IMPLICATIONS OF FINANCIAL DERIVATIVES ON THE CENTRAL BANK'S MONETARY POLICY: A MACRO APPROACH

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Abstract

Recent developments in financial markets have been a mayor concern for policymakers and economic theorists in past years. More developed financial systems lead to the emergence of new liquid assets, which can affect policy both by creating new channels for monetary transmission and by completing traditionally fragmented markets, altering the environment in which monetary policy operates. Derivatives are one such type of financial instruments which help complete financial systems. Their use allows agents to effectively hedge against changes in relative prices induced by monetary policy, reducing the overall effect on their spending and investment decisions. This paper uses a Structural VAR to compare impulse response functions of target variables in Colombia to unexpected innovations on the policy stance, in the absence or presence of derivative markets, focusing both on the diluting effect of these instruments and on the timing of the responses. Evidence that suggests a weakening of the traditional mechanisms is found, confirming a similar hypothesis by Gómez, Vásquez and Zea (2005). However, there is no evidence that implies a change in monetary policy's lag. The policy recommendation that arises from this result suggests the inclusion of the effect of derivative markets on the policymaker's reaction function.

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1. Introduction

Recent developments in global financial markets have led to serious considerations for policymakers with regard to potential structural changes in the traditional monetary transmission channels. Particularly, deeper financial systems are generally characterized by the emergence of new liquid assets which serve both as saving and investment vehicles. These new market instruments may not only directly affect policy by offering new channels for monetary transmission (i.e. new intermediate targets), but could also complete traditionally fragmented markets. This would change the overall economic structure and the traditional mechanisms through which monetary policy typically operates.

Derivatives are one type of such financial instruments which help complete financial markets. With their use, economic agents can effectively hedge against changes in relative prices induced by active monetary policy, reducing the overall effect on their spending and investment decisions. Aside from this, the completion of fragmented markets should give rise to a faster transmission of shocks. As new assets are developed in the market, substitutability among all available instruments should increase. This in turn, interconnects markets which could be traditionally segmented, allowing for changes in the price of an asset to impact other prices sooner, spreading the initial shock through financial markets more rapidly. Therefore, policy shocks operating through the traditional transmission mechanisms may lose some ability to affect real variables in the short-run, and in general, transmission to financial prices should be faster.

Recent literature still has few empirical studies which try to ascertain the diluting impact of derivative markets on the traditional mechanisms of policy transmission. Among the most important are Fender (2000b), who studied the effect of these markets in the United States, Vrolijk (1997), who studied the United Kingdom and Gómez, Vásquez and Zea (2005) who studied the Colombian case.

The idea of this paper is to follow the methodology proposed by Vrolijk (1997), and use a Structural VAR to compare impulse response functions of target variables to unexpected innovations on the policy instrument, both with and without derivative markets.

Although the recent study by Gómez et. al. (2005) for Colombia, analyses the impact of derivative markets on policy transmission, the empirical methodology used in this paper largely differs from the one used by these authors, as do the implications which can be derived from both. Specifically, their study uses microeconomic variables and an unbalanced panel data model to determine the effect of hedging instruments on firms' investment decisions. The authors effectively find evidence to suggest that derivative markets have weakened the transmission mechanisms in Colombia. However, nothing is said about the speed of transmission or possible changes in monetary policy's lag. This paper uses aggregate variables and impulse response functions, to effectively examine both the diluting effect of these instruments and the timing of the responses.

If evidence is found that suggests a weakening of the traditional channels and/or a faster transmission of policy shocks, some important policy considerations should be noted. Particularly, policymakers must internalize the effect of more complete financial markets in their response function, as these innovations may lead to structural changes in the environment policy operates in. If not taken into account, weaker responses by the economy may be misinterpreted by policymakers, who will follow their "typical" response and will increase the size of the initial shock. However, as derivative contracts expire, the overall effect in the medium-run over real variables could be recessive.

This paper is organized as follows. Section 1 presented a brief introduction to the problem derivative markets' pose on monetary policy. Section 2 describes the literature concerning corporate risk management and the effects of hedging over the agency problem that arises with asymmetric information. Section 3 considers the theoretical implications of derivative markets on transmission mechanisms and on the policymakers' optimum strategy. Section 4 presents a brief characterization of Colombia's derivative markets, while section 5 is concerned with the data and empirical methodology used in this paper. Section 6 illustrates the main results found in the impulse responses and concluding remarks and final considerations are in Section 7.

2. Emergence of Derivative Markets in the Literature

Most of the literature relating to derivative markets' impact on monetary policy transmission mechanisms stems from models which question the perfect substitutability between internal and external funds[2] for firms, which arise from capital market imperfections. In such models, informational asymmetries give rise to agency costs, driving a wedge between internally generated funds and external finance. Specifically, the higher cost of external finance reflects the agency cost of lending under asymmetric information (one can think of this as a premium required by investors to make-up for uncontractable risks). Thus, firms will try to rely on internal funding to reduce their demand for costly external finance. The assumption of informational frictions and credit market imperfections, leads to the importance of borrower's net worth (i.e. collateral) in order to gain access to external finance. Under perfect information, lenders can observe all actions undertaken by their borrowers, and they know their "quality" as debtors. When imperfections arise in credit markets, due to informational asymmetries, collateral arises as an imperfect solution to the moral hazard problem.

The role of borrower's net worth in these models is crucial to understand the role of the balance sheet effect. When there is a fall in borrower's net worth (caused by tight monetary policy)[3] internally generated funds are affected in such a way that some firms will need to increase their demand for costly external finance in order to maintain their investment scheme. Given that collateral is determined by cash flows in these models, the creditworthiness of the firm falls and so does the ability of the firm to obtain fully collateralized loans. Thus, investment decisions are affected and tend to contract further than expected from the typical cost-of-capital effect mentioned in Keynesian economics. Since a policy shock affects all cash flows individually, the effect on investment decisions and thus, the economy, may be amplified, hence the term "financial accelerator" (Fender 1999a). In general, this literature suggests that economic shocks which deteriorate balance

[2] This assumption was first formalized by Modigliani and Miller (1958) in a theorem which states that financial structure is irrelevant to corporate investment decisions.
[3] In Fender (1999a) a rise in interest rates affects cash flow by changing the present value of the firms' illiquid assets. Nonetheless, higher interest rates could affect cash flow by directly increasing interest payments on existing short-term or floating rate debt. See Bernanke and Gertler (1995) and Mishkin (1996).

sheet conditions on all agents "accelerate" the effects of such adverse shocks via a contraction of both demand and supply of credit, further depressing investment, prices and overall economic activity.

On the supply side, there is an additional effect to the traditional bank credit channel.[4] Under problems of asymmetric information, reductions in the value of collateral induce investors to tighten lending standards and raise the cost of credit intermediation (i.e. increase the premium for monitoring). On the demand side, the deterioration of the balance sheet of both firms and households will undoubtedly affect their consumption and investment decisions. Wealth effects derived from lower asset prices may adversely affect credit demand and hence, economic activity.

Recent studies, however, have taken a corporate-risk-management approach to the problem of informational frictions in credit markets. Research by Froot et al. (1993) and Fender (2000a), have focused on the economic incentives for developing hedging strategies that arise from the problem of information asymmetries. More specifically, these models show that when external financing is more costly than internally generated funds (i.e. risk premium), firms will have incentives to stabilize their cash flows and lower their demand for external funds. Recent developments in financial derivative markets have led to the emergence of instruments which offer such stabilizing possibilities, by allowing agents to efficiently hedge against financial risks.[5] A firm whose cash flow depends on interest rate fluctuations would therefore have incentives (and instruments) to deal with such exposure in order to stabilize its balance sheet. By doing so, it would certainly affect the impact of monetary policy on its investment decisions. As a result, financial accelerator effects are likely to be reduced and monetary authorities will lose some of their effectiveness to affect real economic activity by ways of monetary impulses (Fender, 2000b). Hence, informational asymmetries, the very force behind "financial accelerator" effects give rise to incentives focused on corporate risk management.

[4] In order for this channel to exist, a reduction in bank reserves, induced by monetary policy, must lead to a decline in loan supply. Additionally, the existence of the mechanism requires that some firms cannot costlessly replace the reduction in bank credit with other types of finance, but rather lower their investment. See Oliner and Rudebusch (1996), Romer and Romer (1990) and Bernanke and Blinder (1992) among others.
[5] See Von Hagen and Fender (1998) for a recent survey.

Nonetheless, theoretical studies have also focused on the potential increase in financial markets' volatility due to the increased use of these type of instruments.[6] Derivatives, by increasing the number of available market instruments, allow for a more interconnected system. In the presence of a an adverse shock, this might lead to a longer chain of individual reactions with a larger overall impact on relative prices (i.e. systemic risk), thus, causing greater wealth effects on the balance sheet of economic agents. Some empirical literature has been focused on measuring the potential impact of derivatives on the underlying securities markets, as some trading strategies may amplify excess supply of assets in times of falling prices.[7] However, another cluster of recent empirical evidence suggests that the emergence of derivative markets has not caused significant additional volatility in spot markets (Von Hagen and Fender, 1998).[8]

Empirical studies which focus on the diluting impact of derivative markets on the traditional channels of monetary policy transmission are still limited. Aside from the papers developed by Fender (2000b) for the U.S., Vrolijk (1997) for the U.K. and Gómez et. al. (2005) for Colombia, this line of research is practically under development. The first two papers mentioned use a similar econometric methodology (i.e. vector autoregression) to examine changes in the monetary policy transmission mechanism under the presence of derivative markets. Nonetheless, the first models their presence implicitly and uses firm-level quarterly data from the *QFR,*[9] while the second does so explicitly and uses aggregate quarterly data. On the other hand, the latter paper uses firm-level data[10] and estimates an investment model with an unbalanced panel data structure.

Fender (2000b) and Gómez et. al. (2005) both find evidence which supports that the emergence of derivative markets has had a structural impact on firms' decisions. In the former, this means that small firms begin behaving similar to large firms once derivative markets emerge in the U.S., hence, diluting the broad credit channel of monetary policy. In

[6] See Morales (2001) and van der Nat (2000).
[7] Empirical studies aimed towards this hypothesis include BIS (1994).
[8] The authors quote IMF (1997), Cohen (1996) and Board et. al. (1995).
[9] Quarterly Financial Report for Manufacturing, Mining and Trade Corporations.
[10] The database for the empirical model contains information from Superintendencia de Valores and Superintendencia de Sociedades. Both data sets combined have annual observations for over 15.000 firms from 1995 to 2003.

the latter, evidence to support the weakening of monetary policy to affect real variables is given by changes in the firms investment decisions, once derivative markets are accounted for. Vrolijk (1997), on the other hand, finds no evidence to support a significant effect on the transmission mechanisms derived from a deeper financial system.[11]

3. Implications of Derivative Use on Monetary Policy Transmission

3.1 Effect of Derivative Markets on Transmission Mechanisms[12]

During the past few years, the central banks' role has shifted toward a main objective, to direct its monetary policy to the goal of maintaining price stability and low inflation by controlling the rate of monetary expansion. For this purpose, the bank uses intermediate instruments, such as overnight interest rates, which affect money growth by controlling market liquidity. When central bank decisions alter interest rates, changes are immediately spread across financial markets, affecting asset prices. As these prices adjust, saving and spending decisions of economic agents are altered, which in turn affects the overall price level and other macroeconomic variables.

The appearance of derivative markets changes this general framework through which monetary policy typically operates. First, it is plausible to imagine a new channel through which monetary policy can work,[13] since new financial instruments are now available in the market. But also, the appearance of a new financial market may have substantial impacts on the overall, thus, changing (in some cases marginally, but possibly significantly) the traditional transmission channels.

The emergence of these instruments alters the financial structure of the economy not only by completing financial markets, but increasing efficiency as well. Derivatives allow for an artificial stripping of the risks embedded in an asset, which in turn creates a market

[11] Nonetheless, Vrolijk argues that his result for the U.K. may be a special case. Perhaps its relatively liquid and well-developed financial markets (before the emergence of these instruments) imply that the effect that derivatives have in completing such markets is marginal, thus, making little difference for monetary policy transmission.
[12] This section closely follows Vrolijk (1997).
[13] Although the effect on the real economy arising from shocks through this channel may be insignificant.

for each and allows agents to allocate risks in a optimal way, given their preferences. For instance, two agents may exchange interest rate payments, thereby taking advantage of the others' more efficient cost structure. Hence, risks are transferred towards agents who can deal with them more efficiently. Due to this, portfolios may be less sensitive to interest or exchange rate shocks, stabilizing agents' cash flows. Derivatives also allow higher leverage, thereby increasing the number of transactions and decreasing the cost of capital. Finally, derivatives create bridges between segmented markets, enhancing substitutability among assets and thus, allow further arbitrage opportunities (Vrolijk, 1997). Therefore, derivatives complete financial markets and permit a better allocation of risks, affecting the environment in which monetary policy operates.

Therein lies the importance of understanding the net impact of derivatives on monetary policy transmission, since a structural change in the traditional channels could call for a whole reconsideration of central bank policy and its role. However, not much research has been done in this direction, being the "Hannoun" report one of the few exceptions.[14]

The report concludes (although no empirical assessment is made) that *a policy change spreads through financial markets more rapidly in the presence of derivatives*. This due to the fact that derivatives allow for a faster transmission of changes in interest rates to all financial prices by completing traditionally fragmented markets, creating higher substitutability between assets. Nonetheless, the Hannoun report suggests that *impacts on the real economy are ambiguous*. While some agents may be faced with the impact of monetary policy sooner, other agents may temporarily hedge against policy shocks, diluting the overall impact and increasing monetary policies' lag to affect real and nominal target variables. It is important to keep in mind that if changes in interest rates are prolonged,[15] agents will ultimately be faced with the impact of the policy action (i.e. as soon as their derivative contracts expire). Hence, the effectiveness of monetary authorities to affect

[14] BIS (1994). "Macroeconomic and Monetary Policy Issues Raised by the Growth of Derivative Markets (Hannoun Report)". Basel, November.

[15] In fact, it is prolonged changes in policy instruments which create mayor concern. If expectations are such an important component of the overall effect on economic activity, a transitory shock (or one that is expected to be) will simply cause agents to perform an intertemporal substitution of spending. If spending is simply postponed for a short amount of time, aggregate annual changes may be insignificant.

inflation rates will remain, though the timing of the economy's response can be altered (Vrolijk, 1997).

Table 1 summarizes the effect that derivatives have on each transmission mechanism and its subsequent sub-channel.[16] Notice that overall, no unambiguous effect may be derived with respect to the real economy's response. On one hand, derivatives weaken the effect of monetary policy on some channels, by allowing agents to effectively hedge against adverse policy shocks (e.g. bank lending channel, balance sheet effect, net exports effect and income effect).[17] On the other hand, by allowing for a faster transmission of policy shocks to asset prices, derivatives expose unhedged agents to the impact sooner (e.g. substitution effect and wealth effect).

Table 1

Channel	Sub-Channel	Derivatives' Potential Effect
Interest Rate	*Substitution Effect*	Derivatives can only have a marginal impact on reducing this effect, due mainly to several uncertainties concerning future funding needs. Agents face the new costs of capital sooner.
	Income Effect	The largest change in the transmission mechanism caused by derivatives is the ability of agents to hedge the income effect associated with changes in interest rates, since agents know the composition of their cash flow.
	Wealth Effect	Hedging this effect is not common, since it operates both through changes in income flows and through changes in the discount factor, thus, affecting the value of assets (both liquid and illiquid). Impact of lower wealth may occur sooner.
Credit	*Bank Lending Effect*	By completing capital markets, these instruments allow for higher substitution of other forms of funding for bank credit, thus, diluting the bank credit channel.
	Balance Sheet Effect	Financial innovation allows firms to secure future prices, hence, keeping the value of their collateral unchanged to fluctuations in relative prices. Overall, agents are still faced with higher costs of capital, but derivatives can help hedge some net worth changes.

[16] A complete explanation of the effect on each mechanism is found in Gómez, Vásquez and Zea (2005), which in turn is based on the discussion found in Vrolijk (1997).
[17] A BIS survey suggests that large-scale hedging occurs for both the net exports and income effects. BIS (1996). "Central Bank Survey of Foreign Exchange and Derivatives Market Activity". May.

Exchange Rate	*Net Exports Effect*	The effect over the nominal exchange rate is easily hedged with derivatives. Real exchange rate fluctuations are significantly more difficult to hedge, particularly if the driving force is a change in relative prices (this creates a substitution effect which is not readily hedged). Even when the change is due to alterations in the nominal exchange rate, agents are still faced with one country being more attractive for future consumption and/or investment. Unhedged agents are affected sooner.
	Interest Rate Parity Effect	Derivatives allow for a more rapid movement of exchange rates, which increases the speed with which real terms of trade change, thus, accelerating capital flows and impacting the real economy sooner.

Here an important issue must be addressed. If agents have the possibility of hedging against adverse scenarios, and still choose not to, one could venture in stating that these agents are possibly less risk averse[18] than those who effectively take hedging positions. This could imply that hedged agents have a higher marginal propensity to consume, and hence, wish to maintain their level of consumption.[19] If this where true, the effect of monetary policy under the presence of derivative markets could lean towards a *faster impact on unhedged agents*[20] (who have a lower marginal propensity to consume and thus, are expected to have a lower negative income effect), *along with an overall weaker net effect*[21] *which could extend with a greater lag.*[22]

For the purpose of this paper, the above statement would mean for impulse response functions to shift (i.e. move to the left) and lessen, and possibly extend for a greater number of periods (i.e. become wider).

[18] Or in the specific scenario addressed in this paper, where policy acts through interest rate changes, less interest-rate sensitive.
[19] When agents hedge, they remove the need for precautionary saving, consequently increasing their marginal propensity to consume (Vrolijk, 1997).
[20] Given financial markets react faster to a change in monetary policy.
[21] For example, when agents lock-in a certain interest rate they may dilute the balance sheet effect. In this case, derivatives *weaken* the policy shock to the traditional cost-of-capital effect.
[22] Since hedged agents will face new interest rates only after their contracts expire.

3.2 Monetary Policy Consequences of Derivatives[23]

The concluding assertion on the impact of monetary policy in the presence of derivative markets has important implications for a naive policymaker. If in the medium-run policymakers experience a weakened effect on target variables, they may decide to increase the size of policy shocks. However, once contracts expire and the impact is spread to all agents in the economy, the additional policy shock may lead to overshooting of the policymakers' reaction, causing perverse effects over the real economy. Therefore, monetary authorities must internalize the effect of derivatives in their response function.

In fact, derivatives contain implicit information about expectations concerning changes in prices of the underlying assets and their volatility. So policymakers need not only take into account the emergence of derivative markets in terms of the impact on transmission mechanisms. Central banks may directly benefit from these markets, as the appearance of these instruments leads to important information *spill-overs* that may help create a more precise picture of market sentiment, and hence, the environment monetary authorities must operate in.

Nonetheless, the increasing growth of derivative markets could lead to a whole different setting altogether. In a more perfect financial system, substitutability between assets increases, and that includes closer substitutes to central bank money as well. Many of these liquid non-monetary substitutes could offer commercial banks a new source for funding with relatively lower price volatility than that of central bank money. If commercial banks effectively substitute their liquid reserves with cheaper and less volatile interest-bearing assets, they could eventually offer a more stable credit supply.[24]

The important point to note here is that this possibility constraints the central bank's role. As long as monetary policy is actively directed on achieving short-run effects on real and nominal variables, central bank money will possibly have higher price volatility than other non-monetary assets. Thus, if policymakers behave in a less steady and transparent

[23] This section follows Von Hagen and Fender (1998).
[24] In fact, substitution is not even necessary for this condition to arise. As long as banks actively hedge against market and credit risk, they can effectively offer a cheaper and more stable credit supply.

way, the more central bank money will lose importance as a reserve asset for commercial banks, leading to less control over money supply (Von Hagen and Fender, 1998). The loss of ability to affect the amount of loans that are effectively extended to the public dilutes one of the main channels of monetary policy transmission (i.e. bank lending channel), weakening the capacity of policymakers to affect target variables.

This, however, cannot be seen as a negative effect of derivatives. Simply put, these instruments "discipline" monetary policy, and orient it in a clear direction. As the central bank realizes that the financial sector's choice between liquid reserve assets and central bank money depends on the stability of lending conditions, it will have incentives to commit to clear policy rules and focus on the long-run goal of monetary policy (i.e. price stability). Moreover, as long as agents also have access to liquid assets that can be used as means of transaction (or even as unit of account), their demand for central bank money along with its role as primary unit of account will also largely depend on the stability of its value,[25] hence, reinforcing the effect mentioned above.[26] Note that as short-run macroeconomic stability loses importance in the central bank's reaction function, so do considerations regarding exchange rates, since actions taken to achieve a certain target will undoubtedly increase central bank money's price volatility (Von Hagen and Fender, 1998).

Therefore, if derivative markets continue to grow, creating "bridges" on traditionally segmented markets and favoring the existence of a more perfect financial system, central banks will need to reconsider their role in economic activity. Specifically, changes in their reaction function must take place, in order to incorporate the structural effects of new financial markets on their actions, and to focus their attention away from short-run discretionary activism and on long-run price stability via stable and predictable monetary policy rules.

[25] Empirical evidence suggests economies switch from one unit of account to another only in times of hyperinflation, when the value of the unit is uncertain and eroding rapidly. Thus, central banks' money could still play its role as unit of account even when it no longer serves as the primary medium of transaction, as long as its value in terms of goods and services is stable (Von Hagen and Fender, 1998).

[26] However, governments can always secure some demand for central bank money from the public, for example, by insisting that all tax payments be done by using it (Von Hagen and Fender, 1998).

4. Stylized Facts of Colombia's Derivative Markets[27]

Despite not having a high degree of development, Colombia's derivative markets have shown an interesting behavior in the past five years, especially exchange rate hedging instruments, which are more common than those for hedging interest rate risk.

Local interest rate derivative markets still lack an important number of available instruments. However, the market does report "simultaneous" operations, which consist on selling a bond in the spot market and subsequently purchasing it forward, which is equivalent to a repurchase agreement (repo). The market for this instrument has been developing hand in hand with the TES[28] market in latter years, mainly because TES have been the primary underlying assets. The average amount of monthly negotiations through the Electronic Negotiation System of Banco de la República, rose from $3.3 trillion in 2002 to $6.5 trillion pesos in 2004.

Various reasons exist for the lack of maturity in this market, but the mayor problems are due to the absence of reference indexes in the spot market, the lack of liquidity and the development of the market itself, as well as problems in monitoring financial system agents.

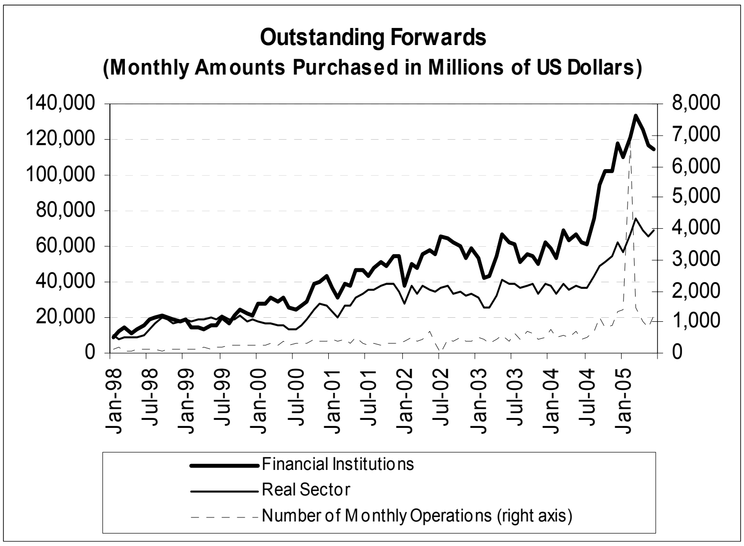
On the other hand, exchange rate derivatives have evolved in a more favorable way than local interest rate derivatives (Graph 1). The exchange rate *forward* is the most liquid of these instruments, and has grown significantly in the last couple of years, particularly after the last half of the 90's, when the exchange rate band suffered from speculative shocks that finally led to the adoption of a floating exchange rate regime. The monthly amount negotiated in this market went from approximately US$1.340 million in December 1999, to around US$5.160 in April 2005. The large increase in the number of monthly operations evidences the higher degree of depth in this market as well, with the number of monthly operations going from 940 to 2.153, for the same time period described above. This

[27] This section follows the one found in Gómez, Vásquez and Zea (2005), which was kindly elaborated by Ana Fernanda Maiguashca.

[28] TES are public debt bonds issued by the government. There are short-term TES (starting from 90 days), which are cero-coupon and long-term TES (up to 15 years), which are coupon-bearing bonds.

significant increase in the number of operations is mainly due to a large number of agents from the real sector who now make active use of this type of instruments.

Graph 1[29]



Source: Banco de la República.

Nonetheless, it must be noted that derivative markets in Colombia do not operate in a perfect way. In fact, there exist various frictions inherent to a developing market that do not allow for the hedging possibilities to be as complete as they would be in more developed markets. Specifically, 1) there is a restriction to the financial systems cash position which does not allow for unlimited hedging of their derivative position; 2) not all internal agents have access to foreign credit markets and hence, they cannot arbitrage prices between derivatives and the cash market and 3) pension funds have a maximum unhedged foreign exchange position which sometimes drives them to derivative markets in a weak negotiating position. But even with these considerations, the growth this market has shown carries important effects in terms of the hedging possibilities that are now available to market agents. Especially in terms of exchange rate risk, since most instruments available in the market are exchange rate *forwards*.

[29] Outstanding amounts include all negotiations made prior to date which are still effective, and will thus be significantly larger than negotiated amounts. Also, financial institutions include all instruments purchased and sold by financial intermediaries with 1) other financial institutions, 2) real sector and 3) pension funds. This is due to the fact that Colombian law establishes that these instruments can only be contracted by private agents with financial institutions.

5. Data and Empirical Methodology

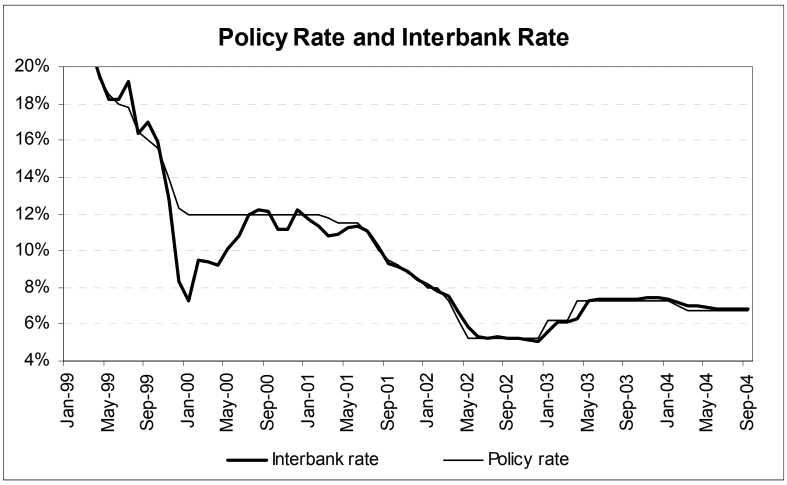
5.1 Variables Used in the Estimation

The model estimated in this paper is comprised of four variables, measured quarterly, which are output gap,[30] the interbank real interest rate, inflation and a measure of derivative markets' size (DM) for the period encompassed between 1990:1 and 2004:3. Thus, it should be apparent that the data used in this paper consists of a set of macroeconomic variables that characterize Colombia's market and which are in their entirety found in Banco de la República's (BR) database.

As a proxy of monetary policy stance, the interbank real interest rate will be used. There are two main considerations regarding this choice. On the first place, this rate is highly sensitive to changes in the policy rate and both behave in a similar way,[31] but is preferred since it has more variance than the latter, which is actually fixed at a certain level for several periods of time (Graph 2). This has important implications in terms of the statistical properties needed to estimate an econometric model (i.e. a variable with small variance is practically deterministic). Secondly, the additional volatility found in the interbank rate can be seen as the effect of market expectations, which not only respond to direct interventions in the policy rate, but also to announcements made by the central bank, volatility and international reserve accumulation auctions or interventions in the public debt market. Hence, this rate captures *all changes made in the policy stance*, which in turn are all the ways in which monetary policy is conducted.

[30] Output gap is defined as *(Observed Output – Potential Output) / Potential Output*. Potential output is calculated using a Hodrick-Prescott filter with priors.
[31] Correlation between both series for the period comprised between 1999 and 2004 (measured monthly) is estimated to be 0.945.

Graph 2



Source: Banco de la República

Another consideration which may arise with respect to the policy instrument is the fact that the central bank in Colombia has increasingly become interested with the effect of its policy actions on long-term interest rates (e.g. spot rate of long-term TES). Indeed, the growing exposure of both financial intermediaries and private agents to such sovereign debt instruments carries important considerations. As their portfolio concentrates in these assets, their exposure to market risk increases. Higher interest rates, which affect the yield curve along different maturities, will lower the price of these bonds (affecting cash flows), and will therefore change the agent's portfolio composition as well as his risk perception. Thus, a significant shock could create movements in capital flows contrary to those expected with higher interest rates. This means that targeting a variable such as long-run interest rates could be increasingly important in the policymakers reaction function. It would then be more precise to use as policy instruments both a short and long-term rate, to capture these two targets of policy transmission.

Nonetheless, given the time period considered, two important issues must be noted with respect to the inclusion of these rates in the model. First, the importance of the TES market in the central bank's reaction function is somewhat relatively new. In fact, there is no information available regarding the spot curve of long-term TES before 2003. Furthermore, there are important liquidity premia embedded in the curves, as well as model risk,[32] which are undesirable features for the purpose of being used as proxies. Also, the importance of a short-term variable as the interbank rate for the policymaker is still high, since monetary authorities rely heavily on their ability to affect market liquidity in short horizons. Still, the increasing importance of long-term variables (which has grown hand-in-hand with the development of the TES market) in the response function of policymakers should be accounted for in future research in related areas.

To approximate the size and evolution of derivative markets, the real notional[33] amount of derivative instruments reported in the balance sheet of financial intermediaries was used. As mentioned earlier, this includes all hedging operations by financial intermediaries with other financial institutions, as well as with the real sector. Derivative markets' size is normalized to range from 0 to 1, where 0 represents no derivative markets and 1 its largest size, which occurs in September 2004. From this perspective, a larger value of the variable is associated with deeper derivative markets, which are expected to dilute the traditional channels of monetary transmission.

5.2 Concerns About the Derivative Markets Variable

Some consideration regarding the data available on derivative markets should be addressed. On the first place, there is no firm-level data on the exact hedging undertaken by each private agent. Thus, aggregate variables are used to asses the impact of changes in the policy stance on private decisions. While this allows capturing hedging *spill-overs* derived from changes in the bank-lending channel[34] (i.e. as banks transfer risks), some interesting firm-level effects cannot be controlled for. Specifically, there will most surely be an intertemporal change in the response of private agents when derivatives are used. If, for example, most instruments available in the market have an average duration of 3 months, then agents taking this coverage will not be faced with the impact of higher capital costs until after this time period. This would result in individual responses shifting from their

[32] The goodness-of-fit of the methodology used to build the public debt spot curve in Colombia has only been recently assessed.
[33] The notional amount refers to the amount (in an interest rate swap, forward rate agreement, or other derivative instrument) or each of the amounts (in a currency swap) to which interest rates are applied in order to calculate periodic payment obligations.
[34] This point is explained in more detail below.

traditional trajectory. However, the aggregation of all individuals[35] in the economy will most likely dampen these effects (however, if the use of dynamic hedging is generalized, even aggregate responses could be expected to change).

Furthermore, the fact that the aggregate variable used for derivative markets includes interbank operations may also raise important issues. Initially, one could think that only direct hedging by private agents will have effects on their spending decisions. However, active usage of these instruments between intermediaries captures important hedging externalities. When financial institutions hedge against different market risks they not only have a direct effect on their private decisions, but also an indirect effect on the private decisions of other agents through the availability of a more stable and cheap supply of credit (i.e. affects the bank-lending channel). Such hedging *spill-overs* imply that approximating the impact of derivative markets on the spending decisions of private agents, using the amount of these instruments negotiated by the financial system as a proxy, is not inappropriate. (Gómez et. al, 2005).

Nevertheless, some of the hedging which occurs between banks may be motivated on speculative positions by traders rather than risk-coverage opportunities. The fact that these positions are taken in the model as though they were solely actively hedging could also generate bias in the estimation, mainly with respect to the effect accounted to derivative markets as hedging instruments for private agents. The former implies that an estimation including only the instruments effectively used by the real sector could isolate the possible bias generated by the speculative positions which are embedded in the data. Unfortunately, there is no information which discriminates between interbank negotiations and those undertaken with the real sector before 1998. Using such a small time frame would lead to a number of serious statistical problems which would invalidate the proposed exercise. On the other hand, the variable used is probably capturing the financial innovations (i.e. availability of hedging instruments) that have occurred in the market and which allow traders to speculate. In such sense, the effects these *trading* positions have on monetary policy transmission are being captured by the depth of financial markets.

[35] Many of which do not use these instruments and/or are not significantly affected by the hedging *spill-overs* derived from a more stable credit supply. In addition, those who do take hedging positions do not make use of these contracts during the same time periods.

Secondly, there may be certain hedging elements which are not considered in the variable used. Banks with subsidiaries operating *off-shore* could be effectively taking hedging positions not captured in the amount of contracts negotiated domestically. For example, banks which invest in other countries through their subsidiaries could have dollar-denominated assets which could eventually hedge loans taken by domestic banks in foreign markets. This type of *natural hedging* is undoubtedly not being controlled for, mainly, because of the impossibility of gathering such information for each bank. Nonetheless, the bias generated by these possibilities would, in the worst of cases, reinforce the effects which are trying to be captured. This means that the effect which would be accounted to derivative markets alone could be overestimated, since part of the dilution could be generated by the *natural hedging* position.

Such consideration aside, for the central bank it is probably not as important to know whether banks are actively hedging via derivative instruments or using *off-shore* coverage, as it is to know whether the traditional channels of monetary transmission are partially diluted. Additionally, the fact that these *off-shore* positions can offer hedging possibilities is not independent of the level of depth of financial markets. Their development greatly influences the flexibility of capital flows and the ability of financial institutions to have access to these resources when needed. In this sense, the effect of more perfect financial systems on the traditional transmission mechanisms is, for the most part, proxied by the depth of derivative markets. Thus, as policymakers incorporate the effect of more complete financial systems in their response function, these effects will be partly internalized.

Finally, it is important to note that most instruments reported and used in the market are exchange rate forwards (although interest rate swaps are also included in the sample). This raises an important issue, since the impacts which are trying to be captured respond to changes in the interbank rate. The relevant issue is to remember that a change in this rate captures all alterations on the policy stance, and not just on the policy instrument as such (i.e. intervention rate). When the change comes from direct modifications of the intervention rate, agents will be able to effectively hedge some adverse effects using currency derivatives. As domestic interest rates rise, international capital flows increase, revaluating currency value and affecting the firm's cash flow. When currency derivatives are used, this type of adverse effects are reduced for those agents in long forward positions, transferring the risk to agents whose comparative advantage allows them to deal with it more efficiently. Moreover, changes in the policy stance, different from movements in the policy rate (i.e. announcements of international reserves accumulation auctions made by the central bank followed by significant interventions in the market), have consistently had an impact on the nominal exchange rate (Julio and Toro, 2005). The former reinforces the notion that active hedging of this risk should have important effects on agents' spending decisions. Hence, adverse effects on the firm's cash flow caused by changes in the policy stance (i.e. changes in the interbank rate) can effectively be hedged with currency derivatives.

The above discussion simply emphasizes some important caveats that must be taken into account when interpreting the results found in this paper. Strictly, the effect of derivative markets alone may be reinforced by *natural hedging* and speculative positions taken by traders which may not be strictly oriented towards hedging of market risks. Still, the exercise probably captures structural innovations that have occurred in the market and which, among other things, allow banks to have *off-shore* coverage and traders to take speculative positions. This merely shows the data here used has certain limitations, especially in allowing for the micro dynamics that operate in the market to be controlled for (including all the inherent limitations of the market described in the former section). Future research must be focused in this direction, so that the way the market operates may be modeled explicitly in order for the central bank to fully understand the environment it functions in and the new restrictions it possibly faces.

5.3 Empirical Methodology

In order to test the hypothesis in this paper, a Structural VAR (SVAR) following Blanchard and Quah's (1989) decomposition is used. Impulse response functions of inflation and output gap to surprise shocks on interest rates are expected to shift and lessen, and probably become wider in the model with derivative markets opposed to the no derivatives scenario. In the impulse response function of interest rates to monetary policy shocks, the effect is expected to disappear more rapidly. This would imply a weaker (probably more persistent) and faster response on target variables (consistent with the notion of a diluted yet faster transmission and a longer lag) along with a faster transmission on the interbank market (consistent with the notion of faster reacting financial markets).

The reason for using a SVAR methodology instead of the traditional VAR method rests in the inherent problems that arise in the latter. Specifically, impulse response functions derived using this method are not representative of identifiable economic shocks.[36] The error terms estimated in the VAR methodology correspond to forecast errors, and hence, cannot be used to trace out the effects of a structural innovation in the endogenous variables (if one where only interested in forecasting, the components of the forecast errors would become irrelevant). The goal of the SVAR methodology is to use economic theory to impose restrictions and recover the structural innovations from the VAR residuals and thus, be able to identify the underlying economic shocks (Enders, 1995).

These restrictions can be categorized as contemporaneous and long-run constraints. A long-run constraint means that an underlying shock on one variable has no *cumulative* effect on another variable (i.e. does not affect its long-run value). A contemporaneous effect means that an underlying innovation on one variable has no *immediate* impact on another. Statistic programs allow for both contemporaneous constraints (Bernanke-Sims, Harvey-Sargan and Cholesky decompositions) and long-run constraints (Blanchard-Quah decomposition) to be used separately as orthogonalization methods to obtain the structural impulse responses.

As the model developed in this paper focuses on the relationship between monetary policy and target variables (including a real variable), the Blanchard and Quah decomposition was chosen. Technically speaking, restrictions are necessary in these models to guarantee identification and hence, sufficient conditions for proper estimation of the

[36] Recall that a VAR is a reduced form of a structural model, and hence, the error term(s) in the VAR, although actually composites of the underlying shock(s), do not have a structural interpretation. For further detail on this discussion see Enders (1995), Amisano and Giannini (1997), Lutkepohl (1991) and Hamilton (1994), among others.

impulse response functions. Any of the different decompositions mentioned above allow for identification, and so the choice of a method relies on the specific variables under analysis and the relationships that are of interest. When analyzing monetary policy and its effect over target variables, long-run restrictions seem more adequate (it would probably not make sense to assume that monetary policy or demand shocks operating through prices can have effects on output in the long-run). On the other hand, short-run relationships between variables, where monetary policy is expected to have some effect,[37] are left unrestricted, and thus, are not constrained to any value *ex ante*.

The economic constraints needed to identify the system are: 1) That monetary policy shocks, represented by changes in interest rates, have no long-run effect on output; 2) that demand side shocks, represented by changes in prices, have no long-run effect on output and real interest rates and 3) finally, that derivative market shocks have no cumulative effect on the three variables mentioned above.

The first restriction can be seen as a typical "monetary veil" constraint, since it implies that monetary shocks operating through changes in market liquidity can only affect real variables in the short-run. The second constraint with respect to output follows the original restriction proposed by Blanchard and Quah (1989) in their paper, which is in turn derived from the natural rate hypothesis.[38] On the other hand, the fact that inflation has no long-run effect on real interest rates is implied by the fact that after a shock to prices, ceteris paribus, money demand is expected to rise, increasing nominal interest rates.[39] This effect should "net-out" with the initial rise in prices, thus, keeping real interest rates unaffected in the long-run.

The last constraint is more intuitive than theoretically imposed, and simply suggests that derivatives, by being mechanisms through which agents and firms smoothen the policy shocks, should have effects over real variables in the short-run, although one would not

[37] Especially in a context of developing financial markets, where policy shocks are expected to have a faster transmission, leading to an earlier effect over target variables.
[38] The natural rate of unemployment hypothesis implies a vertical Phillips-Curve in the long-run, which in turn denotes that there is no *trade-off* between inflation and unemployment in the long-run.
[39] The same argument could be employed by assuming that it is not the market which reacts and causes interest rates to rise, but monetary authorities reacting to the price hike.

expect them to have long-term effects over fundamentals (as would, for example, productivity shocks). The constraint with respect to inflation implicitly assumes that shocks on derivative markets do not change agents' expectations regarding long-run inflation rates.[40] These restrictions, as mentioned above, serve for the sole purpose of identifying the underlying structural shocks and thus, make the interpretation of the model viable through economic theory.

Many VAR and SVAR studies which use impulse response functions in order to determine the specific impact of a particular event or change tend to compare the specific responses of the variables in the model before and after the change.[41] This paper follows instead the method proposed by Vrolijk (1997), which directly incorporates derivative market size. The reason is that, with sample splitting, the differences in impulse responses are attributable to *all* structural changes that may have occurred between the samples. On the other hand, by directly modeling derivative markets, differences in policy transmission with and without derivatives are attributable to what can be thought of as a combination between the growth of derivative markets and structural changes that are in some way co-integrated with the growth of such markets (i.e. structural changes that affect differently with and without derivative markets). On a final note, 90 percent confidence intervals for the estimated structural impulse response functions were calculated.[42]

6. Results

An important consideration regarding impulse response functions and the information contained in them must be addressed. As Vrolijk (1997) states, the model by definition must incorporate the "…normal response of policymakers to changes in the underlying variables" (Vrolijk, 1997, p. 26), and thus, the shocks considered in the system actually represent *unexpected* departures from the typical policy maker response. Hence,

[40] As long as central banks take into account the impact of derivative markets in their response function, the inflation target should be perceived by agents as consistent with the development of such market.

[41] For example Fender (2000b), compares the response of small and large firms to policy shocks in two different samples; one where no derivative markets are present (the original Gertler and Gilchrist (1994) paper) and another after the appearance of such markets.

[42] Confidence intervals are calculated in RATS (using var.src) by bootstrapping a series of residuals from the residuals of the original VAR. The exact technique is found in the source file VAR.SRC, written by Norman Morin (1998).

shocks to the system may not necessarily represent the response of the market to a *regular* action undertaken by monetary authorities. Also, the fact that all variables are stationary should be kept in mind when analyzing impulse responses, since this characteristic implies for all shocks on the system to be transitory, as there can be no persistence in shocks to stationary variables.

The estimated model incorporated lags of five quarters for the following reasons. On the first place, the Akaike Information Criteria (AIC) for model selection was minimized with four lags, but the estimation still presented problems of serial correlation which where corrected when an additional lag was included. On the other hand, it is recommended to include enough lags to encompass a year and an extra period in this type of models, to ensure that the coefficients capture seasonal effects that may be present even with seasonally adjusted data (RATS v.5 user's guide, 2000).

All variables included in the model where tested to be stationary, both in their regular and seasonal frequencies,[43] since no estimation of the SVAR is possible without this condition. Technically, there exists no vector moving average (VMA) representation if variables are non stationary (Wold theorem), and the matrix of VMA coefficients is a fundamental part of the estimation (in order to effectively impose long-run restrictions on the model, the matrix of polynomials containing the sums of the VMA coefficients must be known).[44]

Results presented in this section will focus on the impulse response of the different variables to an unanticipated change in interest rates, which in this setup represents surprise changes in monetary policy stance. Notice that no individual transmission channel is being explicitly modeled, and thus, policy is allowed to work through each and every possible mechanism. The three graphs included in this paper show the impulse response of gap, inflation and real interest rates following a one-period 100-basis point increase in real interest rates at time 0. The continuous lines show the impulse response, while the dashed lines represent the 90% confidence bands. Wider lines correspond to the model with

[43] Appendix B contains a summary of the econometric stationarity properties of the variables.
[44] See Appendix A for a brief discussion on the Structural VAR technique.

derivatives, while the narrow lines correspond to the model with derivative markets "shut-off".

The response of output gap to an unexpected interest rate shock is coherent with standard economic intuition in this model after the fourth period[45] (Figure 1). Following a rise in real interest rates, investment decisions are expected to change, due to a higher opportunity cost (i.e. typical IS-LM effect). On the other hand, higher interest rates lead to changes in spending decisions as well, since agents substitute present consumption with future consumption (i.e. savings). Thus, the shock would lead to postponing several investment and consumption plans, slowing down market inertia and ultimately affecting production decisions. As output contracts (considering potential output has not changed since there have been no technical and/or productivity shock), output gap widens (i.e. becomes negative).

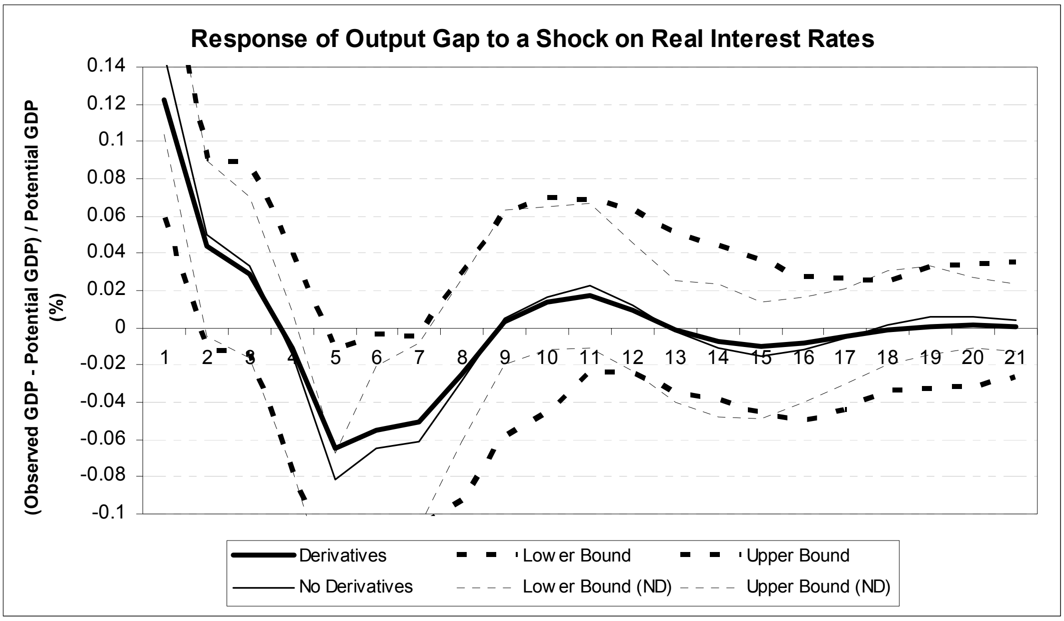
Notice that the response with derivative markets is less pronounced than when derivative markets are unaccounted for. In the model with derivatives, a rise in real interest rates would widen output gap by 0.06% during the fifth quarter, whereas in the absence of these instruments the negative effect would increase the gap by 0.08%. Both negative effects over output gap are significant starting from the fifth quarter, evidencing a monetary policy lag (i.e. approximately fifteen months for a policy shock to affect output). After this, the effect on output gap dilutes, as the effect of interest rates becomes statistically not different from zero.

Note that both responses behave similarly, yet are statistically different during the fifth period since the response with derivatives falls outside the confidence bands of the no derivatives model, and that the effect of the policy shock "disappears" during the same quarter for both models. The latter suggests that, at least for the period under study, there

[45] During the first three periods the result is not as intuitive. This simply reflects the fact that the model here used is a VAR, in which all variables are endogenous and where shocks on the interest rate affect all equations in the system. Thus, some responses may be influenced by effects that are not controlled for. However, the power of this reduced-form model lies precisely in that it can replicate what a structural economic model would predict starting from the fourth period.

does not seem to exist evidence to support either acceleration in the transmission mechanism or a greater lag, although evidence of a weaker response is present.

Figure 1

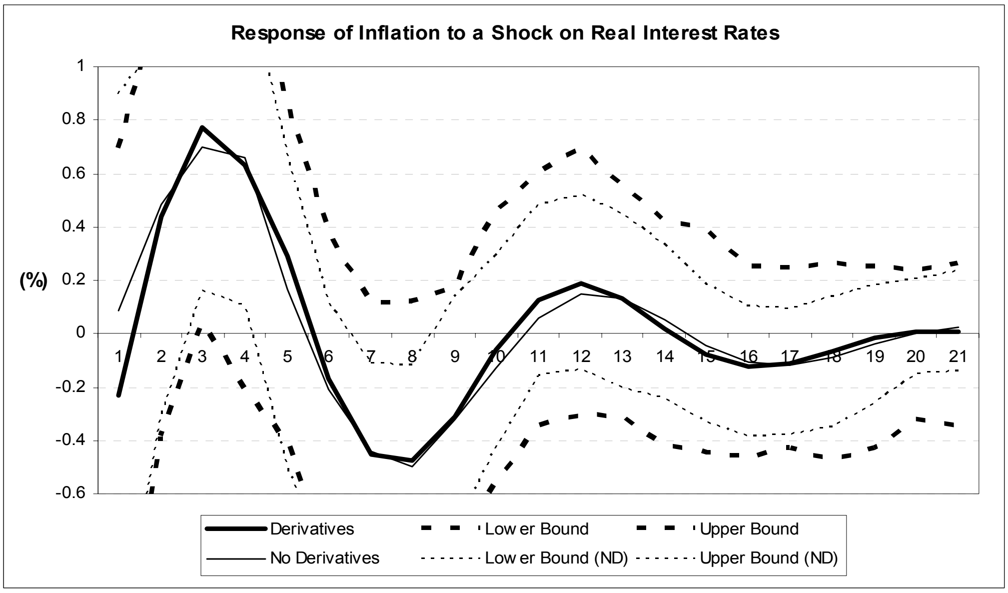


The response of inflation to a surprise increase in the real interest rate may seem awkward at first glance (Figure 2). There seems to be a positive reaction of inflation during the first three periods, after which inflation falls and interest rates have the expected negative effect. This response is not as unusual as it may seem, and is known in the literature as the *price puzzle*. The puzzle arises because a positive innovation on interest rates (i.e. tight monetary policy), is associated with a strong and persistent increase in prices. The reason this happens is simple; policymakers' decisions are mostly forward-looking. They decide upon forecasts of what could happen to try and "get ahead". Hence, if policymakers sense an increase (fall) in inflation expectations, decisions on tightening (loosening) monetary policy are taken. But given that monetary policy has a lag and does not affect prices immediately, these could still increase in the short-run, thus, creating the impression that prices rise temporarily after an interest rate increase.[46]

[46] See Fender (2000b), Sims (1992) and Giordani (2001). Specifically, Sims (1992) suggests the inclusion of price variables that could be important for forecasting inflation, so as to isolate the effect on interest rates. Giordani (2001), however, warns against this solution, since unnecessary noise could be introduced in the model by including variables which are not present in the underlying structural model.

Both the model with and without derivates seem to create the same response on inflation, that is, a "positive" effect on the short-run, followed by a negative effect which becomes significant (for the no derivatives model) during the sixth period and which reduces inflation up to 50 basis points. The fundamental and interesting result in this impulse response function is derived from the fact that, despite both responses being similar, they have significantly different statistical relevance.

Figure 2



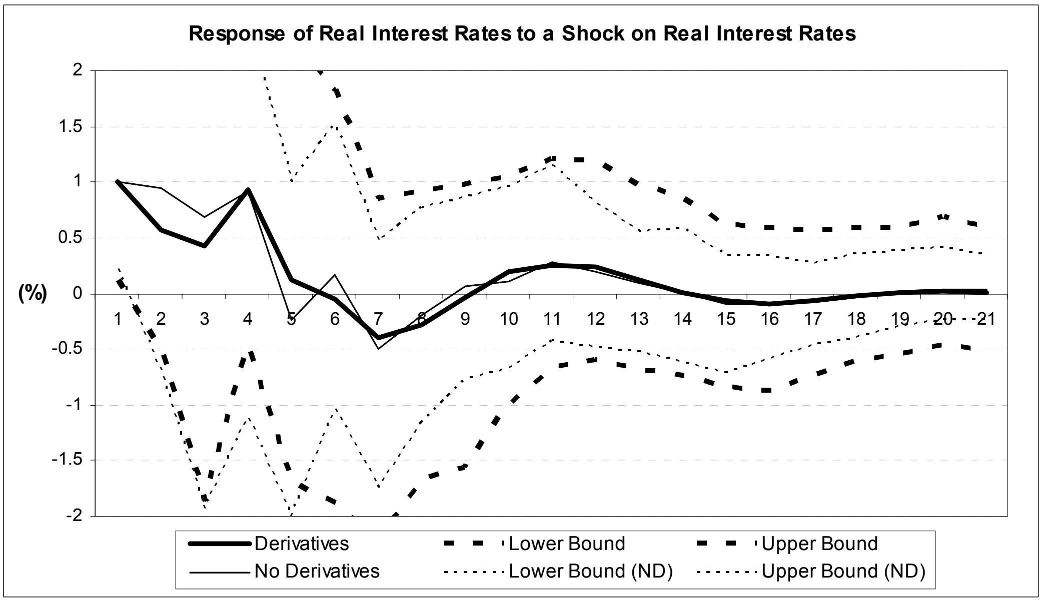
Notice that although both models present a price puzzle, this effect is more persistent on the no derivatives case, and lasts for one complete period (three months) more than on the model with derivatives. Aside from this, the negative effect on inflation is statistically significant only on the no derivatives model, which could be interpreted as the loss of effectiveness of monetary policy due to the development of derivative markets.[47] According to this result, monetary policy has a six period (i.e. 18 month) lag before it

[47] Strictly, this result implies that for the time-period considered in this exercise, the negative effect of an unexpected real interest rate shock on inflation is statistically not different from zero. Thus, for the time-period here considered only the effect without derivatives seems to be statistically significant. Nothing can be said (or is said), about monetary policy not affecting inflation at all. In fact, recall that these functions represent the response to surprise innovations (away from the regular response) and thus, results may not indicate the reaction to a *typical* policy action (Vrolijk, 1997).

significantly affects inflation negatively. No evidence is found to suggest a change in policies' lag.

It is important to keep in mind that this result does not imply that the impulse response function found above concerning the effect on output is invalid. One might think that prices are a regular mechanism through which monetary policy affects output, but even if the effect on these is lessened, higher interest rates still affect production by changing money demand and investment decisions (i.e. a higher opportunity cost still exists).

Figure 3



The response of interest rates after the innovation is strictly the same for both models (Figure 3). None have a statistically significant effect after the first period (when the shock is put forth) and there is no evidence of a weaker (or stronger) response. Confidence bands are also fairly similar, corroborating that both responses are practically equal. It is interesting to note that both shocks tend to dilute completely on the ninth period. This result has important policy implications, as it portraits that there is still no evidence that financial markets react more rapidly when derivatives are used.

7. Concluding Remarks

Continuing development of financial systems in global markets has led to serious considerations for policymakers with regard to the potential impact of structural changes in the traditional monetary transmission mechanisms. Deeper financial systems lead to the emergence of new liquid assets, which can affect policy in two ways: First, by creating new reference prices that may be used as intermediate targets, which link monetary policy actions and long-run target variables. But also, by completing traditionally fragmented markets, changing the structure of the interaction between asset prices through which monetary policy typically operates.

Derivatives are one of such financial instruments which contribute to the completion of financial systems. Agents who effectively use these type of hedging instruments may reduce the impact of changes in relative prices, induced by active monetary actions, over their consumption and investment decisions. On the other hand, agents who remain unhedged may suffer the impact of monetary policy sooner, as asset prices should react faster in a more complete and efficient financial system. Thus, monetary policy is expected to be transmitted faster and have an overall weaker impact on economic agents. However, the effect could extend with a greater lag, as some agents will only face new relative prices when their hedging contracts expire.

This paper used a SVAR approach to effectively test for possible changes in traditional transmission mechanisms, by comparing the response of target variables to changes in relative prices both in a framework with and without derivatives. Consistent with the empirical results of Gómez et. al. (2005), evidence of a weaker response is found, although no result supports either a faster transmission of policy shocks through financial markets or a greater lag. Specifically; 1) a weaker response of output gap is found, along with 2) a shorter persistence of the *price-puzzle* and 3) no significant effect over inflation under the presence of derivatives. The fact that interest rates react similarly both in the model with and without derivatives, corroborates that 4) there is no evidence to support a faster reaction of financial markets, and as a general result, 5) no faster transmission of policy shocks to target variables is found.

However, the results found in this paper carry important consequences and policy considerations, especially when the size of derivative markets is taken into account. Colombia's hedging instruments are still in a premature stage when compared to more developed financial markets, but they have shown important growth in the last few years and a clear tendency to continue deepening. The fact that evidence of a weaker response to policy shocks is found in an economy with relatively small derivative markets, portraits the significant marginal impact these instruments have on developing financial systems, where endogenous frictions and segmentations greatly benefit from them. As these markets continue growing, their effect may not only result in weaker responses, but in changes both in the speed of transmission and the timing of the effects.

Policymakers must therefore incorporate the effect of such structural changes, due to the existence of these instruments, in their response function.[48] Failing to take into consideration the impact of a more developed financial system in their actions, may lead to adverse results. A naive policymaker would interpret a weaker response from target variables as if the initial policy shock had not been strong enough. Following his regular response function, the policy shock would be increased, causing the overall effect in the medium-run over real variables to be recessive once derivative contracts expire. Hence, using the traditional response function would mean ignoring structural changes in the market, which undoubtedly have effects on traditional transmission mechanisms, causing the policymakers' response to be suboptimal.

As a theoretical consideration, the effect on monetary policy strategy may also be affected by deeper financial systems. Specifically, in the context of a more perfect financial system, monetary policy is "disciplined" by the market, forcing its attention to focus on long-run targets (i.e. price stability) and away from short-run discretionary activism. Even when this possibility arises under an extreme situation (i.e. emergence of liquid assets that perform as perfect substitutes of central bank money both for commercial banks and agents), it provides an important implication: the role of monetary policy must also be

[48] This includes a better understanding of the micro market itself. That is, what types of instruments are used, how they are used, are new instruments being developed in the market, how changes in the policy stance alter agents' risk perception, among other things. It is in this direction that new research efforts should be directed in.

reconsidered in a context of developing financial markets. Although it will probably not be constrained to the extent mentioned theoretically, the fact that its impact on real variables is changed does call for a new orientation of its policies, especially regarding discretionary activism to affect macroeconomic stability.

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Appendix A

I. Structural Vector Auto Regression Methodology

The following section is meant for expositional purposes only, and does not intend to recreate the entire Structural Vector Auto Regression analysis (SVAR) found in econometric literature. Rather, it portraits the model used in this paper and the specific restrictions imposed through the Blanchard-Quah decomposition that was used. Complete references on the SVAR methodology can be found in Enders (1995), Amisano and Gianini (1997), Lutkepohl (1991) and Hamilton (1994), among others.

I.I Basic Concepts

To formalize the discussion, suppose one has a VAR model of the following form:

$$A(L)Y_t = E_t \quad ; \quad \text{where } E_t \sim VWN(0,\Sigma) \qquad (1)$$

$$A(L) = I - A_1L - A_2L^2 - \ldots - A_pL^p \qquad (2)$$

In this setup, Y_t is the *4x1* vector of endogenous variables (output gap, real interest rate, inflation and derivative markets), A_i is the *4x4* matrix of the VAR coefficients and E_t is a *4x1* normally distributed vector white noise (i.e. forecast errors of the VAR). In this model, the transpose of the vector of endogenous variables and reduced form shocks can be expressed as;

$$Y_t' = \begin{bmatrix} Y_{1t} & Y_{2t} & Y_{3t} & Y_{4t} \end{bmatrix} \; ; \; E_t' = \begin{bmatrix} E_{1t} & E_{2t} & E_{3t} & E_{4t} \end{bmatrix} \qquad (3)$$

If the variables used in the model are in stationary form (and they must be so that the Blanchard-Quah decomposition can be used), then by Wold's Theorem it must be true that there exists a VAR representation of the form:

$$Y_t = A(L)^{-1}E_t \qquad (4)$$

The model in (4) is known as the Vector Moving Average (VMA) representation of the VAR, which effectively relates Y_t with the reduced form errors. If these forecast errors can now be expressed as a transformation of the structural errors, a Structural VMA (SVMA) representation relating Y_t with the orthogonal innovations (which is what is needed) can be achieved.

I.II Recovering the Structural Innovations from the Forecast Errors

In order to do so, assume a model (i.e. a structural model) which contains the *contemporaneous* relationships between variables in a matrix B, such that;

$$BY_t = \Gamma_0 + \Gamma_1 Y_{t-1} + \ldots + \Gamma_p Y_{t-p} + e_t; \quad \text{where } e_t \sim VWN(0, I) \quad (5)$$

In this setup, e_t is the *4x1* vector of structural innovations, which is normally distributed as well, but whose variance-covariance matrix is given by the identity matrix (i.e. pure structural shocks are assumed to be completely independent and time-invariant).

A typical VAR representation is obtained premultiplying by B^{-1} to find

$$Y_t = B^{-1}\Gamma_0 + B^{-1}\Gamma_1 Y_{t-1} + \ldots + B^{-1}\Gamma_p Y_{t-p} + B^{-1}e_t \qquad (6)$$

Or in more compact notation

$$Y_t = B^{-1}\Gamma(L)Y_t + B^{-1}e_t \qquad (6a)$$

If one defines $B^{-1}\Gamma(L) = D(L)$ the VAR representation in (4) can be obtained. To see this, simply note that (6a) may be written as

$$Y_t = D(L)Y_t + E_t \qquad (7)$$

so that

$$[I - D(L)]Y_t = E_t$$

Defining $A(L) = [I - D(L)]$ yields

$$A(L)Y_t = E_t$$

which is exactly equation (1) and can be easily expressed as (4). Note that the former implies that $B^{-1}e_t = E_t$, so now there exists a relationship between the structural innovations and the reduced form forecast errors. The problem then, is to take the observed values of E_t and restrict them so as to recover e_t.

I.III Imposing Long-Run Restrictions (Blanchard-Quah Decomposition)

The above discussion may be summarized in the following compact notation:

$$Y_t = \phi(L)e_t \qquad (8)$$

where $\phi(L)e_t = A(L)^{-1}E_t$ (9)

Define $A(L)^{-1} = C(L)$, then (9) can be written as

$$C(L)^{-1}\phi(L)e_t = E_t$$

Expressing $C(L)^{-1}\phi(L) = C$ yields

$$Ce_t = E_t \qquad (10)$$

where C is a *4x4* matrix which relates the orthogonal shocks with the reduced form errors. The model implied by (10) is known as the C-model, where

$$Ce_t e_t' C' = E_t E_t'$$

so that

$$CC' = \Sigma \qquad (11)$$

Following Amisano and Gianini (1997), the model in (8) may be seen as a special case of the C-Model, which can be written as

$$Y_t = C(L)Ce_t \qquad (12)$$

$C(L)$ is a matrix polynomial in the lag operator L and can be expressed as

$C(L) = I + C_1 L + C_2 L^2 + \dots$ where C_i is a *4x4* matrix of the VMA coefficients.

Thus, C(*1*) is simply the sum of the infinite order VMA coefficients from the Wold decomposition of the VAR.

Recalling that $C(L)^{-1}\phi(L) = C$ implies that

$$\phi(L) = C(L)C \qquad (13)$$

Ignoring the lag operator and focusing only on the coefficients, allows for the particular case where

$\phi(1) = C(1)\, C$

Multiplying by $\phi(1)'$ on both sides gives

$\phi(1)\phi(1)' = C(1)CC'C(1)'$

and using (11) yields

$$\phi(1)\phi(1)' = C(1)\Sigma C(1)' \qquad (14)$$

So that $\phi(1)$ is a factor of $C(1)\Sigma C(1)'$, and the restriction can be imposed by making it the Choleski factor of that matrix (i.e. making it lower triangular). This yields impulse responses such that the first (1^{st}) variable may have long run effects on all variables, the second (2^{nd}) may have long run effects on all but the first (1^{st}), the third (3^{rd}) on all but the first (1^{st}) and second (2^{nd}) and the fourth (4^{th}) has no cumulative effects on any of the former three variables.

On a final note, observe that since Σ (variance-covariance matrix of the forecast errors) is symmetric, it contains only $(n^2 + n)/2$ independent elements. There are n elements along the diagonal, (n-1) along the first off-diagonal, n-2 along the next and so forth (recall there is an additional free corner element), for a total of $(n^2 + n)/2$ distinct elements (Enders, 1995). Since the C matrix has unity along the main diagonal, it contains $n^2 - n$ unknown values, which added to the n unknown values var(E_{it}) give a total of n^2 unknowns in the structural model. In order to identify the n^2 unknowns from the known independent elements of the Σ matrix, it necessary to impose an additional $n^2 - [(n^2 + n)/2] = (n^2 - n)/2$ restrictions on the system.

In this particular setup, this means that $[(4)^2 - 4]/2 = 6$ restrictions must be imposed in order to exactly identify the system. Note that the three long-run restrictions imposed on the fourth variable, along with the two imposed on the third and the restriction on the second, exactly add up to six restrictions. This means that the model here presented is exactly identified, so no identification tests need to be performed.

Appendix B

I. Stationarity of the Variables Used in the Structural Vector Autoregression

The variables used in this paper consist of a set of macroeconomic variables which are in their entirety found in the database of Banco de la República. Output gap is calculated using a Hodrick-Prescott filter with priors, inflation is calculated as the annual change in the consumer price index, the real interest rate corresponds to the interbank lending rate and derivative market size is approximated by the notional amount of derivatives negotiated by the financial system, all variables measured quarterly.

In order to use long-run constraints in the SVAR methodology, the data must be stationary, so that shocks have coherent effects on variable levels.

Table 1

HEGY test for seasonal unit roots at regular and seasonal frequencies (quarterly data)							
Critical Values (95% confidence interval)	π_1	π_2	π_3	π_4		Ho: $\pi_i=0$	**F-test** Ho: $\pi3=\pi4=0$
Intercept and Trend	-3.56	-1.91	-1.92	-1.7			2.95
Variable - Parametrization	t-statistic				F-Statistic		
GAP - Trend and Intercept	-1.577	-4.068	-3.095	-1.538	15.552	$\pi_1=\pi_4=0; \pi_2, \pi_3, \neq 0$	Ho is rejected
INF - Trend and intercept	-1.073	-4.072	-2.714	-3.962	18.022	$\pi_1=0; \pi_2, \pi_3, \pi_4 \neq 0$	Ho is rejected
TIBR - Trend and Intercept	-2.914	-2.254	-3.086	-1.43	6.652	$\pi_1=\pi_4=0; \pi_2, \pi_3, \neq 0$	Ho is rejected
DDER - Trend and intercept	-1.963	-2.594	-3.419	-3.468	9.26	$\pi_1=0; \pi_2, \pi_3, \pi_4 \neq 0$	Ho is rejected

Since variables are measured on a quarterly frequency, a HEGY test for seasonal unit roots both at regular and seasonal frequencies must be used (Table 1). In order for a variable not to have a unit root at a seasonal frequency, π_2 and either (or both) π_3 or π_4 must be different from zero, which therefore requires the rejection of both a test for π_2 and a joint test for π_3 and π_4 (F-test). For a variable not to have a unit root at a regular frequency, π_1 must be different from zero. Note that, at a 95 percent confidence level, all variables seem to reject the hypothesis of a unit root at seasonal frequencies.

To test for a unit root at the zero frequency, a regular KPSS test was used (Table 2), since the HEGY test seems subject to the same criticism as the Augmented Dickey-Fuller, where the lack of flexibility of the test results in most variables containing a unit root, even when it would seem counter-intuitive (e.g. the fact that the real interest rate seems to have a unit root is particularly strange). Results for the KPSS seem to support the existence of this problem, as in this test the null hypothesis for stationarity cannot be rejected at the 95% confidence level for *all* variables.

Table 2

KPSS test for stationarity around a level or a trend		
Critical Values	95% confidence interval	Ho:
Eta(tau)	*0.146*	*Variable is trend stationary*
Variables - Parametrization	Eta statistic for lag 8	
GAP - Trend and Intercept	*0.09834*	*Ho cannot be rejected*
INF - Trend and intercept	*0.06625*	*Ho cannot be rejected*
TIBR - Trend and Intercept	*0.13129*	*Ho cannot be rejected*
DDER - Trend and intercept	*0.14207*	*Ho cannot be rejected*

Lastly, it may come as a surprise that output gap seems to be integrated of order zero in this paper. KPSS tests for both output and potential GDP where calculated (Table 3). Note that both variables are integrated of first order (i.e. the null hypothesis is rejected when variables are in levels, but cannot be rejected when tested on their first difference), so that one might think their linear combination to be of the same order. A Johansen cointegration test is also included in this appendix (Table 4), from which it is clear that both variables have a long-run relationship, and that a cointegration vector exists. By the Engle-Granger theorem, the linear combination of two cointegrated, first-order variables, is of order 0, and so output gap must be I(0). This result reassures the belief that the HEGY test, *for regular frequencies*, may not be the best approach, and that the results of the KPSS test seem more reliable.

Table 3

KPSS unit root test		
Critical Values	95% confidence interval	Ho:
Eta(mu)	*0.463*	*Variable is stationary around a level*
Eta(tau)	*0.146*	*Variable is trend stationary*
Variable - Parametrization	Eta statistic for lag 8	
GDP - Trend and intercept	*0.259085*	*Ho is rejected - variable is not stationary*
Potential GDP - Trend and intercept	*0.253208*	*Ho is rejected - variable is not stationary*
D(GDP) - intercept	*0.099624*	*Ho cannot be rejected*
D(Potential GDP) - intercept	*0.258161*	*Ho cannot be rejected*

Table 4

Johansen Cointegration test				
Ho: Number of Cointegration Equation(s)	Trace Statistic	Critical Value (95% confidence interval)	P-value	
None	*31,53871*	*25,87211*	*0,0088*	*Ho is rejected*
At most 1	*5,483632*	*12,51798*	*0,5285*	*Ho cannot be rejected*
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level				

II. Normality and Autocorrelation of Forecast Errors

For the VAR estimation, from which the VMA representation is obtained and subsequently the structural impulse response functions, to be consistent with the assumptions of the linear regression model, it must be that the vector of forecast errors has an independent multivariate normal distribution with 0 mean (i.e. normally distributed vector white noise). Thus, the following tests are performed on the reduced form innovations, to test for multivariate normality (Jarque-Bera) and autocorrelation (Portmanteau).

Table 5

VAR Residual Normality Tests				
	Jarque-Bera Statistic			*Ho: Residuals are Multivariate Normal*
Orthogonalization	*Degrees of Freedom*	*Joint Statistic*	*P-value*	
Cholesky (Lutkepohl)	*8*	*4.854699*	*0.773*	*Ho cannot be rejected*
Residual Covariance (Urzua)	*55*	*37.54105*	*0.9654*	*Ho cannot be rejected*

Table 6

Portmanteau Test for Joint Residual Autocorrelation		
*Chi-Sqr (192)**	*P-value*	*Ho: No Residual Autocorrelation*
220.3263	*0.0787*	*Ho cannot be rejected at a 95% confidence level*
** Degrees of Freedom*		