<i>Partial adoption</i>						
Average Treatment on Treated (ATT)	4.57***	4.39***	4.31***	4.19***	4.47***	4.73***	4.56***
	(1.60)	(1.45)	(1.39)	(1.19)	(1.20)	(1.37)	(1.47)
Nb. of treated observations on common support	110	110	110	110	110	108	110
Nb. of treated observations off common support	21	21	21	21	21	23	21
	<i>Fully-fledged adoption</i>						
Average Treatment on Treated (ATT)	4.48***	3.63**	3.07*	3.49**	4.56***	5.45**	4.53**
	(1.93)	(1.81)	(1.88)	(1.53)	(1.57)	(1.63)	(2.06)
Nb. of treated observations on common support	103	103	103	103	97	85	103
Nb. of treated observations off common support	10	10	10	10	16	28	10

Note: A 0.06 fixed bandwidth and an Epanechnikov kernel are used for kernel regression matching. Bootstrapped standard errors are reported in parentheses (1000 replications). *, **, *** refer to statistical significance at the 10%, 5% and 1% respectively.

¹⁹ Matching estimates are obtained using the Stata module PSMATCH2 developed by Leuven and Sianesi (2003).

4.3. Robustness checks

We check the robustness of our empirical results in several ways. Nonetheless, in order to economize space, in this sub-section, we report only probit results for fully-fledged adoption dates. Results for partial adoption dates can be provided upon request.

First, we check whether our results are sensitive to alternative specifications of the probit model. More precisely, we introduce in the basic specification of our probit model some variables that could simultaneously influence the choice of adopting IT and the level of domestic tax revenue. These variables are: the public debt as share of GDP (*DEBT*), general government final consumption expenditure as share of GDP (*GVT_EXPEND*), the Polity2 index (*POLITY2*) developed by the Polity IV Project, the government stability index (*GSTAB*), a partisanship dummy (*RIGHT*), and the logarithm of population (*POP_LOG*). The public debt variable, taken from the new dataset computed by Abbas *et al.* (2010), is introduced to take into account the fiscal soundness. Indeed, as emphasized above, one of the preconditions for successful IT strategy is a sound fiscal policy, which requires a strengthening of tax administration system and improvements in expenditure control and debt management. Following Truman (2003), Hu (2006) and Calderón and Schmidt-Hebbel (2008), we therefore expect a negative effect of public debt on the probability of adopting IT regime. We also introduce a variable that measures the level of government expenditure, since there is a large interdependence between public revenue and expenditure. Concerning the Polity2 index, it measures the ‘degree’ of democratization in a country. It takes value from -10 (very autocratic) to +10 (very democratic) and is constructed by subtracting the democracy score from the autocracy score. This index, which can be viewed as an overall measure of political stability, is expected to be positively related with the likelihood of adopting IT. Moreover, as shown by Ehrhart (2009), there exists a positive relationship between the level of democracy and the domestic tax revenue in developing countries. Similarly, we consider the government stability index computed by the DPI, which counts the number of exits of veto players between year t and year $t+1$ divided by the total number of veto players in year t . Following Gupta (2007), we expect this variable to be positively correlated with the public revenue since efficient reforms in tax administration and so, tax revenue performance, require relative government stability. We also take into account the political orientation of the executive by including a dummy variable taking the value 1 if the executive belongs to a party of the right, and 0 if left-wing or centrist. Indeed, as suggested by Mukherjee and Singer

(2008), there exists a significant relationship between political orientation and the probability of adopting IT, while several empirical studies document the association between ideology and fiscal preferences (see, e.g., Woo, 2003; Tavares, 2004). Finally, we introduce the logarithm of population to take into account the country size. Although the link between this variable and the probability of a country adopting IT is indeterminate, the inclusion of the population size as additional control variable is important since the empirical literature shows a positive relationship between this covariate and the tax revenue/GDP ratio (Khattry and Rao, 2002). The new probit estimates including these additional control variables are presented in the first six columns of table 4. The results indicate that government expenditure and the level of democracy have a positive and significant effect on the probability of adopting IT, while government stability is not statistically significant. Finally, the public debt has the expected sign and is significant. Concerning other covariates, the results are very similar to those reported in the table 2.

Second, we check if our results are robust when we move from a *de facto* measure of central bank independence to a *de jure* measure. We therefore replace in the probit model the turnover rate of central bank governors by the central bank independence index developed by Cukierman *et al.* (1992). This index (hereafter CWN index) has four components relating to each aspect of central bank independence (see Cukierman *et al.* [1992] for a thorough description of the index and its subcomponents). One of these components relates to the possibility of the government to have recourse to central bank financing (*CBI_LENDING*). As shown in section 2, the inclusion of this variable seems particularly important in the framework of our study. Columns (7) and (8) of table 4 reports the results when we include these two variables. Furthermore, following Cukierman *et al.* (1992), we include in the same regression (column 9 of table 4) the *de facto* (*TOR_5*) and the *de jure* (CWN index) measures of central bank independence. Our results confirm the fact that central bank independence is an essential prerequisite for IT adoption.

Third, we check whether our results are robust to different sample periods. We then re-estimate the initial probit model by dropping the pre-1990 observations, and the post-2007 crisis observations. Columns (10) and (11) of table 4 report the results from these probit regressions. Probit results do not change significantly when we consider these sample periods.

Table 4: Probit estimates of propensity scores, robustness checks (fully-fledged adoption)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
GDPPCG	-0.079*** (0.02)	-0.063*** (0.02)	-0.045 (0.03)	-0.070*** (0.02)	-0.091*** (0.03)	-0.066*** (0.02)	-0.048** (0.02)
INF_1	-0.07*** (0.01)	-0.068*** (0.01)	-0.084*** (0.02)	-0.068*** (0.02)	-0.067*** (0.02)	-0.071*** (0.02)	-0.065*** (0.02)
PCRED	0.008*** (0.00)	0.007*** (0.00)	0.008*** (0.00)	0.009*** (0.00)	0.007*** (0.00)	0.011*** (0.00)	0.010*** (0.00)
TOR_5	-1.00** (0.48)	-0.505 (0.49)	-1.775*** (0.58)	-1.026** (0.47)	-1.395*** (0.53)	-1.003** (0.47)	
EXCH	0.228*** (0.02)	0.241*** (0.03)	0.219*** (0.03)	0.231*** (0.03)	0.214*** (0.03)	0.241*** (0.03)	0.242*** (0.03)
OPEN	-0.002 (0.00)	-0.001 (0.00)	-0.001 (0.00)	-0.002 (0.00)	0.002 (0.00)	-0.004* (0.00)	-0.002 (0.02)
NUM_IT	0.101*** (0.01)	0.119*** (0.02)	0.122*** (0.02)	0.103*** (0.01)	0.087*** (0.01)	0.108*** (0.01)	0.088*** (0.02)
DEBT	-0.006** (0.00)						
GVT_EXPEND		0.082*** (0.01)					
POLITY2			0.284*** (0.04)				
GSTAB				0.281 (0.27)			
RIGHT					0.118 (0.19)		
POP_LOG						-0.124* (0.07)	
CWN Index							1.875*** (0.49)
Nb. of obs.	1160	1145	1197	1181	676	1197	816
Pseudo-R ²	0.49	0.52	0.65	0.48	0.46	0.49	0.50

Note: Constant terms are included but not reported. Standard errors are reported in parentheses.

*, **, *** refer to statistical significance at the 10%, 5% and 1% respectively.

Fourth, since some countries of our sample have known high inflation periods, it is possible that outliers associated with these high-inflation episodes affect the results of our probit regressions, and, consequently, the matching estimates. Hence, we check the robustness of our results by dropping all high-inflation periods (defined as an annual inflation rate $\geq 40\%$). The results from the probit regression are reported in column (12) of table 4. The results are very similar to those reported in the table 2. In particular, the estimated coefficient of lagged inflation rate is still negative and significant at the 1% level.

Table 4 (continued): Probit estimates of propensity scores, robustness checks (fully-fledged adoption)

	(8)	(9)	(10)	(11)	(12)	(13)	(14)
GDPPCG	-0.052** (0.02)	-0.060*** (0.02)	-0.073*** (0.02)	-0.076*** (0.02)	-0.073*** (0.02)	-0.069** (0.02)	-0.051** (0.02)
INF_1	-0.067*** (0.02)	-0.069*** (0.02)	-0.067*** (0.01)	-0.061*** (0.02)	-0.068*** (0.02)	-0.071*** (0.02)	-0.077*** (0.02)
PCRED	0.009*** (0.00)	0.010*** (0.00)	0.009*** (0.00)	0.010*** (0.00)	0.009*** (0.00)	0.001 (0.00)	0.002 (0.00)
TOR_5		-1.089** (0.53)	-1.003** (0.47)	-1.201** (0.49)	-0.999** (0.47)	-1.353** (0.59)	-1.509*** (0.52)
EXCH	0.250*** (0.03)	0.242*** (0.03)	0.232*** (0.03)	0.217*** (0.03)	0.232*** (0.03)	0.219*** (0.03)	0.263*** (0.03)
OPEN	-0.002 (0.00)	-0.002 (0.00)	-0.002 (0.00)	-0.002 (0.00)	-0.002 (0.00)	-0.001 (0.00)	-0.003* (0.00)
NUM_IT	0.097*** (0.02)	0.083*** (0.01)	0.101*** (0.01)	0.111*** (0.01)	0.103*** (0.01)	0.124*** (0.02)	0.101*** (0.01)
CBI_LENDING	0.971*** (0.36)						
CWN Index		1.920*** (0.48)					
Nb. of obs.	816	816	952	1137	1022	627	789
Pseudo-R ²	0.49	0.51	0.45	0.48	0.46	0.53	0.53

Note: Constant terms are included but not reported. Standard errors are reported in parentheses.

*, **, *** refer to statistical significance at the 10%, 5% and 1% respectively.

Finally, we check whether our results are robust to changes in the sample of non-IT countries (i.e. the control group), since emerging economies are relatively heterogeneous. Thus, we consider two different samples of non-IT economies taken from Gonçalves and Salles (2008) and Joyce and Nabar (2009). In their paper, Gonçalves and Salles (2008) consider a control group of twenty-six emerging countries, while Joyce and Nabar (2009) consider as emerging economies the countries which appear on at least two of the three following classifications: the Standard & Poor's Emerging Market Index, the Morgan Stanley Capital International Emerging Market Index, and the IMF's International Capital Markets Department's list of emerging markets. Probit results with these two alternative control groups are reported in columns (13) and (14) of table 4. They are consistent with those found in the previous subsection.

The matching results based on these new propensity scores are presented in table 5. Most of the estimated ATTs remain positive and statistically significant, even if they are less or not significant when we add the government expenditure and the partisanship dummy to the baseline probit model than other specifications, especially when we consider fully-fledged adoption dates. Thus, our empirical results are relatively robust to alternative specifications of

probit model and confirm our theoretical prediction that the adoption of IT has had a significant positive impact on tax revenue collection in emerging economies.

Table 5: Matching estimates of treatment effect on the level of public revenue, robustness checks

	Matching algorithms						Kernel matching
	Nearest-neighbor matching			Radius matching			
	n = 1	n = 3	n = 5	r = 0.04	r = 0.02	r = 0.01	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
<i>Partial adoption</i>							
Average Treatment on Treated (ATT)							
Adding public debt	4.64*** (1.69)	4.86*** (1.50)	4.69*** (1.38)	4.53*** (1.26)	4.28*** (1.30)	4.17*** (1.44)	4.46** (1.95)
Adding government expenditure	2.81* (1.67)	2.59* (1.50)	2.96** (1.38)	3.37*** (1.15)	3.15*** (1.20)	2.77** (1.31)	3.07* (1.76)
Adding Polity2	2.42* (1.48)	3.12** (1.25)	3.68*** (1.28)	3.95*** (1.10)	3.75*** (1.21)	2.73** (1.36)	2.66* (1.39)
Adding government stability	3.86** (1.65)	3.57*** (1.38)	4.05*** (1.39)	4.50*** (1.19)	4.61*** (1.22)	4.45*** (1.35)	3.87** (1.60)
Adding partisanship dummy	4.98** (2.21)	3.81** (1.95)	3.83** (1.84)	5.29*** (1.75)	4.94*** (1.63)	5.16*** (1.70)	5.80* (3.28)
Adding log of population	3.72** (1.56)	3.44** (1.42)	3.88*** (1.34)	4.29*** (1.12)	4.34*** (1.14)	3.90*** (1.34)	4.20*** (0.96)
Considering <i>de jure</i> CBI	4.67*** (1.48)	4.95*** (1.35)	5.45*** (1.36)	4.81*** (1.19)	4.70*** (1.23)	4.99*** (1.29)	4.20*** (1.62)
Considering CBI_LENDING	4.93*** (1.44)	4.33*** (1.39)	4.54*** (1.27)	4.54*** (1.18)	4.58*** (1.21)	4.79*** (1.25)	3.33*** (0.95)
Adding CWN index	4.35*** (1.49)	4.19*** (1.36)	4.60*** (1.30)	4.35*** (1.15)	3.92*** (1.31)	4.42*** (1.36)	6.05*** (1.81)
Post-1990 sample	4.65*** (1.62)	4.14*** (1.46)	3.81*** (1.34)	3.95*** (1.18)	3.89*** (1.23)	3.71*** (1.35)	4.53*** (1.51)
Pre -2008 crisis sample	6.13*** (1.68)	5.45*** (1.48)	5.33*** (1.39)	5.27*** (1.24)	5.55*** (1.31)	5.81*** (1.50)	5.89*** (1.58)
Without inflation $\geq 40\%$	6.21*** (1.56)	4.87*** (1.52)	4.55*** (1.42)	4.26*** (1.23)	5.01*** (1.27)	5.37*** (1.42)	5.91*** (1.66)
Joyce and Nabar control group	3.62** (1.73)	3.62** (1.56)	3.80** (1.49)	3.56** (1.43)	3.50** (1.51)	4.33*** (1.61)	3.62*** (1.74)
Gonçalves and Salles control group	4.01** (1.58)	3.81*** (1.46)	3.85*** (1.42)	3.73*** (1.32)	3.43** (1.39)	4.10*** (1.43)	4.01** (1.63)

Note: A 0.06 fixed bandwidth and an Epanechnikov kernel are used for kernel regression matching. Bootstrapped standard errors are reported in parentheses (1000 replications). *, **, *** refer to statistical significance at the 10%, 5% and 1% respectively.

Table 5 (continued): Matching estimates of treatment effect on the level of public revenue, robustness checks

	Matching algorithms						
	Nearest-neighbor matching			Radius matching			Kernel matching
	n = 1	n = 3	n = 5	r = 0.04	r = 0.02	r = 0.01	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
<i>Fully-fledged adoption</i>							
Average Treatment on Treated (ATT)							
Adding public debt	5.94*** (2.04)	3.99** (1.84)	3.93** (1.77)	4.52*** (1.64)	5.34*** (1.69)	4.83*** (1.74)	5.72*** (2.19)
Adding government expenditure	1.05 (1.91)	1.26 (1.82)	1.64 (1.62)	2.43* (1.36)	1.86 (1.54)	1.28 (1.66)	1.05 (1.90)
Adding Polity2	4.47*** (1.72)	4.16*** (1.58)	4.74*** (1.41)	4.37*** (1.29)	4.75*** (1.50)	3.29* (1.82)	4.53*** (1.50)
Adding government stability	3.83* (2.03)	2.96 (1.85)	3.04* (1.84)	3.78*** (1.47)	4.06*** (1.55)	4.76*** (1.62)	3.92* (2.25)
Adding partisanship dummy	1.26 (2.54)	1.40 (2.42)	1.45 (2.23)	2.55 (1.98)	3.17 (2.17)	2.68 (2.24)	2.40 (3.12)
Adding log of population	4.04** (1.95)	3.41* (1.88)	2.78 (1.83)	3.48** (1.59)	3.58** (1.48)	3.80** (1.71)	4.05** (1.91)
Considering <i>de jure</i> CBI	5.93*** (1.58)	5.44*** (1.38)	5.67*** (1.36)	5.22*** (1.28)	6.16*** (1.34)	6.43*** (1.51)	5.81*** (1.52)
Considering CBI_LENDING	5.36*** (1.58)	5.62*** (1.40)	5.65*** (1.42)	6.13*** (1.27)	6.36*** (1.30)	6.39*** (1.45)	5.26*** (1.52)
Adding CWN index	5.20*** (1.56)	5.11*** (1.45)	5.51*** (1.30)	5.25*** (1.33)	4.99*** (1.33)	5.46*** (1.49)	5.01*** (1.50)
Post 1990-sample	5.10*** (1.92)	3.49* (1.94)	3.11* (1.87)	3.42** (1.53)	4.02** (1.61)	5.52*** (1.74)	5.11** (2.04)
Pre -2008 crisis sample	7.40*** (2.02)	5.44*** (1.92)	4.54** (1.80)	5.68*** (1.53)	6.07*** (1.68)	7.14*** (1.72)	7.39*** (1.94)
Without inflation \geq 40%	4.77** (2.00)	3.61* (1.93)	3.01* (1.80)	3.50** (1.53)	4.61*** (1.58)	5.33*** (1.63)	5.91*** (1.66)
Joyce and Nabar control group	3.87** (1.77)	4.59*** (1.53)	4.38*** (1.56)	4.22*** (1.54)	4.36*** (1.62)	5.59*** (1.91)	4.65*** (1.49)
Gonçalves and Salles control group	4.82*** (1.68)	4.76*** (1.53)	4.67*** (1.47)	4.71*** (1.34)	5.13*** (1.45)	4.29** (1.65)	3.93** (1.67)

Note: A 0.06 fixed bandwidth and an Epanechnikov kernel are used for kernel regression matching. Bootstrapped standard errors are reported in parentheses (1000 replications). *, **, *** refer to statistical significance at the 10%, 5% and 1% respectively.

Interestingly, results indicate that the average estimated ATT is larger when we consider a *de jure* measure of central bank independence instead the turnover rate of central bank governors. Thus, this latter result seems to confirm the argument that the instrument independence and the impossibility for the government to have recourse to central bank financing is one the principal channel that explains why the adoption of an IT framework in emerging countries should encourage governments to enhance their tax revenue collection.

Similarly, we find that the inclusion of the public debt in the specification of the probit model increase the average estimated ATT. Indeed, as argued above, the level and the composition of the public debt can explain, in some circumstances, the tax revenue effort displayed by the fiscal authority.

5. Conclusion

Previous empirical studies focused on the impact of IT adoption on macroeconomic performances. In this paper, we attempt to assess whether the adoption of this monetary policy framework, by maintaining inflation at low levels, encourages the government to improve the collection of domestic tax revenue in order to recoup the loss of seigniorage revenue due to a tighter monetary policy. Using a propensity score matching approach, we find that most of the estimated ATTs on the level of total public revenue are positive, highly significant, and large in magnitude. Moreover, results are robust to different alternative specifications. Indeed, our empirical results show that, on average, the adoption of IT has led to an augmentation of public revenue collection in emerging market economies.

These empirical findings suggest therefore that the absence of fiscal dominance, i.e. a sound fiscal policy, is not a fundamental precondition for the adoption of IT, relative to other prerequisites such as central bank independence or the flexibility of the exchange regime. In other words, an unsound fiscal policy should not constitute an impediment to the adoption of IT by emerging economies, since this monetary policy framework may help constrain fiscal policy. The success and the sustainability over the medium term of IT will depend more on the ability of the authorities to plan and drive institutional reforms after adopting IT, in particular reforms aiming to modernize tax and customs administrations.

References

- Abbas, S.A., Belhocine, N., ElGanainy, A., Horton, M., 2010. A historical public debt database, IMF Working Paper 10/245.
- Aktas, Z., Kaya, N., Ozlale, U., 2010. Coordination between monetary policy and fiscal policy for an inflation targeting emerging market, *Journal of International Money and Finance* 29(1), 123-138.
- Amato, J.D., Gerlach, S., 2002. Inflation targeting in emerging market and transition economies: Lessons after a decade, *European Economic Review* 46(4-5), 781-790.
- Ball, L., Sheridan, N., 2003. Does inflation targeting matter?, NBER Working Paper No. 9577, Cambridge, MA: National Bureau of Economic Research.
- Batini, N., Laxton, D., 2006. Under what conditions can inflation targeting be adopted? The experience of emerging markets, Central Bank of Chile Working Paper No. 406.
- Beck, T., Clarke, G., Groff, A., Keefer, P., Walsh, P., 2001. New tools in comparative political economy: the Database of Political Institutions, *World Bank Economic Review* 15(1), 165-176.
- Bernanke, B.S., Laubach, T., Mishkin, F.S., Posen, A.S., 1999. *Inflation Targeting: Lessons from the International Experience*, Princeton University Press.
- Bollard, A., Karagedikli, O., 2006. Inflation targeting : the New Zealand experience and some lessons, Reserve Bank of New Zealand.
- Brito, R.D., Bystedt, B., 2010. Inflation targeting in emerging economies: Panel evidence, *Journal of Development Economics* 91(2), 198-210.
- Brodaty, T., Crépon, B., Fougère, D., 2007. Les méthodes micro-économétriques d'évaluation et leurs applications aux politiques actives d'emploi, *Economie et prévision* 177(1), 93-118.
- Burdekin, R., Laney, L., 1988. Fiscal policymaking and the central bank institutional constraint, *Kyklos* 41(4), 647-662.
- Calderón, C. and K. Schmidt-Hebbel, 2008, What drives the choice of inflation targets in the world?, mimeo.
- Caliendo, M., Kopeinig, S., 2008. Some practical guidance for the implementation of propensity score matching, *Journal of Economic Surveys* 22(1), 31-72.
- Carare, A., Schaechter, A., Stone, M., 2002. Establishing initial conditions in support of inflation targeting, IMF Working Paper 02/102.
- Castellani, F., Debrun, X., 2001. Central bank independence and the design of fiscal institutions, IMF Working Paper 01/205.
- Chambas, G., 2005. Afrique au Sud du Sahara: Mobiliser des Ressources Fiscales pour le Développement, *Economica*.
- Christiano, L.J., Fitzgerald, T.J., 2000. Understanding the fiscal theory of the price level, *Economic Review* 36(2), Federal Reserve Bank of Cleveland.

- Cochrane, J.H., 2001. Long-term debt and optimal policy in the fiscal theory of the price level, *Econometrica* 69(1), 69-116.
- Crowe, C., Meade, E.E., 2007. Evolution of central bank governance around the world, *Journal of Economic Perspectives* 21(4), 69-90.
- Cukierman, A., Edwards, S., Tabellini, G., 1992a. Seigniorage and political instability, *American Economic Review* 82(3), 537-555.
- Cukierman, A., Webb, S.B., Neyapti, B., 1992b. Measuring the independence of central banks and its effect on policy outcomes, *World Bank Economic Review* 6(3), 353-398.
- De Haan, J., Sturm, J.E., 1992. The case for central bank independence, *Banca Nazionale del Lavoro Quarterly Review* 182, 305-327.
- De Mendonça, H.F., De Guimarães e Souza, G.J., 2011. Is inflation targeting a good remedy to control inflation?, *Journal of Development Economics*, in Press.
- De Mendonça, H.F., da Silva, R.T., 2009. Fiscal effect from inflation targeting : the Brazilian experience, *Applied Economics* 41(7), 885-897.
- Dehejia, R., Wahba, S., 1999. Causal effects in non-experimental studies: Re-evaluating the evaluation of training programs, *Journal of the American Statistical Association* 94, 1053-1062.
- Dreher, A., Sturm, J.E., De Haan, J., 2008. Does high inflation causes central bankers lose their job? Evidence based on a new dataset, *European Journal of Political Economy* 24(4), 778-787.
- Edwards, S., 1993. Exchange rates as nominal anchors, *Weltwirtschaftliches Arch* 129(1), 1-32.
- Ehrhart, H., 2009. Assessing the relationship between democracy and domestic taxes in developing countries, *Etudes et Documents E 2009.30*, Centre d'Etudes et de Recherches sur le Développement International.
- Epstein, G., 2006. Too much, too soon: IMF conditionality and inflation targeting, *Bretton Woods Project*, available at: <http://www.brettonwoodsproject.org/art-542599>.
- Fatas, A.M., Rose, A., 2001. Do monetary handcuffs restrain leviathan? Fiscal policy in extreme exchange rate regimes, *CEPR Discussion Papers 2692*, Centre for Economic Policy Research.
- Faust, J., Henderson, D.W., 2004. Is inflation targeting best-practice monetary policy?, *Federal Reserve Bank of St. Louis Review* 86(4), 117-143.
- Fraga, A., Goldfajn, I., Minella, A., 2003. Inflation targeting in emerging market economies, *NBER Working Paper No. 10019*, Cambridge, MA: National Bureau of Economic Research.
- Gerlach, S., 1999. Who targets inflation explicitly?, *European Economic Review* 43(7), 1257-1277.
- Gonçalves, C.E.S., Salles, J.M., 2008. Inflation targeting in emerging economies: what do the data say? *Journal of Development Economics* 85(1-2), 312-318.

- Gupta, A.S., 2007. Determinants of tax revenue efforts in developing countries, IMF Working Paper 07/184.
- Hamman, A.J., 1999. Exchange rate based stabilization: a critical look at the stylized facts, IMF Working Paper 99/132.
- Heckman, J.J., Lalonde, R., Smith, J., 1999. The economics and econometrics of active labor market programs, in: Ashenfelter, O., Card, D. (Eds.), *Handbook of Labor Economics*, vol. 3. Amsterdam, North-Holland, pp. 1865-2097.
- Heckman, J.J., Ichimura, H., Todd, P., 1998. Matching as an econometric evaluation estimator, *Review of Economic Studies* 65(2), 261-294.
- Hu, Y., 2006. The choice of inflation targeting – an empirical investigation, *International Economics and Economic Policy* 3(1), 27-42.
- Huang, H., Wei, S-J., 2006. Monetary policies for developing countries: The role of institutional quality, *Journal of International Economics* 70(1), 239-252.
- IMF, 2006. Inflation targeting and the IMF, Paper prepared by Monetary and Financial Systems Department, Policy and Development Review, March.
- IMF, 2005. Does inflation targeting work in emerging markets? *World Economic Outlook*, September, Chapter IV, 161-186.
- IMF, 2001. The decline of inflation in emerging markets: can it be maintained? *World Economic Outlook*, May, Chapter IV, 116-144.
- Joyce, P.J., Nabar, M., 2009. Sudden stops, banking crises and investment collapses in emerging markets, *Journal of Development Economics* 90(2), 314-322.
- Khandker, S.R., Koolwal, G.B., Samad, H.A., 2010. *Handbook on Impact Evaluation: Quantitative Methods and Practices*, The World Bank, Washington D.C.
- Khattry, B., Rao, J.M., 2002. Fiscal faux pas?: an analysis of the revenue implications of trade liberalization, *World Development* 30(8), 1431-1444.
- Leeper, E.M., 1991. Equilibria under ‘active’ and ‘passive’ monetary and fiscal policies, *Journal of Monetary Economics* 27(1), 129-147.
- Leuven, E., Sianesi, B., 2003. PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing, available at: <http://ideas.repec.org/c/boc/bocode/s432001.html>.
- Levy, G., 2008. The choice of inflation targeting, Central Bank of Chile Working Paper No. 475.
- Lin, S., Ye, H., 2009. Does inflation targeting make a difference in developing countries?, *Journal of Development Economics* 89(1), 118-123.
- Lin, S., Ye, H., 2007. Does inflation targeting really make a difference? Evaluating the treatment effect of inflation targeting in seven industrial countries, *Journal of Monetary Economics* 54(8), 2521-2533.

- Lucotte, Y., 2009. Central bank independence and budget deficits in developing countries: New evidence from panel data analysis, Document de Recherche du LEO No. 2009-19.
- Masciandaro, D., Tabellini, G., 1987. Monetary regimes and fiscal deficits: A comparative analysis, in: Cheng, H.S. (Ed.), *Monetary Policy in Pacific Basin Countries*. Dordrecht: Kluwer, pp. 125-152.
- Masson, P.R., Savastano, M.A., Sharma, S., 1997. The scope for inflation targeting in developing countries, IMF Working Paper 97/130.
- Minea, A., Villieu, P., 2009. Can inflation targeting promote institutional quality in developing countries?, The 26th Symposium on Money, Banking and Finance, University of Orléans, 25-26 June 2009.
- Mishkin, F.S., 2000. Inflation targeting in emerging-market countries, *American Economic Review* 90(2), 105-109.
- Mishkin, F.S., Schmidt-Hebbel, K., 2007. Does inflation targeting make a difference?, NBER Working Paper No. 12876, Cambridge, MA: National Bureau of Economic Research.
- Mohanty, M.S., 2002. Improving liquidity in government bond markets: what can be done?, In: *The Development of Bond Markets in Emerging Economies*, BIS Papers 11, June, 49-80.
- Montiel, P.J., 2003. *Macroeconomics in Emerging Markets*, Cambridge University Press, Cambridge, UK.
- Mukherjee, B., Singer, D.A., 2008. Monetary Institutions, partisanship and inflation targeting, *International Organization* 62(2), 323-358.
- Parkin, M., 1987. Domestic monetary institutions and the deficit, in: Buchanan, J.M., Rowley, C.K., Tollison, R.D. (Eds.), *Deficits*, Oxford, Blackwell, pp. 310-337.
- Pétursson, T., 2004. Formulation of inflation targeting around the world, *Monetary Bulletin* 2004/1, Central Bank of Iceland, 57-84.
- Reddell, M., 1999. Origins and early development of the inflation target, *Reserve Bank of New Zealand Bulletin* 62(3), 63-71.
- Reddy, Y.V., 2002. Issues and challenges in the development of the debt market in India, In: *The Development of Bond Markets in Emerging Economies*, BIS Papers 11, June, 117-126.
- Reinhart, C.S., Rogoff, K.S., 2004. The modern history of exchange rate arrangements: A reinterpretation, *The Quarterly Journal of Economics* 119(1), 1-48.
- Rosenbaum, P., Rubin, D., 1983. The central role of the propensity score in observational studies for causal effects, *Biometrika* 70(1), 41-55.
- Rubin, D., 2007. The design versus the analysis of observational studies for causal effects: Parallels with the design of randomized trials, *Statistics in Medicine* 26(1), 20-36.
- Rubin, D., 1974. Estimating causal effects of treatments in randomized and non randomized studies, *Journal of Educational Psychology* 66(5), 688-701.

Sahinbeyoglu, G., 2008. From exchange-rate stabilization to inflation targeting: Turkey's quest for price stability, in: de Mello, L. (Ed), *Monetary Policies and Inflation Targeting in Emerging Economies*, OECD Publishing, pp. 143-172.

Sargent, T.J., 1993. *Rational Expectations and Inflation*, HarperCollins College Publishers, 2nd edition, New York.

Sargent, T.J., Wallace, N., 1981. Some unpleasant monetarist arithmetic, *Federal Reserve Bank of Minneapolis* 5(3), 1-17.

Sherwin, M., 1999. Strategic choices in inflation targeting: the New Zealand experience, *Reserve Bank of New Zealand Bulletin* 62(2), 73-88.

Sims, C.A., 1994. A simple model for study the determinacy of the price level and the interaction of monetary and fiscal policy, *Economic Theory* 4, 381-399.

Tanzi, V., 1992. Structural factors and tax revenue in developing countries: A decade of evidence, in: Goldin, I., Winters, A. (Eds.), *Open Economies: Structural Adjustment and Agriculture*, Cambridge University Press, Cambridge, UK, pp. 267-281.

Tavares, J., 2004. Does right or left matter? Cabinets, credibility and fiscal adjustments, *Journal of Public Economics* 88(12), 2447-2468.

Tornell, A., Velasco, A., 2000. Fixed versus flexible exchange rates: which provides more fiscal discipline?, *Journal of Monetary Economics* 45(2), 399-436.

Tornell, A., Velasco, A., 1998. Fiscal discipline and the choice of a nominal anchor in stabilization, *Journal of International Economics* 39(2), 197-221.

Tornell, A., Velasco, A., 1995. Money-based vs. exchange rate-based stabilization with endogenous fiscal policy, NBER Working Paper No. 5108, Cambridge, MA: National Bureau of Economic Research.

Truman, E.M., 2003. *Inflation Targeting in the World Economy*, Institute for International Economics, Washington D.C.

Vega, M., Winkelried, D., 2005. Inflation targeting and inflation behavior: A successful story?, *International Journal of Central Banking* 1(3), 153-175.

Woodford, M. 1994. Monetary policy and price level determinacy in a cash-in-advance economy, *Economic Theory* 4, 345-380.

Woo, J., 2003. Economic, Political and institutional determinants of public deficits, *Journal of Public Economics* 87(3-4), 387-426.

Appendix A. Variables definitions and sources

Variables	Definition and source
CBI_LENDING	Fourth component of the central bank independence index developed by Cukierman <i>et al.</i> (1992b), which one measures the degree of financial relations between the central bank and the executive branch. Source: Cukierman <i>et al.</i> (1992b) and Crowe and Meade (2007).
CWN INDEX	<i>De jure</i> central bank independence index developed by Cukierman <i>et al.</i> (1992b). Source: Cukierman <i>et al.</i> (1992b) and Crowe and Meade (2007).
DEBT	Public debt as a share of GDP. Source: Abbas <i>et al.</i> (2010).
EXCH	<i>De facto</i> fine classification of exchange rate regimes: polytomic variable taking values from 1 (hard pegs) to 14 (freely falling). Source: IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAR).
GDPPCG	Real per capita GDP growth. Source: World Development Indicators (2011). WDI are now available free on the World Bank's website at: http://data.worldbank.org/
GSTAB	Number of exits of veto players between year t and year $t+1$ divided by the total number of veto players in year t . Source: Beck <i>et al.</i> (2001) [december 2010 update].
GVT_EXPEND	General government final consumption expenditure as a share of GDP. Source: World Development Indicators (2011).
IT	Binary variable taking the value 1 if a country has in place an IT regime at the period t , and 0 otherwise. Source: Levya (2008).
INF_1	One-year lagged inflation rate, measured by annual percentage change of consumer prices. Source: World Development Indicators (2011).
NUM_IT	Number of industrialized and emerging countries that have adopted IT at the period t . Source: Author's calculations based on Levya (2008).
OPEN	Trade openness is the sum of exports and imports of goods and services as a share of GDP. Source: World Development Indicators (2011).
PCRED	Domestic credit provided by deposit money banks and other financial institutions as a percentage of GDP. Source: World Development Indicators (2011).
POLITY2	Index taking values from -10 (very autocratic) to +10 (very democratic) and constructed by subtracting the democracy score from the autocracy score. Source: Polity IV Project. Database available at: http://www.systemicpeace.org/polity/polity4.htm
POPULATION	Total population. Source: World Development Indicators (2011).
RIGHT	Dummy variable taking the value 1 if the executive belongs to a party of the right and 0 if left-wing or centrist. Source: Beck <i>et al.</i> (2001) [december 2010 update].
TAX_REV	Total public revenue as a share of GDP. Source: Center for Studies and Research on International Development.
TOR_5	<i>De facto</i> central bank independence measured by the turnover rate of central bank governors based on 5-years averages. Source: Author's calculations based on central bank websites and Dreher <i>et al.</i> (2008; april 2009 update). Dreher's database available at: http://www.uni-goettingen.de/en/datasets/89555.html

Appendix B. Summary statistics

Variables	Obs.	Mean	Std. Dev.	Min	Max
<i>Inflation targeting countries (1980-2009)</i>					
CWN INDEX	527	0.44	0.22	0.1	0.89
DEBT	509	48.25	33.37	1.02	283.95
EXCH	535	10.82	2.96	5	14
CBI_LENDING	527	0.42	0.28	0.02	1
GDPPCG	559	3.50	4.14	-14.57	13.28
GSTAB	540	0.16	0.31	0	1
GVT_EXPEND	535	13.75	6.01	4.99	41.47
INF	499	69.77	419.01	-0.84	7481.66
OPEN	531	63.27	32.71	6.32	174.48
PCRED	520	43.27	32.29	1.54	165.71
POLITY2	561	4.89	5.72	-9	10
POPULATION_LOG	587	17.18	1.02	15.17	19.26
RIGHT	415	0.50	0.49	0	1
TAX_REV	403	22.92	9.71	4.5	52.2
TOR_5	559	0.26	0.23	0	1.2
<i>Non-inflation targeting countries (1980-2009)</i>					
CWN INDEX	628	0.44	0.17	0.14	0.86
DEBT	1075	68.21	46.50	0.97	454.86
EXCH	1188	8.01	4.02	1	14
CBI_LENDING	628	0.45	0.23	1.01	1
GDPPCG	1224	3.68	5.45	-30.51	34.5
GSTAB	1194	0.10	0.26	0	1
GVT_EXPEND	1097	13.82	5.18	1.37	45.26
INF	1075	88.65	871.80	-11.45	24411.03
OPEN	1168	64.82	32.69	9.10	220.41
PCRED	1100	27.59	24.17	0	158.50
POLITY2	1253	-0.50	6.30	-9	9
POPULATION_LOG	1364	16.87	1.26	14.99	21.01
RIGHT	645	0.18	0.39	0	1
TAX_REV	1034	20.68	8.79	2.9	53.1
TOR_5	1120	0.25	0.26	0	1.4

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