Does Monetary Policy Transparency Aid Technological Knowledge?[☆]

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Abstract

This paper studies the role of central bank transparency in shaping the real economy through the innovation channel, both from the input (R&D) and output (patents) side, which is an essential driver of economic growth. Based on a panel of 44 developed and developing countries over the period 1999-2019 and a fixed effects identification and appropriate instrumentation strategy, we provide three novel and robust results. Firstly, markets with high degree of financial sophistication and trust do not require tremendous central bank information disclosure in order to observe positive effects on R&D investment. In contrast, when financial sophistication is low and institutional distrusts prevails, channeling large information to the market is necessary for the economy to increase R&D investment. Secondly, while transparency is important for both developed and developing countries, the effect on innovation is an inverse U-shape for the former, and a U-shape for the later. Those findings demonstrate the existence of an optimal monetary policy transparency level. Finally, our results suggest that policymakers should focus on the economic and operational transparency in developed countries, and on procedural transparency in the developing countries, as those particular aspects of transparency are more conductive to R&D activity.

Keywords: innovation, R&D, patents, central bank transparency, institutions

JEL: C23, E52, E58, O43, O50

[☆] We are very grateful to Ilias Aretos for excellent research assistance. We thank Tryfonas Christou, Kyriakos Drivas, Dimitris Karamanis, Dimitrios Konstantios, Eleni Kyrkopoulou, Panayotis Michaelides, Lambros Pneumatikos, Nikolas Topaloglou, Emmanuel Tsiritakis, and Razvan Vlahu for useful comments and suggestions. The author Claire Economidou would also like to thank Clemens Kool for insightful discussions on monetary policy effectiveness. This work has been partly supported by the University of Piraeus Research Center. The usual disclaimer applies.

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1. Introduction

Technological knowledge is the major driver of economic growth that benefits the country it originates from (Romer, 1986; Grossman and Helpman, 1991), and, to the extent it spills over to the geographical space, is also a key factor in shaping income inequality across countries (Saxenian, 1994; Swann et al., 1998; Coe et al., 2009).

An important input in the creation of technological knowledge is research and development (R&D). Knowledge asset, created by R&D investment, is intangible, partly embedded in human capital, and ordinarily very specialized to the particular firm in which it resides. Most of the R&D expenditure accounts for the wages and salaries of highly educated scientists and engineers; therefore, liquidity constraints, or excess sensitivity to cash flow shocks can be detrimental for the financing of innovative projects. As R&D projects often take a long time between conception and commercialization, financial market volatility and instability could be detrimental for a firm's or country's knowledge capital and in turn, for economic growth.

Central banks, as a shaper of monetary policy expectations, have a pivotal role in easing financial market turbulence, which can harm innovation activity. Transparency in central bank's intentions, targets, policies and future actions helps in reducing asymmetric information between central bank and market participants, which in turn, decreases agents' uncertainty.[1] In principle, more information is expected to improve market functioning as financial markets become better at predicting the outcome of unrealized fundamentals. Increased information is a way to improve the predictability of monetary policy, thereby lowering financial market volatility and contributing to a more stable economy. Transparency can also build up credibility and reputation (Dincer and Eichengreen, 2014), which enhance trust (Faust and Svensson, 2001), and in turn the effectiveness of monetary policy in achieving desirable economic outcomes.[2]

This paper raises the question whether greater central bank transparency aids a country's technological knowledge. In principle, more information is expected to lead to better economic decisions about innovation, which is of high risk investment that needs time to be realized. Theoretical contributions, however, point to possible adverse effects of increased transparency, as the provision of costless public information could lead market participants to invest less in private information placing too great a weight on public information.

[1] There is not precise definition of central bank transparency; however, "[...] a central bank is transparent if its actions are "easily detected", its policies are "easily understood" and its pronouncements are "free from deceit". In brief, the central bank should be open, intelligent and honest [...]" (Blinder, 2002, p.3).

[2] Trust in institutions derives from the capacity of these institutions to fulfil a commitment. Some commitments are explicit while others are not, and eliciting implicit commitments is required to build trust. Further, some commitments are legally enforceable, while others are not. While compliance matters, restoring or enhancing trust requires moving beyond compliance (Kirby et al., 2018).

Hence, private information could potentially be crowded out as individuals overreact to the public signal undermining the accuracy of future monetary policy.[3]

We posit that there could be an optimal central bank transparency level, in the sense that improving the information disclosure of central banks is constructive, in the case of a low degree of transparency; however, when optimal transparency is exceeded, too much information may be harmful for firms and investors as it increases the signal-to-noise error. Motivated by the lack of evidence on innovation performance, our paper contributes to the literature by studying the effect of central bank transparency on a country's innovation input (R&D) and output (patents). Our study abstracts from heterogeneity at the firm level, which could be a potential caveat compared to event studies, but it employs appropriate econometric estimation techniques and a rich database to perform a comprehensive analysis for a wide set of countries.

We model R&D investment as a function of central bank transparency, among other controls, and by applying a fixed effects identification strategy and instrumentation techniques, we obtain the effect of central bank transparency on R&D investment. We then estimate a typical R&D-based endogenous growth model (Ha and Howitt, 2007; Ang and Madsen, 2011), where new knowledge (ideas) -the output of innovation production process, proxied by the number of patents (Jaffe, 1986)- is generated using existing technological knowledge and new R&D investment. Central bank transparency affects the generation of new ideas through its impact on stabilizing the economy (and the financing of R&D investment) and on reducing future uncertainty.

To unfold the effects of central bank transparency, we employ a dataset developed by Dincer et al. (2022) that differentiates among different types of transparency, allowing thus for a more detailed analysis. Therefore, one can assess the type of transparency that is of upmost importance for nurturing technological innovation. A relevant question in this respect is the following: Is there a particular type of transparency a central bank should focus on in order to increase innovation activity?

Our paper relates to a wide strand of research on the effects of central bank transparency on macroeconomic aggregates such as structure of interest rate, inflation, exchange rate volatility, output growth (Chortareas et al., 2002; Crowe and Meade, 2008; Weber, 2019; Ye et al., 2022) and on financial variables such as risk, stability, money markets, among others (Ehrmann et al., 2012; Neuenkirch, 2012; Andries

[3] Theoretical models of Morris and Shin (2005) and Demertzis and Hallett (2007) show that a sufficiently clear signal from the central bank can act as a coordinating point that could distract market participants from their private information and possibly away from fundamentals. Dale et al. (2011) demonstrate that if the private sector is not able to learn the precision of the central bank's information, it may overreact to central bank communication. In a laboratory experiment, Kool et al. (2011) demonstrate that for intermediate levels of public information precision, it is optimal for the central bank to actually disclose less than it knows. Such crowding out effect can occur even in the case where public information is more precise than private information.

et al., 2020; Zhang et al., 2023). We contribute to this literature by bringing evidence of the effect on monetary policy transparency on the real economy via the channel of innovation. We also contribute to a long-standing debate about the desirability of greater transparency. On the one hand, theoretical models express reservations (Morris and Shin, 2005; Dale et al., 2011; Kool et al., 2011), which are also shared with empirical studies documenting diminishing benefits from ever higher levels of transparency (Siklos, 2013; Jitmaneeroj et al., 2019) that could be harmful for the economy (Andries et al., 2020) at least after some specific level (van der Cruijsen and Eijffinger, 2010; Horvath and Vasko, 2016; Zhang et al., 2023). Our paper documents a non-linear relationship between transparency and innovation and supports the existence of an optimal level of transparency for R&D investment. In this respect, our study is closer to Zhang et al. (2023) who also document non-linear patterns and different outcomes of transparency on systemic risk for developing and developed countries.

Our empirical analysis is based on a sample of 44 developed and developing countries, for which innovation and central bank transparency data are available over the 1999-2019 period. We address two key questions: (i) How important is central bank transparency in shaping innovation activity? and (ii) What type of central bank transparency is more conductive to innovation?

The evidence we provide is straightforward and robust. Monetary policy transparency does matter for R&D investment. Contrary to nuanced evidence on the impact of transparency on macroeconomic aggregates, we document a number of unambiguous findings. Results point to a non-linear relationship between monetary policy transparency and R&D. The effect, however, varies depending on the level of financial sophistication and trust, which both act as moderators. High levels of financial knowledge and trust in institutions (which usually are attributes of advanced economies) do not require huge central bank information disclosure for increases in R&D investment to be observed. In this case, more information disclosure could be useless for innovation activity, as highly sophisticated investors flag early on opportunities and growth options to enter first into the market and acquire high monopoly rents. In contrast, when financial sophistication is not adequate and institutional distrusts prevails (which is mainly the case in the developing economies), then channeling large information disclosure is necessary for the realization of positive effects on innovation.

Optimality of central bank transparency issues unfold when we examine separately the developed and the developing countries. We find a robust inverse U-shaped effect of transparency on innovation activity (both in terms of R&D and patent counts) for developed countries and a U-shaped effect for the developing ones (in terms of R&D) The roots of dissimilar patterns between developed and developing economies could be traced to institutional and supervision deficiencies (Mertzanis, 2020; Binder, 2021) and low levels of financial literacy in the developing countries that create (dis)trust and shape differently the effects of transparency on innovation compared to the developed economies. The attempt of central banks to change from 'confidential' to 'open' could be puzzling for the market participants in the developing countries; this skepticism, however, gradually decays at the very increased levels of monetary policy transparency, which becomes beneficial for innovation. In contrast, increased central bank transparency is welcomed in the case of developed countries where initially this information is converted into higher R&D investment; yet, the releasing of too much (and sometimes perhaps 'noisy') information can result in bad decisions by the private sector (Dale et al., 2011) with negative economic repercussions, including on the investment in innovation.

Some important policy suggestion emerge: our evidence certainly does not advocate less central bank transparency for central banks that are already very transparent. Focusing on providing information is necessary but not sufficient for a central bank to shape a country's technological knowledge. Rather, as our results show, it pays off for a central bank to take care of its reputation in terms of trustworthiness and to support the enhancement of the sophistication of the financial sector. If these two conditions hold, the efficiency of information disclosure increases and has real economy effects through its impact on innovation. The main takeaway message, especially for developing countries, is that policies targeted at bolstering central bank trust and the development of a sophisticated financial sector are conductive to higher economic growth. Furthermore, among the different aspects of central bank transparency, the type that is important for R&D is substantially different between developed and developing countries. Developed countries should focus on economic and operational transparency. Policymakers should therefore be transparent about (i) the economic information used in monetary policy; and, (ii) the implementation of monetary policy actions, including an evaluation of the outcomes. Developing countries should pay attention to procedural transparency instead, as this seems to be the only type of transparency able to turn the effect of central bank transparency to a positive outcome on R&D innovation. Excluding economic transparency which is not significant, all other types of transparencies display a negative linear pattern with R&D in the developing countries.

The remainder of the paper proceeds as follows. Section 2 introduces the framework of our analysis. Section 3 presents the data. Section 4 discusses the results. Section 5 summarizes the findings and concludes.

2. Analytical Framework

This section lays out the theoretical background, the specification(s) under estimation, and the econometric framework of our empirical analysis.

2.1. Theoretical Background and Empirical Specification

At the very heart of endogenous growth models lies the technological knowledge (or ideas) production function that describes the evolution of technological knowledge creation.

A simplified version of endogenous growth models assumes that output, Y, in country i at time t is produced using labor, L, and knowledge stock -accumulation of ideas that have been invented or developed by people- A. There are two sectors, the goods sector that produces output and the R&D sector that produces new knowledge. Labor is fixed, but it can be freely allocated to either of the two sectors, to produce output or to produce new knowledge.

New technological knowledge, ideas, are generated in the R&D sector. Then, $\dot{A}$ represents the flow of new knowledge or the number of new ideas generated in the economy at a point in time. New ideas are produced by researchers, L_A, according to the following production function:

$$\dot{A} = \tilde{\delta} L_A \tag{1}$$

where $\tilde{\delta}$ denotes (average) research productivity and is modeled as a function of the existing stock of knowledge (A) and the number of researchers (L_A) according to:

$$\tilde{\delta} = \delta A^{\phi} L_A^{\lambda-1} \tag{2}$$

where $\delta>0$, ϕ is the returns to scale in knowledge (for $\phi>0$, ideas in the past may facilitate the discovery or creation of ideas in the present indicating a positive "spillover of knowledge" to future researchers; for $\phi<0$, the most obvious ideas might have been discovered first and new ideas become harder to find over time), and λ is duplication parameter (0, if all innovations are duplications and 1, if there is no duplicating innovations). All parameters are constant.[4]

Taken together, equations (1) and (2) suggest the following knowledge (or ideas) production function:

$$\dot{A} = \delta A^{\phi} L_A^{\lambda} \tag{3}$$

Dividing by the stock of knowledge, A, and by taking logs, equation (3) yields:

[4]Overall, the restrictions imposed on ϕ and λ and existence of product proliferation relate to particular forms of knowledge production function and accordingly to different strands of endogenous growth theory. For a detailed discussion and empirical evidence on different 'generations' of endogenous growth theory models, consult Ha and Howitt (2007) and Ang and Madsen (2011).

$$ln(\frac{\dot{A}}{A}) = (\phi - 1)ln(A) + \lambda ln(L_A) \tag{4}$$

The parameter ϕ, as it has been noted above, is associated with the effect of the existing stock of knowledge, A (proxied by the past performance of patents), while L_A represents the efforts to acquire new technical knowledge through the intensity of domestic R&D expenditure. The growth rate of a country's innovation output, $ln(\frac{\dot{A}}{A})$, could be proxied by the annual change of the (log) number of patent applications in the country. Two types of unobservable factors are considered: permanent and time-varying elements, which typically are part of an error term. Taking these into consideration, the resulting final estimating model adopts the following form:

$$\Delta lnPatents_{i,t} = \theta lnPatents_{i,t-1} + \lambda ln(R\&D/Q)_{i,t} + \zeta_i + \phi_t + \epsilon_{i,t} \tag{5}$$

where, $\Delta lnPatents_{i,t}$ is the logarithmic transformation of the annual growth of patent applications[5] and $R\&D/Q$ represents private sector R&D expenditure over product variety (Q), which is proxied by the size of the economy's output (GDP). The latter, is a standard proxy for innovation input widely used in the literature (Feldman and Florida, 1994; Acs et al., 2002; Crescenzi et al., 2007).[6] It further captures a country's capacity to 'absorb' innovation generated elsewhere (Cohen and Levinthal, 1989). Finally, ζ_i, ϕ_t, and $\epsilon_{i,t}$, are country fixed effects, time fixed effects, and the white noise error term, respectively.

We model R&D investment as a function of central bank transparency (CBT) and a vector of controls, Z, as follows:

$$(R\&D/Q)_{i,t} = \beta_i + \beta_1 CBT_{i,t-1} + \beta_2 CBT^2_{i,t-1} + \beta_3 Z_{i,t-1} + \alpha_i + \delta_t + \eta_{i,t} \tag{6}$$

[5]We measure the production output of new knowledge (ideas) using patents as observable as a well-grounded proxy for measuring technological innovations in the literature (Griliches, 1990; Trajtenberg, 1990; Eaton and Kortum, 1999). Let us note, however, that different industries have different propensities to patent and also not all new inventions are patented. In particular, process innovations have a significantly lower degree of patentability than product innovations. As a consequence, the use of a patent-based indicator as dependent variable may underestimate the effect of our explanatory variables on innovation in countries whose innovativeness is less measurable through patenting. However, the lack of comparable statistics on other measures of innovation, leaves no viable alternative. Measuring new knowledge indirectly by total factor productivity (TFP) comes also with some drawbacks: First, TFP combines knowledge as well as efficiency. For example, two economies with the same stock of knowledge may have quite different levels of TFP because one economy uses its resources more effectively than the other. Second, it is well known that the use of TFP is subject to measurement problems (Griliches, 1979; Aghion and Howitt, 1998).

[6]The variable $R\&D/Q$ could be a range of innovation-related indices depending on the endogenous growth paradigm. It could be the number of research workers (scientists) in Romer's model, or R&D spending (to GDP) in the semi-endogenous growth theory, or productivity-adjusted R&D input in the Schumpeterian (fully-endogenous) growth theory. Product variety (Q) is usually measured by the size of population or employment (Aghion and Howitt, 1998; Ha and Howitt, 2007) or by GDP (Krugman, 1989), or by the stock of trademarks (Madsen, 2008).

where Z is a set of socio-economic variables that describe the conditions which determine the rhythm at which a society adopts innovation and transforms it into real economic activity (Rodríguez-Pose, 1999), and α_i, δ_t, and $\eta_{i,t}$, are country fixed effects, time fixed effects, and the white noise error term, respectively. All variables are lagged one year to avoid potential endogeneity.

If central bank transparency is defined as the absence of asymmetric information between the central bank and the private sector, then transparency automatically increases when the central banks provide more information. Greater information is important for the effectiveness of monetary policy as it is conducive to improving the accuracy of market participants', firms', and consumers' expectations and shape their decisions (Crowe and Meade, 2008; Demertzis and Hallett, 2007; Wu et al., 2022). In this regard, firms and investors could take up and support long term and riskier investments, particularly related to R&D. However, steering market expectations by providing more information may lead to confusion among financial agents (van der Cruijsen and Eijffinger, 2010), because few can fully understand the whole content. To capture the effect of an optimal size, we introduce central bank transparency (CBT) in quadratic term.

We focus on the coefficients β_1 and β_2 and expect four scenarios: Central bank transparency has a U-shape effect on R&D if coefficient β_1 is statistically negative and coefficient β_2 is significantly positive; Central bank transparency has an inverted U-shape effect on R&D if coefficient β_1 is statistically positive and coefficient β_2 is significantly negative; Central bank transparency has a linear effect on R&D, if coefficient β_1 is statistically negative or positive and β_2 statistically insignificant. If both coefficients are statistical insignificant, then there is no effect at all.

The set of controls, Z, includes a number of variables that capture aspects of an economy relevant to innovation, namely human capital and labour market rigidity, sectoral composition, institutions, access to finance and aspects of openness. The scientific nature of R&D is human capital intensive. A country with high levels of human capital not only achieves higher levels of R&D investment (Mankiw et al., 1992; Romer, 1994; Aghion et al., 2009; Francesco and Streb, 2017) but also 'absorbs' more foreign advanced knowledge from abroad and benefits from the realization of R&D spillovers (Redding, 1996). Rigid labor markets also shape innovation performance as they decrease labour turnover and consequently hamper 'job matches' and learning spillovers (Nickell and Layard, 1999) that would occur otherwise. Further, labor rigidity reduces incentives for taking innovative risks (Malcomson, 1997), limits the inflow of new people with new ideas and new networks that may foster innovation and entrenches employees in safe jobs, who gradually lose their creativity (Rodríguez-Pose and Cataldo, 2014). The sectoral composition of an economy is also of upmost importance for a country's innovation capabilities as a high primary sector share increases the effect of reallocation impediments and thereby reduces the efficiency with which countries produce output and innovation (Temple, 2005; Vollrath, 2009). Poor economic institutions -corruption, red tape, weak protection of property rights, unhealthy business environment and ineffective rule of law- significantly increase uncertainty about financial returns on innovation, increase the cost of investment needed to develop new products and services and do not provide incentives to realize long-term and risky investments (Olson, 2000). As a result, physical and human capital cannot be employed effectively. Access to finance is of upmost importance for nurturing technological innovation. Important functions of the financial markets are to overcome information asymmetries, adverse selection, moral hazard problems and play an important role in facilitating risk taking, thereby, reducing a firm's cost of external capital. We, therefore, include the level of a country's financial development (FD) also in the vector Z.[7] Additionally to domestic factors, foreign innovation activity could also shape domestic R&D investment.[8] Foreign knowledge can bring in advanced foreign technology, managerial skills, and other know-how and make domestic markets more competitive through the trade of technological goods and entry of foreign companies. Trade of foreign capital and intermediate goods allow a recipient country to learn from the R&D-, or 'technology'-content embodied in the traded goods. (Grossman and Helpman, 1991; Coe and Helpman, 1995; Eaton and Kortum, 2001; Keller, 2002; Caselli and Wilson, 2004). Foreign direct investment (FDI) inflows is a conduit of knowledge dissemination, namely through imports of capital goods by the subsidiaries of multinational corporations, R&D flows carried out in the parent country, movements of employees/managers across countries, and the links between multinational corporations subsidiaries and local firms (Glass and Sagg, 1998; Borensztein et al., 1998; Xu, 2000; van Pottelsberghe de la Potterie and Lichtenberg, 2001).

To reveal potential differential responses of R&D to greater central bank transparency, we introduce moderator variables which affect the strength and direction of the relationship between innovation input (R&D) and central bank transparency. Among potential moderators, we focus on the degree of financial sophistication, proxied by the level of financial development (FD) (Ma and Lin, 2016) and of trust in institutions (Zak and Knack, 2001), proxied by the control of corruption ($Institutions$) (Hakhverdian and Mayne, 2012). Both, moderators enter into the equation (6) as controls and are also interacted with CBT_{t-1} and CBT_{t-1}^2.

Financial sophistication and trust in institutions are important for understanding and trusting the information provided by the the central bank, as well as, for managing resources and investing in long term risky

[7]A newly grown literature has studied the finance-innovation nexus (Brown and Petersen, 2009; Brown et al., 2012; Ayyagari et al., 2011; Hsu et al., 2014) stressing the important role of financial markets for innovation.

[8]See Drivas et al. (2016) for a comprehensive review of the literature on the different channels of international knowledge diffusion.

projects such as R&D. If financial literacy of private and public market participants is low, then greater central bank transparency will not be effective as agents' financial knowledge and skills are not sufficient to understand and assess the information. To that end, many developed countries' central banks have recently started to channel attention and resources on engaging with the wider public, though information, education and citizens' consultations, all the way to collaborating with the public (Gardt et al., 2021) to build trust and make their message get across.[9] Measures of the public's financial literacy is unfortunately only available for very few recent years. We use the level of financial development as a proxy for financial sophistication of an economy. A more sophisticated financial system has the ability to understand the relevance of information released by the central bank and take actions: to mobilizing savings, managing risk, and facilitating investment in R&D (Bencivenga and Smith, 1991; Jappelli and Pagano, 2002).

Trust impacts all economic activities. If the public trusts the authorities' actions, it will incorporate these actions in determining their own behaviour. As a result, it is more likely that the authorities will achieve their objectives. In the extreme, if trust evaporates, the capacity to make effective policies disappears. It is therefore a constant challenge for the central bank to preserve credibility. Information about the level of trust (in banks or institutions in general) at the country level does not exhibit time variation within a country (which could be an issue in using fixed effects in estimation). As a proxy of trust we therefore use the variable control of corruption, as corruption is the ultimate betrayal of public trust (Hakhverdian and Mayne, 2012).

A potential challenge we face, however, in our empirical attempt is to identify the causal effect of bank transparency on innovation. We apply appropriate estimation techniques that are discussed in the next section.

Estimation

Our purpose is to estimate the effect of central bank transparency on R&D (equation 6) and, through R&D, on patents (equation 5).[10]

There are two challenges that we need to confront. First, the problem of error cross sectional dependence in panel regressions caused by the presence of common factors (due to a single currency, policies adopted by the central authority and so on) and spacial and spillover effects, which are unobserved, resulting in

[9] Recent evidence based on social media traffic shows that central bank communication can be successful in reaching non-experts and can foster more factual and moderate discussions (Ehrmann and Wabitsch, 2021).

[10] A way to do this is to treat both equations as a system and therefore apply Seemingly Unrelated Regression (SUR) estimation method. However, diagnostic tests (Breusch-Pagan test) support that error terms of both equations are uncorrelated and so we proceed in treating each equation separately. We begin by estimating equation (6) as the first stage of a two-stage estimation process - R&D acts as an endogenous variable in equation (5).

inefficient estimates (De Hoyos and Sarafidis, 2006). We test for cross-sectional dependence (under the null hypothesis of cross sectional independence) across countries using the CD-test of Pesaran (2004). We correct for cross sectional dependence using Driscoll and Kraay (1998) robust standard errors.

Second, another potential challenge is to identify the causal effects of central bank transparency on R&D and, in turn, on patents. To confront this challenge, we take the following steps in our estimation approach. First, we allow for a saturating set of country and time fixed effects as several unobserved country characteristics might be correlated with both central bank transparency and innovation performance. Each of these effects control for different aspects and shocks in an economy. For example, the country fixed effects control for time-invariant characteristics and this implies identification from (changes in) central bank transparency on innovation activity. The year fixed effects control for annual unobserved shocks common to all countries in our sample. Second, given all relevant control variables and fixed effects, omitted-variable bias is only possible in the presence of unobserved time-variant characteristics, which correlate with a change in both monetary policy transparency and innovation. To further insulate our analysis from the possibility of inconsistency and bias, and address concerns regarding endogeneity, we additionally apply a two-step instrumental variable (IV) and GMM estimation using appropriate instruments.

3. Data Description and Analysis

Our empirical analysis is based on annual data of 44 countries (28 developed and 16 developing) for the period 1999-2019. The list of all countries is presented in Table A.1 in the Appendix. We necessarily focus only on countries that report R&D expenditures and number of patent applications for the whole period under investigation.

Our data come from a range of sources. Information on the input of innovation, research and development share of Gross Domestic Product ($R\&D/GDP$), and innovation output, patent applications ($Patents$), comes from the World Bank, *World Development Indicators* (WDI).

Information on central bank transparency index (CBT) is derived from Dincer et al. (2022), who compiled an index of monetary policy transparency from 1998 to 2019 for 112 central banks and for nearly 150 countries.[11] The monetary policy transparency index is based on the disclosure of particular types of information that are pertinent to understanding the monetary policymaking process. An attractive feature of this dataset is that the transparency index can be decomposed into five aspects: political ($CBTpolitical$), economic

[11] Dincer/Eichengreen/Geraats Central Bank Transparency Data for 1998-2019. New updated indices based on revised methodology. For details, see Dincer, Eichengreen and Geraats, "Trends in Monetary Policy Transparency: Further Updates," International Journal of Central Banking, March 2022. Available at https://eml.berkeley.edu/ eichengr/data.shtml.

($CBTeconomic$), procedural ($CBTprocedural$), policy ($CBTpolicy$) and operational ($CBToperational$) transparency - each of which has three components that are scored 0, 1/2 or 1 based on the disclosure of specific information freely available in english. The overall transparency index equals the sum across all components, resulting in a score between 0 and 15. The higher the score is, the higher the degree to which a central bank discloses information on the monetary policy formulating process. Table A.2. in the Appendix provides detailed information about the definitions of those five sub-indices.

Figure 1 below shows the evolution of monetary policy transparency (total and by aspect) for developed (left) and developing countries (right).

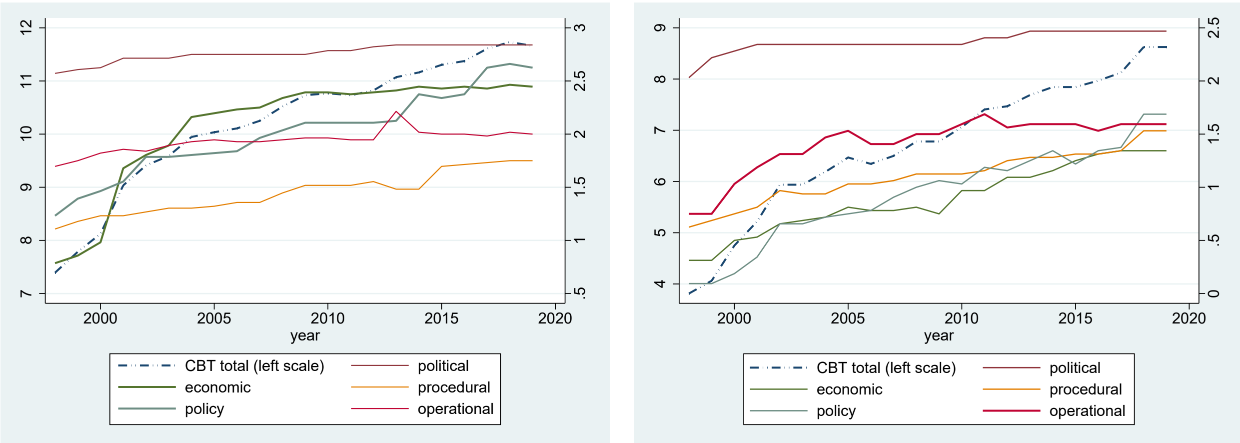

Figure 1: Development of various Aspects of Central Bank Transparency

Over time, as Figure 1 shows, there has been an increase of central bank transparency (CBT) across all countries, with developed countries exhibiting higher levels of central bank transparency throughout the period.

Data on an economy's sectoral composition, proxied by the share of employment in agriculture ($Agriculture$ $Share$), are obtained from the WDI. From the same source, we also derive information of a country's social aspects relevant to innovation, namely, human capital and labor market rigidity - the former, is proxied by the Human Development Index (HDI) and the latter, by the long-term unemployment ratio ($Unemployment$). A country's gross domestic product (GDP), to weight R&D investment, trade openness share to GDP ($Trade$) and FDI inflows share to GDP ($FDIinflows$) are also derived from the WDI.

Information on the quality of economic institutions ($Institutions$) is derived from the World Bank, *Worldwide Governance Indicators* (WGI) database. Among the five indicators the database provides, we employ the "Control of Corruption" which captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.[12]

To measure a country's level of financial development (FD), we employ a newly developed index constructed by the International Monetary Fund (IMF).[13] The index displays the multidimensional process of contemporary financial sector by capturing the key features of financial systems - depth (size and liquidity of markets), access (ability of individuals and companies to access financial services), and efficiency (ability of institutions to provide financial services at low cost and with sustainable revenues, and the level of activity of capital markets).

Table 1 below provides summary statistics of the variables in our analysis.

Table 1: Summary Statistics, 1999-2019

variables	Observations	Mean	St. Dev.	Min	Max
$Patents$	946	43,666	141,914	3	1,542,002
$R\&D/GDP$	942	1.57	1.03	0.04	5.14
CBT	968	8.95	2.88	1.5	14.5
$CBTpolitical$	968	2.62	0.60	1	3
$CBTeconomic$	968	1.65	0.92	0	3
$CBTprocedural$	968	1.32	0.70	0	3
$CBTpolicy$	968	1.62	0.96	0	3
$CBToperational$	968	1.75	0.58	0	3
$Unemployment$	952	7.78	4.99	1.87	33.29
$AgricultureShare$	968	8.97	9.53	0.03	51.03
HDI	968	0.83	0.09	0.57	0.96
FD	968	0.58	0.21	0.11	1.00
$Institutions$	968	0.87	1.05	-1.27	2.47
$FDIinflows$	968	6.32	18.58	-40.33	280.13
$Trade$	968	91.54	68.29	16.44	442.62

Note: *Patents* is a count (non-negative integer); *R&D* is a ratio of GDP; CBT is an index of central bank transparency (ranges from 0 to 15; where 0 denotes low transparency and 15 high transparency, Dincer et al. (2022); $CBTpolitical$, $CBTeconomic$, $CBTprocedural$, $CBTpolicy$ and $CBToperational$ are political, economic, procedural, policy and operational aspects of transparency, respectively (all five are indices and range between 0 and 3) - pairwise correlations range from 0.21 (political and procedural aspects) to 0.70 (economic and policy aspects); $Unemployment$ is a ratio (unemployed to labor force); $AgricultureShare$ is a ratio of employment in agriculture to total employment; HDI is the Human Development Index which proxies for human capital and ranges between 0 and 1; FD is an IMF-index of financial development; $Institutions$ refer to control of corruption; $FDIinflows$ and $Trade$ capture aspects of country's openness and are both ratios of GDP.

The average central bank of our sample appears to be fairly transparent with a mean of (CBT) about 9 over a range of 0 (low) to 15 (high). Bank of Sweden is the most transparent central bank while the central bank of China is the least transparent. Descriptive statistics by sub-sample (developed and developing),

[12] Consult World Governance Indicators (WGI) for definitions of institutional quality indices: https://info.worldbank.org/governance/wgi/.

[13] Available at: https://www.imf.org/external/pubs/cat/longres.aspx?sk=43621.0. For a description, see, Svirydzenka, K., *Introducing a New Broad-based Index of Financial Development*, Strategy, Policy, and Review Department, IMF Working Paper, WP/16/5., 2016.

reported in Table A.3 in the Appendix reveal considerable differences of transparency scores. On average, a central bank in a developed economy has a 10.23 score, while a central bank in a developing country scores 6.70 - and this difference is statistically significant. For all countries in our sample, among the different aspects of transparency, political transparency ($CBTpolitical$), which considers openness about monetary policy objectives, ranks higher than any other aspect of transparency with a mean of 2.64 over a range of 0 (low) to 3 (high), while procedural transparency ($CBTprocedural$), which concerns the way in which monetary policy decisions are reached, scores the lowest. As Table A.3 depicts, political transparency remains the highest aspect in both developed and developing countries, while procedural and economic are the lowest ranked aspects in developed and developing countries, respectively. Standard deviations in all aspects and the total index of monetary policy transparency are high, indicating considerable heterogeneity in the central bank transparency in our sample.

On average, countries in our sample spend about 1.6% of their output (GDP) on R&D investment and report about 44 thousands patent applications per year. Israel (4.13%) has the highest R&D spending while Philippines (0.14%) the lowest. The leader in patent applications is China, while Cyprus is on the opposite side of the spectrum.

Concerning the rest of the variables, there is also a wide heterogeneity in the sectoral production distribution across countries as indicated by the unemployment ratio and the employment in agriculture, as well as, in their degree of financial development, openness (trade of goods and services and the share of foreign investment), and in their effort to control for corruption. Finally, countries are fairly close to their potential when it comes to human capital development, as the mean value (0.83) is very close to the maximum value in our sample (0.96).

4. Empirical Results

This section presents the results. We first examine the importance of monetary policy transparency on innovation and the channels through which central bank transparency works to shape R&D. Then, we proceed to identify the particular aspect(s) of monetary policy transparency that matter most for innovation activity.

4.1. Does Monetary Policy Transparency Matter for Innovation?

Table 2 summarizes the results. Panel A presents OLS estimates of the innovation input ($R\&D$) equation (6) and Panel B of the innovation output ($\Delta lnPatents$) equation (5). All specifications include country and year fixed effects and control for cross sectional dependence. Standard errors are reported in parentheses. The last section of Table 2 presents a summary of the (total) effects of central bank transparency on innovation input ($R\&D$).

Table 2: Monetary Policy Transparency and Innovation Estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PANEL A	**Estimates of eq. (6): Innovation Input (dep. var.: $R\&D_t$)**							
CBT_{t-1}	-0.024***		-0.088*		-0.288***		-0.175***	
	[0.008]		[0.047]		[0.043]		[0.047]	
CBT^2_{t-1}			0.004		0.013***		0.010***	
			[0.002]		[0.003]		[0.002]	
FD_{t-1}	-0.003		- 0.021		-2.255***		-0.152	
	[0.246]		[0.244]		[0.635]		[0.230]	
$Institutions_{t-1}$	0.225***		0.230***		0.219***		-0.241**	
	[0.055]		[0.053]		[0.055]		[0.109]	
$CBT_{t-1} * FD_{t-1}$					0.477***			
					[0.134]			
$CBT^2_{t-1} * FD_{t-1}$					-0.023***			
					[0.007]			
$CBT_{t-1} * Institutions_{t-1}$							0.141***	
							[0.020]	
$CBT^2_{t-1} * Institutions_{t-1}$							-0.009***	
							[0.001]	
$Unemployment_{t-1}$	- 0.009***		-0.009***		-0.009***		-0.007**	
	[0.003]		[0.003]		[0.002]		[0.003]	
$AgricultureShare_{t-1}$	-0.010***		- 0.009**		-0.002		-0.005	
	[0.003]		[0.003]		[0.005]		[0.005]	
HDI_{t-1}	3.612***		4.098***		3.79***		2.804***	
	[0.976]		[0.974]		[1.021]		[0.988]	
FDI_{t-1}	-0.001***		-0.001***		-0.001***		-0.001***	
	[0.000]		[0.000]		[0.000]		[0.000]	
$Trade_{t-1}$	0.001**		0.001**		0.001**		0.001	
	[0.001]		[0.001]		[0.001]		[0.001]	
PANEL B	**Estimates of eq. (5): Innovation Output (dep. var.: $\Delta lnPatents_t$)**							
$lnPatents_{t-1}$		-0.121***		-0.112***		-0.104***		-0.103***
		[0.037]		[0.037]		[0.036]		[0.036]
$ln(R\&D/GDP)_t$		0.531***		0.330**		0.074		0.113
		[0.135]		[0.154]		[0.076]		[0.149]
Observations	892	878	892	878	892	878	892	878
Number of countries	44	44	44	44	44	44	44	44
Within R-squared	0.31	0.09	0.31	0.08	0.33	0.08	0.35	0.08
Year effects	Y	Y	Y	Y	Y	Y	Y	Y
Country effects	Y	Y	Y	Y	Y	Y	Y	Y
	Summary Effects of CBT							
CBT (local) max					8.39		6.57	
CBT (local) min					12.38		8.70	

Dependent variable in columns (1), (3), (5) and (7) is $R\&D/GDP$, while in columns (2), (4), (6) and (8) is $\Delta lnPantents$; (*), (**), (***) are significance levels at the 10%, 5% and 1%, respectively. We use the CD test of Pesaran (2021) for cross sectional dependence, for which we reject the Ho (no cross sectional dependence) and correct the standard errors by following Driscoll and Kraay (1998) in all specifications. Country and year fixed effects are included in all specifications; standard errors are reported in parentheses.

We begin by analyzing estimates in Panel A. Column (1) reports estimates for all countries in our sample without including the quadratic term CBT^2, while column (3) includes the quadratic term CBT^2. Greater central bank transparency appears to negatively associate with R&D activity in a linear fashion, as the coefficient of the quadratic term, CBT^2_{t-1}, reported in column (3) is statistically insignificant.

However, considerable heterogeneity, across countries could mask the effect of central bank transparency on innovation input. To reveal potential differential responses of R&D to greater central bank transparency, we introduce moderator variables which affect the strength and direction of the relationship between innovation input (R&D) and central bank transparency. Among potential moderators, we focus on the degree of financial sophistication, proxied by the level of financial development (FD) (Ma and Lin, 2016) and of trust in institutions (Zak and Knack, 2001), proxied by the control of corruption ($Institutions$) (Hakhverdian and Mayne, 2012).[14]

Both, moderators enter into the equation (6) as controls and are also interacted with CBT_{t-1} and CBT^2_{t-1}. Column (5) in Table 2 extents the specification in column (3) to allow for interactions between the moderator, level of financial development (FD) and central bank transparency (CBT_{t-1} and CBT^2_{t-1}). In a similar fashion, column (7) allows for interactions between the moderator, trust in institutions ($Institutions$), and central bank transparency (CBT_{t-1} and CBT^2_{t-1}).

The introduction of the moderators alters the picture: the estimates of central bank transparency (CBT_{t-1} and CBT^2_{t-1}) and of all interaction terms are statistically significant, supporting the existence of non-linear patterns. To read the effect of financial development on the central bank transparency and R&D relationship, we need to take first-order derivatives and study the range of responses as the moderator (FD) takes its mean, max and min values.[15]

Based on our calculations (see footnote 15), for FD values lower than approximately 0.60 (ranges from 0 to 1), the central bank transparency effect on R&D is U-shaped, while for larger values of FD the effect is inverse U-shaped.[16] Consequently, the strength and the direction of central bank transparency and R&D alters depending on the level of financial development: for highly financially sophisticated countries (FD

[14] Descriptive analysis by group of countries reported in Table A.1 in the Appendix shows that financial development (FD) and control of corruption (trust in institutions) ($Institutions$) greatly differ between groups.

[15] By accounting for any moderator, M, the estimating equation (6) becomes: $(R\&D/Q)_{i,t} = \gamma_i + \gamma_1 CBT_{i,t-1} + \gamma_2 CBT_{i,t-1} * M_{t-1} + \gamma_3 CBT^2_{i,t-1} + \gamma_4 CBT^2_{i,t-1} * M_{t-1} + \gamma_5 Z_{i,t-1} + \eta_{i,t}$, where M is FD in column (5) and $Institutions$ in column (7). The marginal effect of central bank transparency (CBT) on R&D is equal to the first-order derivative, $CBT^{\star} = \frac{\gamma 2 * M + \gamma 1}{-2 * (\gamma 4 * M + \gamma 3)}$). To quantify the effect, we substitute the estimated coefficients from specifications (5) and (7) in Table 2 and the value of the moderator M at the data means, max and min to study the range of responses. For example, based on our estimates in column (5), the effect of the moderator FD, on central bank transparency and innovation relationship is: $CBT^{\star} = \frac{0.477 * FD - 0.288}{0.046 * FD - 0.026}$. Based on this formula, we can calculate turning points of FD, which may alter the behavior of the central bank transparency and innovation relationship.

[16] We can obtain local minimum and maximum values for CBT: for economies which have FD values below (above) 0.60, a local minimum (maximum) for central bank transparency is 12.38 (8.39).

above 0.60) greater transparency is beneficial till a certain point (8.39 in particular) and beyond that it has negative effects, while for countries with lower financial sophistication (FD below 0.60) central bank transparency begins to have positive effects on R&D only after the value of 12.38.

Similarly, when control of corruption (proxy for trust) is lower than approximately 1.24 (ranges from -1.27 to 2.47), the central bank transparency effect on R&D is U-shaped; for larger values of control of corruption the effect is inverse U-shaped.[17] Therefore, for countries which enjoy trust, greater transparency is beneficial till a certain point (6.57 in particular) and beyond has negative effects, while for countries with low trust, central bank transparency begins to have positive effects on R&D after the value of 8.70.

All remaining control variables, in most specifications, carry the expected sign, as expected from the economic theory.

We now turn our attention to the relationship between central bank transparency and innovation output, proxied by the annual change in the log of patent applications ($\Delta lnPatents$). After estimating equation (6), we obtain the fitted values of R&D and place them in equation (5). Estimates are reported in Panel B. Results show that past accumulated knowledge, proxied by the lagged value of patents, strongly associates with the generation of new ideas in all groups. The current innovation investment, proxied by the fitted values of R&D, associates with the generation of new ideas only in the first two specification, while when introducing moderators into the model, the effect of current R&D becomes insignificant. Therefore, there seems to be no direct effect of central bank transparency on the innovation output, the number of patents a country files.

To cement our findings, we have performed a number of sensitivity analyses concerning samples and variables. We re-estimate all specifications in Table 2 excluding the 12 Eurozone countries (Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Italy, Latvia, Netherlands, Portugal and Spain) which share a common central bank, the European Central Bank, and therefore, all 12 have the same CBT index. Results, reported in Table A.4 do not change in any significant way. We have also used different definitions of a country's financial development.[18] We also controlled for financial stress using a newly developed continuous index of financial stress (FSI) constructed by the IMF employing text analytics methods (Ahir et al., 2023).[19] Our results remain unchanged, while the FSI coefficient appears statistically insignificant.

[17]We can obtain local minimum and maximum values for CBT: for economies which have control of corruption values below (above) 1.24, a local minimum (maximum) for central bank transparency is 8.70 (6.57).

[18]Results are available upon request. The IMF has created a number of indices that summarize how developed financial institutions and financial markets are in terms of their depth, access, and efficiency. These sub-indices are aggregated into two higher level indices, financial institutions (FI) and financial markets,(FM) which measure, respectively, how developed financial institutions and financial markets are overall.

[19]The FSI is available for 110 countries over each quarter during the period 1967-2018.

Estimates varied mildly, but the main findings pertain. Along with the level of financial development and its various definitions, we have also explored whether the level of public financial literacy plays any role. That was not an easy task as there are still no rich data on financial literacy with time and country variation. Still, we made an effort to include a proxy of financial literacy defined as 'the percentage of respondents who report that made or received a digital payment (% age 15+)' - data were retrieved from the World Bank with information limited only for the years 2014, 2017 and 2021 (the latter year is not in our sample) - without however obtaining any statistical significant effect. Next, we also control governmental policies in terms of R&D credits which are tax benefits on innovative firms, either SMEs or large firms. Data are derived by the OECD database and for the period 2005-2019 with missing data for Hong Kong, Iran, Malaysia, Moldova, Philippines, Saudi Arabia, Singapore, Tunisia, Ukraine. Both measures range between -0.03 and 0.45, without any significant variation in their values within countries. Results do not alter in any significant way for both measures. Finally, we explore further institution's trustworthiness measured by World Value Survey Database.[20] The lack of time dimension hampered our analysis and we had to resort to a narrower but more relevant index of trust provided by the *Eurobarometer* that of 'Trust in the European Central Bank (ECB)' for the 12 Eurozone of our sample. In addition to providing more robustness on the trust measure, an extra benefit on focusing only on the Eurozone countries is to eliminate any concern that these countries are subject to the same monetary policy implemented by a common central bank, the ECB and therefore all have exactly the same central bank transparency score. Basic descriptive analysis showed that among the Eurozone countries the Dutch (73%) and the Finnish (70%) place high trust in the ECB, whereas less than half (42%) of the Greeks and just about half of the French (49%) trust the ECB. Then, we re-estimate specification in column 7 of Table 2 by including 'Trust in ECB' (in place of $Institutions$) and its interaction with CBT. Results are presented in Table A.5 in the Appendix. By using the formula in footnote 15, we compute the range of values of optimum CBT in Eurozone countries. We find that the optimum value of CBT for Greece and Netherlands is 14.48 and 11.81, respectively. Assuming that if a country were to absolutely trust the ECB (trust score equal to 1), then the optimum CBT in this case would be 10.5 which is very close to the reported value of CBT for all Euro area countries in our dataset. The takeaway message of this result is that the ECB should take into account the trust of Eurozone civilians before determining the level of monetary policy transparency; if ECB decides to be more transparent, the innovation input of highly ECB-trusted countries may be undermined.

Summing up, we find that monetary policy transparency is relevant for innovation input, R&D. The

[20]Availiable at (https://www.worldvaluessurvey.org/wvs.jsp).

effect, however, varies depending on the level of financial sophistication and trust, which both act as moderators. High levels of financial knowledge and trust in institutions (which usually are attributes of advanced economies) do not require huge central bank information disclosure for R&D investment to flourish. In contrast, when financial sophistication is not adequate and institutional distrusts prevails (which is mainly the case in the developing economies), channeling large information disclosure is necessary to increase innovation investment. Central bank transparency leaves the output of innovation, patents, almost unaffected.

Our findings align with theoretical contributions which emphasize possible adverse effects of increased transparency. Provision of costless public information may crowd out private information or even distract market participants from their private information causing under(over)reaction (Morris and Shin, 2005; Demertzis and Hallett, 2007). Evidence based on experimental set ups also advocates that it is optimal for the central bank to actually disclose less than it knows in presence of intermediate levels of public information precision (Kool et al., 2011).

We also find that there is no need for abundant public information in high financially sophisticated and trusted environments. Investors' private information suffices for reacting timely in economic challenges and spotting investment opportunities. High trust in institutions further allows investors to pursue investments with higher risk, such as R&D. The interplay of timely information and opportunity is of pivotal importance for the realization of R&D investment. If too much public information is released, uncertainty dissipates as well as investment opportunities and fewer firms go for major R&D investment as monopoly rents are lower. Less central bank information, therefore, increases incentives for risky investment. The opposite is the case in environments of low financial sophistication and trust: it takes a significant amount of disclosure to ease financial concerns and incompetencies and clear the air of mistrust for firms to take the risk and invest in R&D.

A direct implication that emerges from our results: the sophistication of a country's financial system and the level of trust in institutions make monetary policy more efficient as with little information real outcomes, such as innovation, are achieved. Therefore, policies should aim at increasing the access, depth and efficiency of the financial sector, and consequently its sophistication. The central bank should invest in her reputation to be a trusted institution, by increasing the level of her commitment to deliverables and not necessarily the level of information communication as the former would increase the impact of central bank transparency on the real economy. A trusted (committed) central bank which discloses clear and concrete information in financially knowledgeable environments could turn the economic growth wheels via investment in innovation. This is a lesson that developing countries need to be aware of: central bank transparency is vital but it is efficient only in presence of high level of financial knowledge and trust. Under those conditions, without wasting resources and time, central bank communication in developing economies can have economic growth effects.

The divide between high financial sophistication and trustworthy institutions versus low financial sophistication and mistrusted institutions points, in essence, to developed and developing countries divide. The section that follows explores central bank transparency within each group raising the issue of optimal level of transparency.

Is There any (Dis)Similarity of Behaviors Between Developed and Developing Countries?

Table 3 presents the results. Panel A reports OLS estimates of the innovation input ($R\&D$) equation (6) and Panel B of innovation output ($\Delta lnPatents$) equation (5). Columns (1) and (2) show estimates for the developed and columns (3) and (4) for the developing countries.

Two noteworthy findings emerge: first, a non-linear relationship is revealed in both groups of countries, as the coefficients of CBT_{t-1} and CBT^2_{t-1} appear statistically significant, which resonates views of optimal level of monetary policy transparency (van der Cruijsen and Eijffinger, 2010; Horvath and Vasko, 2016; Zhang et al., 2023), and second, the effect of central bank transparency on R&D between those two groups is dissimilar - an inverse U-shaped effect for developed countries and a U-shaped effect for the developing ones. The dissimilarity of patterns between developing and developed countries aligns with findings reported in recent studies (Zhang et al., 2023).

The optimal level of central bank transparency for the developed economies is estimated at 9.76 (on a scale of 0 to 15)[21]; ex-ante this value, a unit change in the central bank transparency index relates with an increase in R&D activity of about 0.03 per cent, while ex-post a unit change in central bank transparency associates with a decline in R&D of about 0.02 per cent, as the lower part of Table 4.1 reports.[22]. Evidently, some level of information provided by central banks is beneficial for R&D investors; the releasing, however, of too much ('noisy') information can result in bad decisions (Dale et al., 2011) with negative consequences for R&D investment.

[21] To calculate the maximum value of 9.76, we take the first derivative of R&D in equation (6) with respect to central bank transparency (CBT) and set it equal to zero, and obtain the maximum value of CBT that equals to: CBT= - $\beta 1/(2^*\beta 2)$.

[22] The formula used for all these calculations before (ex-post) and after (ex-ante) max value of CBT is the following: $\beta 1+2^*\beta 2^*$(mean value of central central bank transparency ex-post max) and $\beta 1+2^*\beta 2^*$(mean value of central bank transparency ex-ante max).

Table 3: Monetary Policy Transparency and Innovation Estimates for Developed and Developing Countries

	Developed		Developing	
	(1)	(2)	(3)	(4)
	Estimates of eq. (6): Innovation Input (dep. var.: $R\&D_t$)			
CBT_{t-1}	0.161**		-0.199***	
	[0.076]		[0.046]	
CBT^2_{t-1}	-0.008**		0.011***	
	[0.003]		[0.003]	
$Unemployment_{t-1}$	-0.003		- 0.010	
	[0.003]		[0.006]	
$AgricultureShare_{t-1}$	-0.033***		0.015**	
	[0.006]		[0.004]	
HDI_{t-1}	0.119		7.710***	
	[1.595]		[1.301]	
$Institutions_{t-1}$	0.192***		0.216**	
	[0.057]		[0.088]	
FD_{t-1}	-0.301		0.624	
	[0.222]		[0.494]	
FDI_{t-1}	0.001***		-0.003	
	[0.000]		[0.002]	
$Trade_{t-1}$	0.002**		0.001	
	[0.001]		[0.001]	
PANEL B	**Estimates of eq. (5): Innovation Output (dep. var.: $\Delta lnPatents_t$)**			
$lnPatents_{t-1}$		-0.101**		-0.104**
		[0.039]		[0.048]
$ln(R\&D/GDP)_t$		0.300		0.018
		[0.234]		[0.026]
Observations	587	564	305	310
Number of countries	28	28	16	16
Within R-squared	0.34	0.08	0.44	0.13
Country effect	Y	Y	Y	Y
Year effects	Y	Y	Y	Y
	Summary Effects of CBT			
	(max)		(min)	
CBT optimum	9.76		9.09	
ex-ante (average effect)	0.03		-0.08	
ex-post (average effect)	-0.02		0.03	

Dependent variable in columns (1) and (3) is $R\&D/GDP$, while in columns (2) and (4) is $\Delta lnPantents$; (*), (**), (***) are significance level at the 10%, 5% and 1%, respectively. We use the CD test of Pesaran (2021) for cross sectional dependence, for which we reject the Ho (no cross sectional dependence) and correct the standard errors by following Driscoll and Kraay (1998) in all specifications. Country and year fixed effects are included in all specifications; standard errors are reported in parentheses.

We would like to note here that the group of developed countries has, an average CBT score 10.23, as Table A.3 in the Appendix shows, which is above that of the optimum value (9.76). Consequently, increasing the level of information disclosure above the optimum value could be, on average, detrimental for the advanced economies' R&D investment. However, within the group, there are heterogenous responses:

Hong Kong and Singapore report the lowest CBT scores (7.25 and 7.34, respectively), and, therefore, could benefit from one unit of increased transparency (till the optimum value) by 0.04 per cent in terms of R&D, while on the other spectrum is Sweden with CBT score of 13.43 which is way above the optimum and thus, a further increase of its central bank transparency by one unit undermines R&D efforts by 0.06 per cent. Among the socio-economic variables in the control set Z, higher openness, in terms of trade and FDI inflows, greater control for corruption, and a more advanced production structure positively relate with higher levels of R&D.

The opposite pattern emerges for the group of developing countries, where a U-shaped effect of central bank transparency on innovation is observed. The minimum level of central bank transparency is at 9.09 (on a scale of 0 to 15). A unit change in the central bank transparency index -till the value of 9.09- relates with a decrease in R&D of about 0.08 per cent, while beyond the value of 9.09, a unit change in central bank transparency associates with an increase in R&D of about 0.03 per cent, as the lower part of Table 4.1. Developing economies display, on average, a CBT value of 6.70, as Table A.3 in the Appendix shows, which is far from the local minimum of CBT (9.09). Further, developing economies appear to be a much more heterogenous group in terms of central bank transparency performance as the standard deviation (2.85) in this group is higher compared to that of developed economies (1.97). China and Iran have the lowest CBT score (2.2 and 3, respectively), while Hungary has by far the highest value (10.45). Therefore, within the developing economies group, the impact of one unit increase of central bank transparency on R&D investment ranges between -0.15 per cent (for China) and 0.03 per cent (for Hungary). Concerning the control variables, the role of human capital singles out as an important factor for innovation ($R\&D$). Advancing the structure of the production also associates to higher $R\&D$ investment.

We now turn our attention to the relationship between central bank transparency and innovation output, proxied by the annual change in the log of patent applications ($\Delta lnPatents$). After estimating equation (6), we obtain the fitted values of R&D and place them in equation (5). Estimates for developed and developing countries are reported in columns (2) and (4) of Panel B, respectively. Results show that past accumulated knowledge, proxied by the lagged value of patents, strongly associates with the generation of new ideas in all groups. The negative and lower than one coefficient of past knowledge ($lnPatents$) suggests a process of convergence in patenting activity. Less innovative countries have, during the period of analysis, been able to reduce the technological gap with more advanced countries (Rodríguez-Pose and Cataldo, 2014). The effect of current innovation investment, proxied by the fitted values of R&D, appears to be statistically insignificant and, therefore, central bank transparency, through the channel of R&D, exerts no effect at all on innovation output, patents.

Overall, our results concur with concerns expressed in theoretical literature about the role of greater transparency in shaping economic outcomes (Morris and Shin, 2005; Demertzis and Hallett, 2007; Dale et al., 2011; Kool et al., 2011). When it comes to developed economies more information disclosure by the central bank enables market participants to form more accurate expectations of economic development trends, which are conducive to reducing financial volatility (Demertzis and Hallett, 2007; Dincer and Eichengreen, 2014; Wang and Sun, 2019). However, large amounts of information could lead to confusion and deterioration of people's prediction quality. For the case of developing economies, when central banks change from 'confidential' to 'open', market participants perhaps are skeptical in trusting central bank information that even causes negative reactions which eventually decay and even turn positive at greater levels of central bank information disclosure.

The literature highlights potential reasons as to the differences in the reactions between developed and developing countries. According to Zhang et al. (2023) institutional problems, like loopholes in regulations (Wang and Sun, 2019) supervision deficiencies (Mertzanis, 2020), political interference (Binder, 2021) and corruption (Sami et al., 2020) in developing countries could ignite a sentiment of distrust in central bank information releasing. Financial literacy incompetencies could also be responsible for negative reactions to central bank openness hampering the effectiveness of communication between the two.

Robustness: Accounting for Endogeneity

A common concern when dealing with policy variables, such as monetary policy transparency and economic outcomes, such as innovation performance, is endogeneity. Innovation may be influenced by monetary policy transparency and, in turn, (financial) innovation may influence the effectiveness of transparency of the central bank. Further, both variables could be influenced by institutions and other policies not included in the model. We address endogeneity and omitted variable bias using IV for R&D (equation 6) and GMM for patents (equation 5) estimation. Therefore, we re-estimate specifications in Table 3 using IV and GMM methodologies.

Table 4: Monetary Policy Transparency and Innovation IV & GMM Estimates

	Developed		Developing	
	(1)	(2)	(3)	(4)
PANEL A	**Estimates of eq. (6): Innovation Input (dep. var.: $R\&D_t$)**			
CBT_{t-1}	0.199**		-0.219***	
	[0.085]		[0.059]	
CBT^2_{t-1}	-0.012***		0.013***	
	[0.004]		[0.004]	
FD_{t-1}	-0.124		0.474	
	[0.291]		[0.490]	
$Institutions_{t-1}$	0.258***		0.200*	
	[0.081]		[0.102]	
$Unemployment_{t-1}$	0.004		0.010	
	[0.006]		[0.006]	
$AgricultureShare_{t-1}$	-0.008		0.017***	
	[0.008]		[0.004]	
HDI_{t-1}	1.775		8.942***	
	[1.272]		[1.330]	
FDI_{t-1}	-0.000		-0.002	
	[0.000]		[0.002]	
$Trade_{t-1}$	0.007***		0.001	
	[0.001]		[0.001]	
PANEL B	**Estimates of eq. (5): Innovation Output (dep. var.: $\Delta lnPatents_t$)**			
$lnPatents_{t-1}$		-0.132***		-0.156***
		[0.048]		[0.053]
$lnR\&D_t$		-0.099		0.013
		[0.160]		[0.035]
Observations	519	462	287	266
Number of countries	26	26	16	16
Within R-squared	0.36	0.10	0.42	0.08
Year effects	Y	Y	Y	Y
Country effects	Y	Y	Y	Y
Hansen J-test		0.65		0.42
K-P rk Wald		234.28		212.99
Durbin-Wu-Hausman		0.42		0.30
K-P rk LM F-statistic		0.00		0.00
Arellano-Bond AR-1		0.31		0.19
Arellano-Bond AR-2		0.67		0.27
Arellano-Bond AR-3		0.78		0.27
CBT max	8.00			
CBT min			8.35	

Dependent variable in columns (1) and (3) is $R\&D/GDP$, while in columns (2) and (4) is $\Delta lnPantents$; (*), (**), (***) are significance level at the 10%, 5% and 1%, respectively. We use the CD test of Pesaran (2021) for cross sectional dependence, for which we reject the Ho (no cross sectional dependence) and correct the standard errors by following Driscoll and Kraay (1998) in all specifications. Country and year fixed effects are included in all specifications; standard errors are reported in parentheses.
Diagnostics of GMM estimation: Hansen J-test (p-value) examines whether instruments are valid (null); Kleibergen-Paap (K-P) rk Wald (F-statistic) tests whether instruments are weak (null), with critical values varying between 7.25 and 19.93; Durbin-Wu-Hausman (p-value) tests whether instrumental variables techniques are required (null); Kleibergen-Paap (K-P) rk LM statistic (p-value) tests whether the estimated equation is underidentified (null); Arellano-Bond for AR(1) to AR(3) (p-value) test for no autocorrelation (null).
Instruments used in equation (5): $lnpatents_{t-2}$ and $lnpatents_{t-3}$. Instruments used in equation (6): CBT_{t-1}, the CBI_{t-1} and the set of control variables used in equation (6).

Results are reported in Table 4. Column (1) and column (3) report IV estimates of the R&D equation (6) for the case of developed and developing countries, respectively. Specifically, we instrument for our presumed endogenous variables: lagged central bank transparency (CBT_{t-1} and CBT^2_{t-1}). An appropriate instrument will impact on the depending variable ($R\&D$) only through the instrumented variable (CBT) and not through any other variable in the model. Among potential candidates, are lagged values and differences of lagged values of the variable itself (CBT). Going back in time, by taking lagged values, ensures that there is no feedback effect, as the past may influence the present but not the opposite. Central bank's institutional arrangements could also serve as potential candidates for instruments. The degree of central bank independence (CBI) is one of them. Central bank independence leads to higher political transparency, because there is less political pressure to the central bank (Dincer and Eichengreen, 2014) and very importantly, its effect on $R\&D$ runs only through central bank transparency. We apply a two-step IV estimation method: In the first step, we regress central bank transparency (CBT) on lagged values of central bank independence (CBI), lagged values of central bank transparency (CBT) and include all variables of equation (6) as additional controls (Wooldridge, 2010). In the second, the fitted value of CBT is used to instrument for the actual value of CBT in the R&D equation (6).

Then, we proceed with plugging the fitted value of $R\&D$ into Patent equation (5), which is a dynamic equation and is estimated by using a two-step efficient GMM estimator (Baum et al., 2007).[23] Patent GMM estimates are presented in columns (2) and (4) for developed and developing countries, respectively. To claim causal effects of central bank transparency on patents, we use again various fixed effects and GMM estimation using, as instruments for the endogenous variable ($lnPatents_{t-1}$), lagged values (($lnPatents_{t-2}$, ($lnPatents_{t-3}$)). A set of instrument tests is performed to confirm that our instrumentation strategy is relevant. Specifically, we test the instrument validity by applying a Hansen J-test with the null hypothesis that the over-identifying restrictions are valid (i.e., that instruments are exogenous). To test for weak instruments (i.e., excluded instruments are correlated with the endogenous regressors, but only weakly), we report Kleibergen-Paap rk Wald F-statistics compared to their respective critical values. In addition, a Durbin-Wu-Hausman test for the exogeneity of the endogenous regressors is also reported, where a rejection of the null hypothesis indicates that instrumental variable techniques are required. We also perform a set of diagnostic tests for the fitness of our specification. We apply a Kleibergen-Paap rk LM test under the

[23]By using system GMM, a great number of instruments is usually used for estimation, both in levels and in differences (Arellano and Bond, 1991; Arellano and Bover, 1995). Roodman (2009) suggests that the difference and system GMM have been designed for few time periods and many individuals. The dynamic bias becomes insignificant when a great number of time periods exists and thus, it is more convenient to use a fixed-effects estimator. In the meanwhile, the number of instruments in difference and system GMM tends to explode increasing time periods and thus in case the number of individuals is small, the cluster-robust standard errors and the Arellano-Bond autocorrelation test may be unreliable.

null hypothesis that the model is underidentified (i.e., that the excluded instruments are correlated with the endogenous regressors). We use Arellano-Bond AR(1) to AR(3) tests, under the null hypothesis of no autocorrelation, to examine whether autocorrelation is present.

Overall, we conclude that even controlling for endogenity by employing IV and GMM estimation techniques, results are considerable stable as they do not show any significant change compared to those reported in Table 3. Consequently, endogeneity is not a serious concern in our analysis and, therefore, proceed with OLS estimations controlling for country and year fixed effects and for cross sectional dependence.

4.2. What Aspect of Monetary Policy Transparency Matters Most for Innovation?

So far, we have estimated the aggregate effect of the composite index of monetary policy transparency on innovation activity. In this section, we focus on the effects of different aspects of monetary policy transparency. Table 5 summarizes estimates of equation (6).

Table 5: Monetary Policy Transparency Aspects and Innovation Estimates

	Developed					Developing				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Estimates of eq. (6): Innovation Input (dep. var.: $R\&D_t$)									
CBT_{t-1}	0.112	0.367**	0.112	0.248	0.941***	-0.756*	-0.029	-0.380***	-0.125*	-0.160*
	[0.145]	[0.153]	[0.075]	[0.184]	[0.135]	[0.433]	[0.050]	[0.070]	[0.060]	[0.079]
CBT^2_{t-1}	-0.022	-0.128***	-0.054***	-0.074	-0.212***	0.119	0.021	0.116***	0.034	0.035
	[0.044]	[0.042]	[0.017]	[0.055]	[0.030]	[0.106]	[0.023]	[0.018]	[0.035]	[0.030]
$Unemployment_{t-1}$	0.005	0.004	0.003	0.004	0.003	0.009	0.008	0.008	0.007	0.010
	[0.003]	[0.003]	[0.002]	[0.002]	[0.002]	[0.006]	[0.007]	[0.008]	0.007	[0.008]
$AgricultureShare_{t-1}$	-0.027***	-0.027***	-0.027***	-0.037***	-0.016**	0.014***	0.013***	0.015***	0.013***	0.014***
	[0.005]	[0.005]	[0.005]	[0.008]	[0.007]	[0.004]	[0.005]	[0.005]	[0.004]	[0.004]
HDI_{t-1}	1.297	0.437	0.270	-0.589	0.002	7.112***	7.518***	7.460***	6.987***	8.067***
	[1.359]	[1.595]	[1.389]	[1.621]	[1.758]	[1.764]	[1.560]	[1.277]	[1.503]	[1.742]
$Institutions_{t-1}$	0.223***	0.215***	0.210***	0.223***	0.153***	0.155	0.130	0.188	0.099	0.179
	[0.048]	[0.055]	[0.051]	[0.044]	[0.049]	[0.133]	[0.142]	[0.118]	[0.147]	[0.113]
FD_{t-1}	-0.313	-0.185	- 0.253	-0.426	-0.304	0.643	0.932**	0.844**	0.908*	0.753
	[0.211]	[0.211]	[0.211]	[0.231]	[0.252]	[0.522]	[0.430]	[0.388]	[0.493]	[0.450]
FDI_{t-1}	0.001***	0.001***	0.001***	0.001***	0.001***	-0.003	-0.004	-0.004	-0.003	-0.003
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.002]	[0.003]	[0.003]	[0.002]	[0.003]
$Trade_{t-1}$	0.001**	0.001	0.002**	0.002**	0.002**	0.001	0.001	0.001	0.001	0.001*
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
CBT optimal		1.45			2.22			1.64		

Columns (1) to (5) report estimates for developed countries while columns (6) to (10) for developing. Dependent variable is $R\&D/GDP$; Central bank transparency index (CBT) is political ($CBTpolitical$) aspect in columns (1) and (6), economic ($CBTeconomic$) aspect in columns (2) and (7), procedural ($CBTprocedural$) aspect in columns (3) and (8), policy ($CBTpolicy$) aspect in columns (4) and (9), and operational ($CBToperational$) aspect in columns (5) and (10); (*), (**), (***) are significance level at the 10%, 5% and 1%, respectively. We use the CD test of Pesaran (2021) for cross sectional dependence, for which we reject the Ho (no cross sectional dependence) and correct the standard errors by following Driscoll and Kraay (1998) in all specifications. Country and year fixed effects are included in all specifications; standard errors are reported in parentheses.

Columns (1) to (5) present OLS estimates controlling for cross sectional dependence of political ($CBTpolitical$), economic ($CBTeconomic$), procedural ($CBTprocedural$), policy ($CBTpolicy$) and operational ($CBToperational$) aspects of transparency, respectively, for the developed economies, while columns (6) to (10) for the developing countries. All specifications include country and year fixed effects and standard errors are reported in parentheses.

Estimates for the developed economies reported in columns (1) to (5) show that among the different types of central bank transparency, it is the economic and mainly the operational aspects that relate the most with higher R&D activity. These types of central bank transparency focus on informing the market participants about, on the one hand, the economic information used in monetary policymaking, which is crucial for forecasting purposes, and on the other hand, the implementation and evaluation of monetary policy actions, which is crucial for the adjustment of market expectations for better future predictions. The optimal values (maxima) presented in the last line of Table 5 indicate that markets appreciate some (concrete) information transparency from the central bank about its economy targets and operations, and therefore sophisticated agents who have trust in institutions react in a positive manner and invest in R&D. However, greater information creates rather noise which results in negative outcomes.

The picture is very different when it comes to developing economies (columns (6) to (10)), where the procedure aspect of central bank transparency, which concerns the way in which monetary policy decisions are reached exhibits a U-shaped effect, while political, policy and operational aspects have a linear and negative (at 10% level of statistical significance) relationship with R&D. The greater the information the central bank discloses about its monetary policy objectives (political transparency), the promptness of monetary policy decisions (policy transparency) and the implementation of monetary policy actions (operational transparency), the more confusion is created in developing countries and, therefore, the higher the negative economic outcomes, such as decreases in R&D investment. Those results are crucial for policymakers as they suggest that the only transparency, which when enhanced, is able to turn the relationship with R&D into positive territories, is the procedural one. Hence, policymakers in developing countries should provide an explicit monetary policy strategy, a comprehensive, timely account of monetary policy deliberations and the voting record for monetary policy decisions. Any other type of transparency will actually hinder R&D innovation.

5. Conclusion

The pivotal role of market expectations places a central bank's communication policy at center stage. Our paper offers new insights into the impact of monetary policy transparency on real economy through its effect on innovation activity.

We first ask whether central bank transparency shapes innovation activity, both from the input and output side. We model R&D investment as a function of central bank transparency, among other controls, and by applying appropriate econometric techniques, we are able to obtain the effect of central bank transparency on R&D. Then, we estimate a typical R&D-based endogenous growth model, where new knowledge -the output of innovation production process- is proxied by the annual growth of patents, while new investment in knowledge -the input of innovation production process- is R&D.

Our results support a robust non-linear relationship between R&D and central bank transparency, which operates via the channels of financial market sophistication and trust. Results show that environments with high degree of financial knowledge and trust do not require tremendous central bank information disclosure for R&D investment to flourish. In contrast, when financial sophistication is low and institutional distrusts high, then channeling large information to the market is necessary for investment in R&D to increase. Non-linearities emerge very intensely when we study the issue of optimal monetary policy transparency for developed and developing countries. Central bank transparency and R&D relationship exhibits an inverse U-shape pattern for developed countries and a U-shape for the developing ones. On average, for the developing countries, increased information about central bank's monetary policy can be beneficial till a certain point, and thereafter has negative effects on R&D. Centrals banks that have not been reluctant in releasing information should be cautious about further increasing the level of disclosed information, as this may distract and stress the markets by creating noise; otherwise, they could harm their innovation and consequently, future growth perspectives. The opposite is the case for the developing countries whose central banks are plugged by severe institutional problems. Releasing more information, at the beginning could stir up skepticism and chaos having thus a negative impact on R&D; gradually, an increased level of policy openness could restore trust and be beneficial for innovation activity.

Second, we ask whether a particular aspect of transparency matters for innovation. Our results support that the economic and mainly, the operational aspect of central bank transparency matter the most for developed economies. However, while any greater disclosure on political, policy and operational aspects relates negatively to R&D in developing countries, greater openness about central bank procedures becomes beneficial for innovation, after a certain level.

Most important, our results highlight that central bank information disclosure can aid technological knowledge; the effects of such disclosure, however, strongly depend on the level of financial sophistication and trust in institutions. If these two conditions hold, even some level of information disclosure has real economy effects through its impact on innovation. The main takeaway is that policies targeted at bolstering central bank trust and the development of a sophisticated financial sector increase the efficiency of central bank information communication and are conductive to economic growth.

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Appendix

Table A.1: List of Countries

Australia	Finland	Korea	Russian Fed.
Austria	France	Latvia	Saudi Arabia
Belgium	Germany	Malaysia	Singapore
Brazil	Greece	Mexico	South Africa
Bulgaria	Hong Kong	Moldova	Spain
Canada	Hungary	Netherlands	Sweden
China	Iceland	New Zealand	Switzerland
Colombia	Iran	Norway	Tunisia
Cyprus	Israel	Philippines	Ukraine
Czech Rep.	Italy	Poland	United Kingdom
Denmark	Japan	Portugal	United States

Table A.2: Aspects of Monetary Policy Transparency

Aspects of Monetary Policy Transparency	Definition
Political ($CBTpolitical$)	considers openness about monetary policy objectives, including
	(i) a formal statement and prioritization of the objectives;
	(ii) a quantification of the main objectives; and
	(iii) explicit institutional arrangements, such as instrument independence.
Economic ($CBTeconomic$)	focuses on the economic information used in monetary policymaking, including
	(i) key macroeconomic and financial variables;
	(ii) the macroeconomic model(s) used by the central bank for its monetary policy analysis; and
	(iii) numerical macroeconomic forecasts by the central bank.
Procedural ($CBTprocedural$)	concerns the way in which monetary policy decisions are reached, including
	(i) an explicit monetary policy strategy;
	(ii) a comprehensive, timely account of monetary policy deliberations; and
	(iii) the voting record for monetary policy decisions.
Policy ($CBTpolicy$)	refers to the prompt disclosure of monetary policy decisions, including
	(i) prompt announcement of adjustments in the main monetary operating instrument or target;
	(ii) explanation of monetary policy decisions; and
	(iii) explicit policy inclination or forward policy guidance.
Operational ($CBTpolicy$)	captures the implementation of monetary policy actions, including
	(i) an evaluation of the achievement of the main monetary policy operating targets;
	(ii) shocks affecting the transmission of monetary policy; and
	(iii) an evaluation of monetary policy outcomes.

Source: Dincer, Eichengreen and Geraats (2022).

Table A.3: Descriptive Statistics by Group

	Developed Countries (28)			Developing Countries (16)			Differences	
	(Obs)	(Mean)	(Std. Dev.)	(Obs)	(Mean)	(Std. Dev.)	(Mean)	(p-value)
Patents	599	44,947	4,593	347	41,455	9,776	3,492	0.72
R&D	616	2.02	0.98	347	0.72	0.42	1.27	0.00
CBT	616	10.23	1.97	352	6.70	2.85	3.53	0.00
CBTpolitical	616	2.76	0.02	352	2.37	0.04	0.39	0.00
CBTeconomic	616	2.08	0.03	352	0.89	0.04	1.19	0.00
CBTprocedural	616	1.45	0.03	352	1.10	0.04	0.35	0.00
CBTpolicy	616	2.01	0.03	352	0.93	0.05	1.08	0.00
CBToperational	616	1.94	0.02	352	1.41	0.03	0.52	0.00
FD	616	0.69	0.16	352	0.39	0.14	0.30	0.00
Institutions	616	1.51	0.69	352	-0.24	0.48	1.75	0.00
Unemployment	615	7.01	3.97	337	9.18	6.22	2.17	0.00
AgricultureShare	616	4.22	3.38	352	17.29	11.01	13.07	0.00
HDI	616	0.89	0.04	352	0.74	0.06	0.15	0.00
$FDI_{i}nflows$	616	7.85	22.60	352	3.65	6.68	4.19	0.00
Trade	616	98.33	78.82	352	79.66	41.68	18.67	0.00

Columns (1) to (3) present descriptive statistics of developed (28 in total) and columns (4) to (6) for developing (16 in total) economies. The last two columns test for the mean differences between the two groups and report p-values.

Table A.4: Monetary Policy Transparency and Innovation Estimates w/o Eurozone Countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PANEL A	**Estimates of eq. (6): Innovation Input (dep. var.: $R\&D_t$)**							
CBT_{t-1}	-0.018**		-0.093**		-0.350***		-0.175***	
	[0.007]		[0.043]		[0.068]		[0.042]	
CBT^2_{t-1}			0.004*		0.016***		0.010***	
			[0.002]		[0.004]		[0.002]	
FD_{t-1}	0.649**		0.600**		2.093***		0.476*	
	[0.267]		[0.259]		[0.570]		[0.248]	
$Institutions_{t-1}$	0.312***		0.316***		0.293***		-0.225*	
	[0.064]		[0.060]		[0.062]		[0.111]	
$CBT_{t-1} * FD_{t-1}$					0.604***			
					[0.157]			
$CBT^2_{t-1} * FD_{t-1}$					-0.029***			
					[0.009]			
$CBT_{t-1} * Institutions_{t-1}$							0.155***	
							[0.023]	
$CBT^2_{t-1} * Institutions_{t-1}$							-0.009***	
							[0.001]	
$Unemployment_{t-1}$	0.006		0.006		0.005		0.002	
	[0.005]		[0.004]		[0.005]		[0.005]	
$AgricultureShare_{t-1}$	0.012***		0.010***		-0.003		0.004	
	[0.003]		[0.003]		[0.005]		[0.005]	
HDI_{t-1}	4.618***		5.317***		4.947***		3.784***	
	[1.112]		[1.119]		[1.192]		[1.101]	
FDI_{t-1}	-0.002		-0.002		-0.002		-0.002	
	[0.002]		[0.002]		[0.002]		[0.002]	
$Trade_{t-1}$	0.001*		0.001		0.001		0.000	
	[0.001]		[0.001]		[0.001]		[0.001]	
PANEL B	**Estimates of eq. (5): Innovation Output (dep. var.: $\Delta lnPatents_t$)**							
$lnPatents_{t-1}$		-0.116**		-0.106**		-0.098**		-0.099***
		[0.044]		[0.042]		[0.042]		[0.041]
$ln(R\&D/GDP)_t$		0.225***		0.093*		-0.031		0.010
		[0.072]		[0.069]		[0.036]		[0.095]
Observations	640	649	640	649	640	649	640	649
Number of countries	32	32	32	32	32	32	32	32
Within R-squared	0.29	0.10	0.30	0.09	0.33	0.09	0.35	0.09
Year effects	Y	Y	Y	Y	Y	Y	Y	Y
Country effects	Y	Y	Y	Y	Y	Y	Y	Y
	Summary Effects of CBT							
CBT (local) max					8.39		6.57	
CBT (local) min					12.38		8.70	

Dependent variable in columns (1), (3), (5) and (7) is $R\&D/GDP$, while in columns (2), (4), (6) and (8) is $\Delta lnPantents$; Table A.1 in the Appendix lists the countries of our sample excluding the 12 Eurozone (Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Italy, Latvia, Netherlands, Portugal and Spain); (*), (**), (***) are significance level at the 10%, 5% and 1%, respectively. We use the Pesaran (2004) test for cross-sectional dependence (we obtain a p-value equal to 0.08) and correct the standard errors by following the approach proposed by Driscoll and Kraay (1998) in all cases. Further, country and year fixed effects are included in all specifications; standard errors are reported in parentheses.

Table A.5: Monetary Policy Transparency and Trust in ECB (Eurozone countries)

	Estimates of eq. (6): Innovation Input (dep. var.: $R\&D_t$)
CBT_{t-1}	0.518**
	[0.255]
CBT^2_{t-1}	-0.010
	[0.010]
$CBT_{t-1} * Trust_{t-1}$	0.320***
	[0.117]
$CBT^2_{t-1} * Trust_{t-1}$	-0.033
	[0.009]
Observations	230
Number of countries	0.54
Year effects	Y
Country effects	Y

Dependent variable is $R\&D/GDP$ and Control variables (omitted for brevity from the Table) are: $AgricultureShare$ is a ratio of employment in agriculture to total employment; HDI is the Human Development Index which proxies for human capital and ranges between 0 and 1; FD is an IMF-index of financial development; $Institutions$ refer to control of corruption; $FDIinflows$ and $Trade$ capture aspects of country's openness and are both ratios of GDP; The sample includes 12 Eurozone countries which are Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Italy, Latvia, Netherlands, Portugal and Spain; (*), (**), (***) are significance level at the 10%, 5% and 1%, respectively. We use the Pesaran (2004) test for cross-sectional dependence (we obtain a p-value equal to 0.04) and correct the standard errors by following the approach proposed by Driscoll and Kraay (1998) in all cases. Further, country and year fixed effects are included in all specifications; standard errors are reported in parentheses.