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The Effectiveness of Monetary Policy Transmission Channels in the Presence of Islamic Banks: The Case of Saudi Arabia

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ABSTRACT

Using a structural vector autoregressive models, this paper empirically investigates the effectiveness of monetary policy transmission in Saudi Arabia in the presence of Islamic banks over the period 1990 Q4 – 2013 Q3. The results indicate that bank lending channel is relatively effective in influencing non-oil private output, but less effective in influencing consumer prices. Indeed, a positive shock on bank financing extended by Islamic banks or on loans granted by conventional banks results in an improvement of the economic activity. While the empirical result show that conventional and Islamic banks react to each other, the reaction of conventional banks to a shock on the financing provided by Islamic banks seems to be more significant than the reaction of Islamic banks to a shock on the conventional banks credit.

JEL Classifications: E5, C01

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I. INTRODUCTION

The empirical evaluation of the effectiveness of the channels of monetary transmission provides to Central Banks information that can be useful for the improvement of their decisions in terms of monetary policy. If the monetary policy decision-makers' do not know accurately how influent are their decisions on different macroeconomic variables, if they do not identify well the sequence of reactions that may occur further to their actions, then they can't assess, with certainty, neither the required time for transmission nor the effectiveness of their decisions.

While all the studies that examine the transmission of the monetary policy in the GCC countries (in particular Saudi Arabia) have found that the exchange rate channel is not significant in the monetary policy transmission process, because of the fixed exchange rate regime adopted by these countries, they assert that other channels may play an important role in the transmission mechanism.

In two papers published in 2005 and 2008, Al-Jasser, the former governor of the SAMA (Saudi Arabian Monetary Agency), and Banafe have tried to explain analytically the transmission mechanisms of the monetary policy in Saudi Arabia. In their analysis, they consider that the bank-lending channel is potentially the only channel that plays an important role in the transmission of the monetary policy. Also, Al-Hamidy (2011:302) thinks that the interest rate channel is marginal in Saudi Arabia and that an increase of the real interest rate is not likely to contain the inflation because, according to him, the credit-to-GDP ratio is relatively low. In this paper, we will see that, for three main reasons, the analysis made by Al-Hamidy (2011) is put into perspective. First, the bank credit to non-oil GDP ratio has improved over the last three decades (it shows a positive trend since the 1970s), and, according to Westelius (2013:22), this should improve the effectiveness of monetary policy. Second, it is necessary to understand the structure of the value added in Saudi Arabia to understand to which compartment of the economic activity the monetary policy has to be interested. Third, economic theory suggests that the Saudi Monetary policy is, partially at least, not independent. Given its largely liberalized capital account and its fixed exchange rate against the US dollar, the Saudi Arabian Monetary policy is, de facto, dependent: it is propped up on the US monetary policy. Consequently, the improvement of the synchronization between the business cycles of Saudi Arabia and those of the United States is likely to improve the effectiveness of the interest rate policy of the SAMA.

The results found in the empirical literature that focuses on the monetary policy transmission in Saudi Arabia are quite stable. Unlike the analysis of Al-Jasser and Banafe (2005 and 2008) and Al-Hamidy (2011), empirical studies have found that the interest rate and the bank lending channels seems to be effective in the transmission process. As for the exchange rate channel, it is non-existent because of the fixed exchange rate regime adopted by Saudi Arabia (Prasad and Khamis, 2011; Cevik and Teksöz, 2012; Espinoza and Prasad, 2012; Westelius, 2013). These results do not appear to be outliers as the effectiveness of the bank lending channel requires that banks play an important role as a source of funding for the private sector (Bernanke and Gertler, 1995), a condition which, a priori, is likely to be verified in emerging and developing economies.

So that the analysis of the transmission of monetary policy to be relevant, it is necessary, first of all, to understand the structural features of the Saudi economy and to which part of the output the monetary policy should be transmitted. Authors who have studied the monetary policy transmission in Saudi Arabia and in other oil-producing countries (e.g., Prasad and Khamis, 2011; Cevik and Teksöz, 2012; Ziaei, 2012; Westelius, 2013) think that monetary policy influences all the non-oil GDP. We will see that this conception is relatively imprecise, and this imprecision may question the relevance of the analysis of the transmission process. Indeed, the exploration of the structure of the wealth creation sources' in Saudi Arabia show that the monetary policy can't influence the entire non-oil activity but rather the part of the activity carried out by the private sector, i.e. the non-government-funded part.

Although the study of the monetary policy transmission in Saudi Arabia has been the subject of very few empirical investigations, the monetary policy transmission in the presence of Islamic banks remains, to the best of our knowledge, unexamined at the empirical level. In a footnote, Cevik and Teksöz (2012:9), two IMF economists, wrote: "The issue of monetary policy transmission under Islamic banking is beyond the scope of this paper, but this fast-growing segment of banking sectors may behave differently, compared to conventional banks, in transmitting monetary policy shocks". Therefore, the purpose of this paper is to empirically investigate the role of Islamic banks in the monetary policy transmission process.

The rest of the paper is organized as follows. Section II analyses the Saudi economy and its structural features. Section III provides a review of the existence literature and the main results that have been found. Section IV presents the empirical model, its theoretical framework, and outlines the econometric results and their economic and statistical interpretation. Finally, Section V highlights the major conclusions to be drawn.

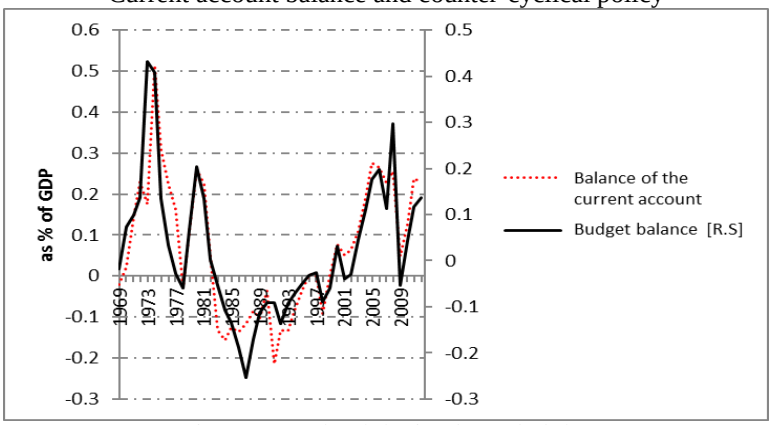
II. THE SAUDI ECONOMY

A. Structural Features

As it is the world's largest producer and exporter of crude oil and being the second largest country with proven oil reserves, Saudi Arabia is a resource-based economy with low level of economic diversification. In fact, oil revenues account for almost 88.5% of Government revenues in 2012 and the oil sector contributes to the formation of almost 50% of the GDP. Therefore, government spending is funded mainly by oil export earnings, and the current account is the main source of growth in Saudi Arabia. As most of the oil revenues of Saudi Arabia accrue directly to the Government, the public sector plays an important role in the economic activity. Since 1999, Saudi Arabia began to show a positive current account, as shown in Figure 1. The improvement of the current account, largely explained by the improvement of the oil revenues, has enabled the government to realize budgetary surpluses and, based on these surpluses, to reduce the weight of the public debt.

Monetary policy in Saudi Arabia is implemented by the Saudi Arabian Monetary Agency (SAMA) and is based primarily on a fixed exchange rate policy vis-à-vis the US dollar as an intermediate target. The choice made by Saudi Arabia to anchor its domestic currency, the riyal, on the US dollar has four motivations essentially. First,

Figure 1
Current account balance and counter-cyclical policy



Sources: Datastream / SAMA annual statistics / Authors calculations'

given that external payments and receipts of Saudi Arabia are mostly in US dollars, the credibility of this strategy should help and facilitate domestic price stability. Second, such a strategy may reduce the uncertainty related to the exchange rates and, therefore, improve the trade and investment. Third, as exports are dominated by oil and petrochemical products, changes in the USD/SAR parity do not contribute significantly to the terms of trade of Saudi Arabia (Al-Hamidy, 2011: 301). Fourth, the emitted riyals are fully backed by equivalent foreign exchange reserves resulting mainly from oil export revenues and investment income, adds Ramady (2009: 244).

Economic theory suggests that when a country adopts a fixed exchange rate regime and liberalizes its capital account, it loses mechanically the autonomy of its monetary policy (Mundell, 1962). Therefore, and as the interest rate policy is technically constrained, the government spending plays an important role in the regulation of the economic activity. To protect the domestic economy from oil price fluctuations and production shocks, the government sets up a discretionary countercyclical policy to support steady and regular growth of the domestic demand.

The inflow of oil revenues has allowed the government to increase its spending and to reduce, at the same time, issues of new securities and the weight of the public debt. This has stimulated the economic activity and improved the liquidity of the banking system. As the government has pursued, since the mid-2000s, a refund policy of its public debt, domestic banks were "forced" to dissave from government securities, and they have responded by increasing consumer credit (Al-Jasser and Banafe 2009: 425).

The fact that Saudi Arabia is an oil-based economy led us to ask whether the policy of the SAMA could really influence the output. In other words, understanding the sources of the value added in Saudi Arabia may allow us to identify the part of the activity that is likely to react to the monetary policy and, thereby, to better predict the true influence of the monetary policy on the output.

B. Sources of the Value Added in Saudi Arabia

To ensure that the study of the monetary policy transmission is relevant, it is necessary to discern the part of the economic activity that may react to the monetary policy decisions, namely the non-oil part which is not funded by the public sector. The previous works that studied the transmission of the monetary policy in Saudi Arabia did not pay attention to this important detail (Ziaei, 2012; Cevik and Teksöz, 2012; Westelius, 2013), and they have considered in their empirical investigations that monetary policy may influences the total non-oil GDP.

As Saudi Arabia is an oil-based economy, the monetary policy can have no significant influence on the value added created by the oil sector. Also, as a part of the non-oil activity is funded by the government, whose resources come mainly from oil export revenues, the actions of the SAMA cannot have a significant influence on this part of the activity. Thus, we have to distinguish between the wealth created by the oil activity and the wealth created by the non-oil activity. This distinction is useful for two reasons mainly. First, the Saudi Monetary policy has no influence on oil revenues: It is the international demand which is the main factor that influences the oil price (at least from the 1990s) and, thereby, oil revenues. Second, it is the growth of the non-oil part of the GDP that contributes more to the creation of employment in the oil-producing countries. It is the non-oil GDP generated by the private sector that is likely to react to the monetary policy decisions, and must be considered to analyze the transmission of the monetary policy.

C. The Saudi Banking System

Until the mid of the twentieth century, Saudi Arabia had no formal monetary and banking system, and foreign currency in circulation was the only available means of payment[1]. Money changers, usually from Yemen, are the only financial actors who were present, and they were present in Hijaz, Jeddah, Mecca, and Medina where there was a high demand for conversion of currencies and precious metals (especially gold) in silver riyals from the pilgrims who came to perform Hajj.

The slow development of a banking system can be explained, in part, by the prohibition of interest under Islamic law and by the fact that the Saudi economy was almost a "dead" economy before the discovery of oilfields in 1939 and the oil crises of the 1970s.

The Algemene Bank (Saudi Hollandi Bank [SHB] after the decision of "Saudization" of the foreign banks in May 1977)[2], a branch of the Netherlands Trading Society, is the first bank established in Saudi Arabia in 1926. In the absence of a monetary authority at that time, the SHB held the gold reserves of the Kingdom and was receiving oil revenues on behalf of the Saudi government. This bank remained a monopoly until the late 1940s.

In 1947, the Banque de l'Indochine opened a branch, followed by the Arab Bank Limited (1949), the British Bank of Iran and the Middle East (1950) and the National Bank of Pakistan (1950). The first Saudi domestic bank, the National Commercial Bank (NCB) has obtained a license to operate in Saudi Arabia in 1953. The second largest domestic bank, Riyadh Bank, was established in 1957.

Despite the fact that the NCB appeared in 1953, its roots go back to 1937. Indeed, in 1937, Mahfouz and Musa Kaki families, who were the biggest money changers, have requested permission from the King to establish the first domestic bank. A year later, the Kaki Salah Company (NCB since 1953) start working in Jeddah and it was held by Mahfouz family (51.5%) and Musa Kaki family (48.5%). Over time, the share of Mahfouz family in the capital of the NCB has increased at the expense of a decline in the share of Musa Kaki family who become minority shareholders. In 1988, Salim bin Mahfouz handed the control of the bank to his son Khaled. But this transfer of power was disastrous for the bank. In fact, the NCB has failed to produce its financial statements for 1990 and 1991 (Ramady, 2009: 241). In 1997, the police and the Saudi intelligence services had evidence about the involvement of Khaled in dubious money transfers (in the form of religious charities). During the same year (1997), Khaled was stripped of his Saudi nationality, while he was abroad[3].

As the bankruptcy of one bank in a system composed of 12 commercial banks can have disastrous consequences on the entire banking system and even on the economy as a whole, the SAMA has supported, on several occasions, the banking system, despite the fact that its founding charter forbids it to act as "lender of last resort".

Since it started, the banking system has encountered several problems. In fact, commercial banks were increasingly under pressure made by ambitious merchants and members of the royal family. Given the political influence of these customers, the banks could not refuse to grant them loans. Wilson et al. (2004: 59) speak about "unscrupulous" businessmen who do not repay their debts on time, and who justify their behavior by the prohibition of riba in Islam, despite the fact that they were aware of the contractual funding conditions when the loans were granted.

These pressures have affected Riadh Bank and Al Watany Bank that, in 1960/1961, have experienced serious liquidity problems resulting from mismanagement and inappropriate loans to the members of the Board of Directors. The SAMA has decided to liquidate Al Watany Bank, and then it organized its merger with Bank Riadh. And to keep the stability of the banking system, the SAMA has acquired, on behalf of the government, 38% of the shares of the new Riyadh Bank. Further to this event, the authorities admitted the necessity to find a more sustainable solution: The solution was the implementation of the Banking Control Law in 1966. The introduction of this Law clarifies and strengthens the role of the SAMA in the regulation of the Saudi banking system[4].

The weakness of the nascent domestic banking system has limited its ability to support the efforts made by the government to modernize and diversify the economy. For this reason, the government made two important reforms as part of its efforts. The first consists in establishing Specialized Credit Institutions. Their role is to provide subsidized medium and long term financing for specific economic sectors to facilitate the capital accumulation. The second is the "Saudization" of the foreign commercial banks. Indeed, in 1976 the government has decided that foreign banks operating on Saudi territory have to be transformed into local banks with majority Saudi ownership (joint-venture).

In 1980, the modernization process was finalized and the structure of the banking system remained almost the same until today (Westelius, 2013:8). At present, the Saudi banking system contains 24 banks, including 12 Saudi banks and 12 branches

of foreign banks. The assets of the 12 Saudi banks represent about 63.6% of the GDP and 98.9% of the total banking system assets. Saudi banks are not all purely Islamic, although they all provide Shari'a compliant financial products. Islamic banks hold about 23.44% of the total Saudi banks assets in 2012.

Saudi banks' assets are highly concentrated. In fact, the three largest Saudi banks (NCB, A-RB and SFG) hold 47.3% of the total banking assets in 2012, while the three smaller banks possess only 7.8%.

In 1983, Al-Rajhi Bank has applied for a license to become the first qualified Islamic bank in the Kingdom. The SAMA has refused to grant the license to this bank because if Al-Rajhi bank obtains such a license, then it means that the other banks are "un-Islamic". But in 1988, the SAMA has granted the license for Al-Rajhi Bank on condition that the latter do not use the adjective "Islamic" in its commercial name. Currently, the Saudi banking system contains four Islamic banks (Al-Rajhi [Islamic since 1988], Alinma [founded in 2008], Al-Jazeera [established in 1976 and Islamic since 2002] and Al-Bilad [created in 2004]) that hold about 25% of the assets of all domestic banks.

Because of the weakness of the financial market, banks play a key role in financing the Saudi economy. Indeed, the claims on the economy are mainly provided by the Saudi Arabian domestic banks and specialized credit institutions. Credit to private sector, which grew at an annual average rate of 15.3% over the period 1963-2013, has largely contributed, alongside oil revenues, in financing capital accumulation. The importance of intermediation in the Saudi economy is likely to improve the responsiveness of financial intermediaries to monetary policy and, therefore, improve the effectiveness of the monetary transmission mechanisms.

Since the mid-1990s, bank credit to public sector scaled by total bank credit shows downward trend. This can be explained by the improvement in the financial position of the government, which allowed it to finance several public projects with its own resources. At the same time, bank credit to private sector scaled by total bank credit shows an upward trend since the early 1990s. This suggests that the bank lending channel is likely to play an important role in the transmission process, as the effectiveness of this channel implies that banks play a significant role in financing the private sector.

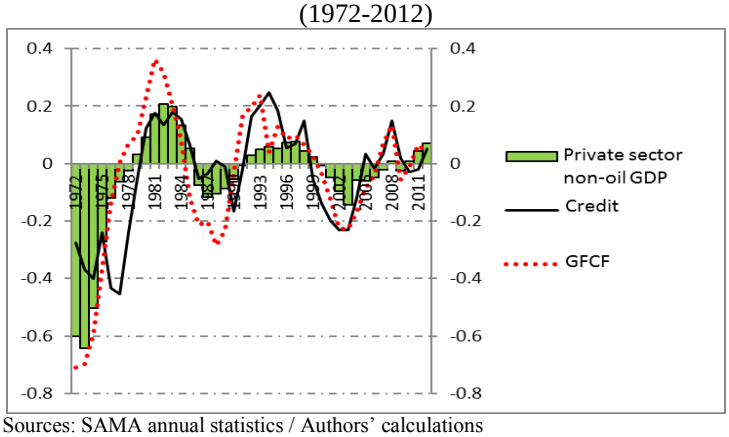
To better understand the interference between the monetary sphere and the real economy, it is important to examine the relationship between bank credit and the business cycles of Saudi Arabia. Figure 2 shows that, over a long period (from 1972 till 2012), the dynamic of the private non-oil GDP (at current prices) is correlated with both the dynamics of total bank credit and investment.

It is clear that the dynamics of the bank credit are highly correlated with the Saudi Arabian business cycles of the non-oil private sectors, which explains that, a priori, bank credit contributes to the financing of the non-oil Saudi economy significantly.

D. Interaction between Islamic and Conventional Banks in A Dual Financial System

Most of the countries that have integrated Islamic banks in their financial structures have not ruled out the conventional banks, because the mixed structure allows reaching a greater efficiency in the allocation of resources (Saadallah, 2012).

Figure 2
Correlation between Saudi Arabian non-oil business cycles, bank credit, and investment (1972-2012)



Sources: SAMA annual statistics / Authors' calculations

Empirical studies that address dual banking systems, such as the work of Abdul Kader and Leong (2009) and Chong and Liu (2009), show a strong correlation between returns on Mudharaba accounts of Islamic banks and returns on deposit accounts of conventional banks. They also show, through statistical causality tests, that the change in the remuneration of savings deposits with conventional banks generates a change in the remuneration of PSIA with Islamic banks. These authors explain this result by the direct competition[5] between Islamic and conventional banks and by the fact that the returns offered by Islamic banks are administratively linked to the returns on savings deposits with conventional banks.

Thus, the dual structure is likely to improve the responsiveness of Islamic banks to monetary policy, as these banks are aligning their practices, in terms of pricing of financial assets, on the practices of conventional banks that are sensitive to the decisions of the monetary policy. In fact, we can easily demonstrate that, in a dual system, the profit-sharing ratio (α) that the bank applies vis-à-vis the entrepreneur is[6]:

$$\alpha = \min\{\frac{K(\theta + x)}{\pi}; 1\} \quad (1)$$

where K is the capital of the mudharaba, θ=f(i) is the rate applied by conventional banks on loans to the economy which is an increasing function of i, x is a risk premium, and π is the expected cash-flow of the mudharaba.

For this reason, and despite the fact that Islamic banks are supposed to meet and respect a particular legal framework (in particular the prohibition of riba), we think that the role they plays in the transmission of monetary policy should not be very different from the role of conventional banks.

III. THE TRANSMISSION OF MONETARY POLICY

A. An Overview

The inflation rate in Saudi Arabia was low and relatively stable since the late 1980s to the early 2000s. From 2006, it begins to rise, exceeding 10% in 2008. This increase is primarily due to higher international food prices and higher rental and real estate prices.

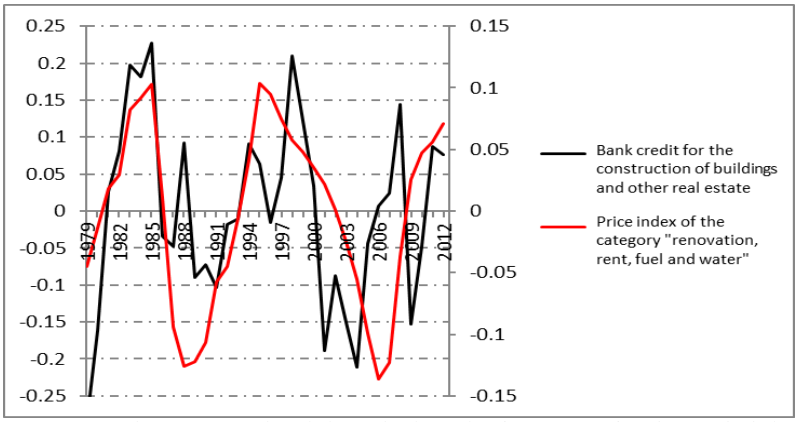
For Saudi Arabia, the price of the basic foodstuffs is an exogenous price, which depends rather on international prices and not on the Saudi domestic demand. Therefore, it is not the Saudi monetary policy (the interest rate policy more precisely), expansionary since the outbreak of the subprime crisis in the United States, which has pushed up food prices. Al-Hamidy (2011:303) explains that the increase of foodstuffs prices is due to the drought and the increase of the domestic demand in exporting countries of foodstuffs[7], and he explains the increase of rental and real estate prices by demographic pressure combined with a low level of housing supply.

Between 2000 and 2006, bank credit to private sector[8] grew at an annual growth rate ranging between 9.75% and about 40%, passing from 161 billion riyals in 2000 to over 460 billion in 2006. This has contributed to the increase of the domestic demand and, therefore, inflationary pressures.

Figure 3 illustrates the dynamics of the price index of the category "renovation, rent, fuel and water" and the dynamics of bank credit for the construction of buildings and other real estate properties over the period 1979-2012. It shows that, overall, the dynamics of bank credit influences the dynamics of the price index. It shows also that, from the early 2000s, the increase of bank credit explains, at least partly, the increase of inflationary pressures.

Since the early 2000s, domestic private investors tend to keep their additional funds in the national banking system instead of placing them abroad to diversify their portfolio. This behavior led to the abundance of the liquidity in the banking system and, thereby, to the growth of monetary aggregates to a rate higher than the economic growth. In other words, the behavior of domestic private investors since the early 2000s has exacerbated inflationary pressures in Saudi Arabia.

Figure 3
Dynamics of the price index and the bank credit for the construction of buildings and other real estate



Sources: Central Department of Statistics and Information / Datastream / Authors' calculations

As the Saudi riyal is pegged to the US dollar and as the Saudi Arabian capital account is largely liberalized, the SAMA cannot always efficiently manage the abundance of liquidity by adjusting the repo and reverse repo rates since these rates cannot deviate too much from the US policy rates. This does not mean that the monetary authority cannot handle the economic situation: SAMA may use structural quantitative instruments such as reserve requirements. Indeed, in May 2008, and to counter inflationary pressures, SAMA raised the reserve requirement ratio on demand deposits and on time deposits from 7 to 13% and from 2 to 4 % respectively, while maintaining the key interest rates at low levels. But due to the internationalization of the financial crisis, the SAMA has lowered the reserve requirement on demand deposits at 7% to avoid creating pressure on the banking system.

To summarize, the rapid growth of bank credit, a direct consequence of a more and more lax monetary policy and a forced public debt reduction policy, and the dramatic increase in the price of commodities at the World level accompanied, by the depreciation of the US dollar, and therefore the Saudi riyal, intensified domestic inflationary pressures in Saudi Arabia. SAMA has not used its interest rates policy to deal with these tensions, but it mobilized temporarily more quantitative instruments, including reserve requirements.

B. The Role of Islamic Banks

The purpose of this subsection is to study the role of Islamic banks in the transmission of the monetary policy. The procedure of data collection contains two stages. We used, in a first step, the Thomson One Banker database to collect data relative to the four Saudi Islamic banks since the mid-2000. Then, in a second step, we mobilized other databases (Bankscope and IBIS Online) to collect data going back to 1990.

Before examining empirically the transmission channels of monetary policy in the presence of Islamic banks, we examine, at first, if the dynamics of credit granted by Islamic banks is important for the dynamics of Saudi business cycles. One way to test this hypothesis is to study the ability of credit granted by Islamic banks to predict the fluctuations in Saudi non-oil GDP. In other words, and by using the terminology of time series econometrics, we study the Granger causality between bank financing extended by Islamic banks and the non-oil GDP.

Table 1
Granger causality test

	1990 Q4 - 2012 Q4
Does the Islamic bank financing Granger-cause the non-oil GDP?	Yes
(p-value)	(0.00)
Does the non-oil GDP Granger-cause the Islamic bank financing?	Yes
(p-value)	(0.00)
Does the Islamic bank financing Granger-cause the investment?	Yes
(p-value)	(0.00)
Does the investment Granger-cause the Islamic bank financing?	Yes
(p-value)	(0.03)

* The test was performed with two lags, but the results are also robust with three and four lags.

Table 1 provides summary results of the Granger causality test between the private non-oil GDP (at current prices) and the total of Islamic bank financing (at current prices), and between the GFCF (at current prices) and the Islamic bank financing. The test rejects the null hypothesis (H0) of no causality and shows that causality is in both directions, i.e., Islamic bank financing Granger-cause GFCF and private non-oil output, and vice versa.

IV. LITERATURE REVIEW

Westelius (2013) has used a VAR model on annual data (1980 to 2010) to empirically investigate the relationship between bank credit and the non-oil output. Because of the limited number of observations, he has used a parsimonious model with two endogenous variables (bank credit and non-oil GDP) and one exogenous variable (oil price). He estimates the model three times: once over the entire period (1980-2010), a second time over the period 1980-1995, and a third time over the period from 1996 to 2010, and he compares impulse responses and variance decomposition for the two sub-samples (from 1980 to 1995, and from 1996 to 2010) to examine whether the influence of bank credit on non-oil economy has evolved through time. He has found that, when the full sample is considered, the response of the non-oil GDP to a positive one-standard-deviation shock to bank credit is positive but statistically insignificant during the first two years. When the sample is split in two (1980-1995 and 1996-2010), the insignificant effect only holds for the first period but turns statistically significant in the second period.

The author has also found that, over a horizon of 5 and 10 years, credit explains most of the forecast error variance decomposition of the non-real GDP over the period 1996-2010, against a lower explanatory power over the period 1980-1995.

In line with the study of Bernanke and Blinder (1992), Cevik and Teksoz (2012) estimate an SVAR model to study the importance of the different monetary policy transmission channels in GCC countries over the period 1990-2010 on quarterly data. They have found that the interest rate channel and the bank-lending channel are relatively efficient in the transmission of monetary policy in the GCC countries. They also find that the exchange rate does not play an important role in the transmission process given the fixed exchange rate regime adopted by these countries. The results of Cevik and Teksoz (2012) are in line with the results found by Espinoza and Prasad (2012) and Ziaei (2012). They think that the underdevelopment of domestic financial markets is the main reason that explains the relative weakness of the transmission channels of monetary policy in the GCC countries. Strengthening the financial intermediation and facilitating the development of domestic capital markets may improve the efficiency of the transmission mechanisms in these countries, they say.

By estimating a VAR model on panel data for the GCC countries over the period 1978-2009, Khamis Prasad (2011) have found that the monetary policy of the United States has a strong and statistically significant impact both on the money supply, the non-oil activity and the inflation in the GCC countries. They have found that an increase by 150 basis points of the federal funds rate decreases the growth of the money supply M2 by more than 1 percentage point and the non-oil activity by 1.5% two years after the shock.

Ziaei (2012) has also empirically examined the monetary policy transmission channels in Saudi Arabia. To do so, he used an SVAR model over the period 1992-2007 on quarterly data. He has found that following an unexpected increase in money supply, the SAMA reacts by increasing its interest rates. He also found that shocks on the interest rates affect output, but they do not have a significant impact on prices. Despite the low impact of interest rates shocks on the price level, the author found that a shock on the nominal effective exchange rate leads to the decrease of the price level. According to Zaiei (2012), the credit channel is the most important transmission channel: the variance decomposition shows that bank credit largely explains the fluctuations of the output in the long term. This result can be explained by the fact that, in developing countries the financial sector is dominated by the banking sector whose main function (and almost the only) is to finance the economy by collecting deposits.

V. EMPIRICAL MODEL

A. Specification

To determine the effects of the monetary policy, we need to identify how macroeconomic variables respond to specific shocks. The VAR approach, proposed by Sims (1980) as an alternative to traditional macro-econometric models, provides a convenient framework for simulations, forecasting and analysis of economic policy (Kilian, 2013:515), and it allows to avoid a heavy work of specification and estimation.

However, VAR models, instead of basing the structure of the modeling on principles derived from the economic theory, they attribute more importance to data. Also, as the variance-covariance matrix of the residual innovations vectors of VAR models may have non-zero values elsewhere than on its main diagonal, important residual information will be contained in the vector of residual innovations. This means that many variables are subject to correlated impulses, even to same impulses, and that the effect of a specific shock on the endogenous variables cannot be isolated.

For this reason, some authors (e.g. among others: Bernanke and Blinder, 1992; Keating, 1992; Christiano et al., 1999; Bernanke and Boivin, 2003; Teksöz and Cevik, 2012) have used SVAR models that allow designing the structure of the system by referring to economic theory. While the reduced VAR connects each of the endogenous variables to its own lagged values, to the lagged values of other endogenous variables, and to any exogenous variables, the structural form of the VAR does the same thing, but it also allows for contemporaneous interactions between endogenous variables.

SVAR models, whose validity requires the stationarity of the considered variables, "are the backbone of empirical macroeconomics" (Kilian, 2013:515). The methodology of the SVAR models has become a widely used tool for the analysis of the monetary policy transmission mechanisms (Buckle et al. 2002; Kilian, 2013). These models allow contemporary feedbacks between variables while imposing the minimum of structural restrictions.

In the SVAR models, identification focuses mainly on the errors of the system that are interpreted as linear combinations of structural exogenous shocks. SVAR models are able to adopt restrictions in accordance with economic theory to identify the structural components of the error terms.

Economists are often interested in the response of endogenous variables to some shocks that may arise from the economic policy. The purpose of using the SVAR approach is to get the orthogonal structural components of the error terms and evaluate the impulse response functions of the different models retained. Indeed, thanks to the orthogonalization of the variance-covariance matrix, SVAR models would allow to highlight the reaction of the considered system of simultaneous equations to a specific structural shock. Therefore, this approach can be seen as a tool that allows, with regard to the traditional VAR models, a better fit between reality and its representation theory.

To analyze the transmission channels of the monetary policy in Saudi Arabia, we use the methodology of structural vector autoregression models with short-term restrictions and with exogenous variables (SVAR-X). More precisely, we use the "AB" model of Amisano and Giannini (1997). It is possible through this structural model to explicitly model the instantaneous relationship between the endogenous variables (through the matrix A), and the effect of the orthogonal shocks on the equations of the systems (through the matrix B) analysis (Lütkepohl and Krätzig, 2004). A reduced-form VAR model of order p [VAR(p)] can be written as:

$$Y_t = A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + u_t \quad (2)$$

Where $Y_t = (Y_{1t},...,Y_{kt})'$ is the vector of endogenous variables of dimension k×1, A_i(i=1,2,…p) are k×k parameter matrices and the k×1 error process u_t with $u_t \sim (0,\Omega_u)$ and $E(u_t u_s')=0$ for any $t \neq s$.

This reduced form may be associated with a dynamic structural representation in which each of the endogenous variables in the vector Y_t is a linear function of its present and past values and the lagged and contemporaneous values of the other endogenous variables:

$$A_0 Y_t = A_1^* Y_{t-1} + \cdots + A_p^* Y_{t-p} + B\varepsilon_t \quad (3)$$

Here the k×k matrix A_0 reflects the instantaneous relations and $A_i^* = A_0 A_i$ (with i=1,2,…,p). The structural form error ε_t is iid white noise with $E(e_{t-1} e_{t-j}') = I_k$ if i=j and 0 if not, and $E(\varepsilon_t)=0$. B is the matrix of structural parameters associated with the vector of structural innovations. It is a diagonal matrix that verifies that elements of ε_t are mutually non-correlated and it allows modeling the effects of orthogonalized shocks on the system (Hamilton, 1994:321; Lüetkepohl, 2011:7).

From (2) and (3) can be deduced the linear relationship between the disturbances of the reduced form and the innovations of the structural form:

$$u_t = A_0^{-1}.B.\varepsilon_t \Leftrightarrow A_0.u_t = B.\varepsilon_t \quad (4)$$

In the model "AB", restrictions can be placed on both matrices A_0 and B. For k variables and p lags, the number of parameters in the reduced-form is equal to $k^2p+(k^2+k)/2$, while the number of parameters in the structural form is equal to $k^2(p+2)$. The order condition for identification requires that $2k^2-[k(k+1)/2]$ linear restrictions be placed on the elements of the matrices A_0 and B in order to identify all the $2k^2$ elements

of both matrices (Breitung, Brüggemann et Lütkepohl, 2004)[9]. A_0 and B are estimated by maximizing the concentrated log-likelihood function (Lüetkepohl, 2011:9)[10].

We use the following VAR-X model as a reference model to analyze the effects of monetary shocks in Saudi Arabia:

$$Y_t = D + \sum_{i=1}^{p} A_i Y_{t-i} + \sum_{j=0}^{s} C_j X_{t-s} + u_t \quad (5)$$

Here the k×1 vector X_t is the vector of exogenous variables and C_j (j=0,2,…s) are k×k parameter matrices.

The Saudi economy is mainly affected by two exogenous external factors: the oil price and the U.S. business cycles. Also, the portion of the output that monetary policy may influence is sensitive to the fiscal policy: all other things being equal, the improvement (deterioration) of the budget balance reduces (increases) the share of the total GDP that is sensitive to the monetary policy. Therefore, the vector of exogenous variables X_t contains the real price of crude oil [OIL], the U.S output [PIBUS], the U.S. nominal interbank three months rate [T3MUS] and the Saudi budget balance [BUD].

$$X_t^{'} = [Oil_t \;\; PIBUS_t \;\; T3MUS_t \;\; BUD_t] \quad (6)$$

The exogenous variables are included in the model to control on the one hand, changes in economic conditions in the United States and around the world and on the other hand, changes in the scope of monetary policy in the Saudi economic activity. The assumption of exogeneity of these variables is relatively uncontroversial. Indeed, the economic fluctuations in the U.S. and the evolution of world oil prices are unlikely to be affected by the Saudi private non-oil real GDP (Cevik and Teksoz, 2012:14).

To capture the different transmission channels, several macroeconomic variables are required. The vector of endogenous variables Y_t contains three types of variables: (1) the monetary policy control variable VCO=T3MAS, (2) the transmission variable VTR=[CBC,CBI], and (3) the monetary policy target variable VCI=[PIBNPPC,CPI]. $Y_t^{'} = [VCO_t \, VTR_t \, VCI_t]$. PIBNPRSP (non-oil GDP of the private sector in constant prices) and ΔCPI (the inflation rate) are the targets of the SAMA policy. CBI and CBC are bank financing extended by Islamic banks and loans granted by conventional banks respectively. T3MAS is the Saudi Arabia three-month interbank rate, and, given its strong correlation with policy rates, it can be considered as an indicator of the orientation of monetary policy (Ziaei, 2012; Cevik and Teksoz, 2012). In line with Bernanke and Blinder (1992), Ziaie (2012), Teksoz and Cevik (2012) and Westelius (2013) we use the nominal interest rates. First, the nominal rates reflect better the orientation of the monetary policy. Second, nominal interest rates reflect better the policy of linking the Saudi riyal to the U.S. dollar.

B. Stationarity

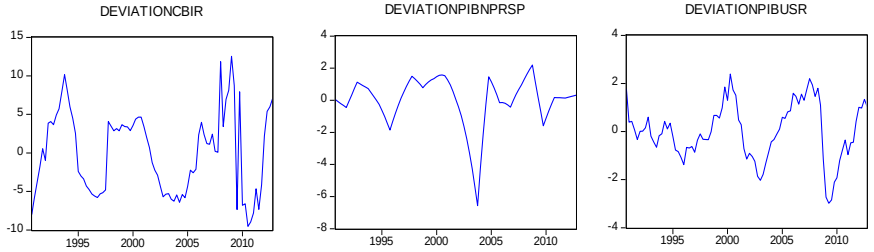
As SVAR-X models require the stationarity of the variables, we have to check, in a first step, if this condition is satisfied. The Augmented Dickey-Fuller [ADF] unit root test and the Kwiatkowski-Phillips-Schmidt-Shin [KPSS] stationarity test show that all the variables are non-stationary, except for the inflation rate (Table 2).

Table 2
ADF unit root test and KPSS stationarity test (untransformed variables)

Variables	T3MAS	T3MUS	ΔCPI	PIBNPRSP	PIBUS	OIL	CBI	BUD
Intercept								
ADF-t	-2.19	-1.69	-6.41	1.25	-1.51	-1.14	3.21	-1.12
VC 1%	-3.50	-3.50	-350	-3.50	-3.50	-3.50	-3.50	-3.50
VC 5%	-2.89	-2.89	-2.89	-2.89	-2.89	-2.89	-2.89	-2.89
VC10%	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58
KPSS-t	0.69	0.67	0.43	1.08	1.19	0.97	1.12	0.99
VC 1%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
VC 5%	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
VC10%	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34

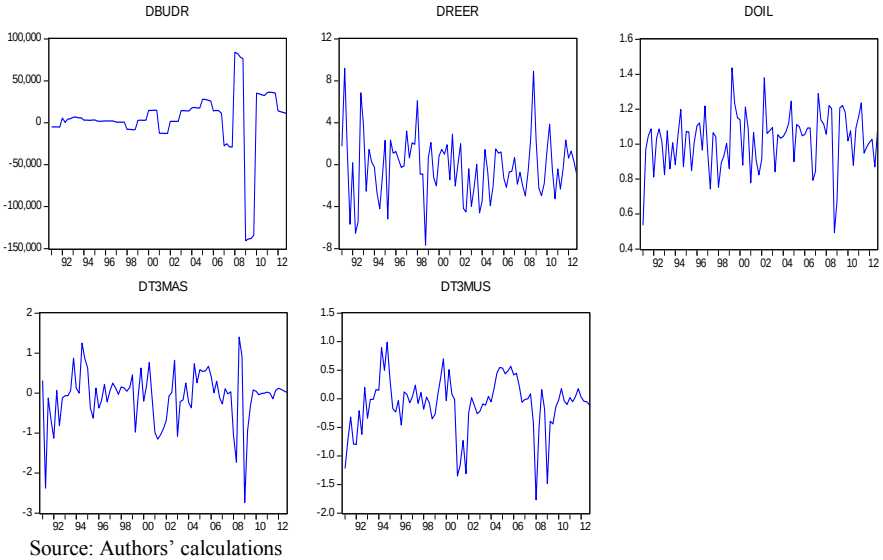
Note: « VC X% » denotes the « critical value» at a significance level of X% (X=1, 5 or 10) for the ADF test and « asymptotic critical value » at a significance level of X% (X=1, 5 or 10) for the KPSS test.

Figure 3
Deviation from the trend: CBI, PIBNPRSP and PIBUS



Source: Authors' calculations

Figure 4
Transformed variables (BUD, T3MUS, T3MAS and OIL)



Source: Authors' calculations

Therefore, we have to transform the series considered to respect the stationarity condition. The transformation procedure that we have used contains two stages. In a first step, and in line with Westelius (2013), we have used a Hodrick-Prescott filter to detrend the variables CBI, PIBNPRSP and PIBUS. Then we have calculated the deviation from the trend for these variables (Figure 3). Then we have calculated the first difference of the budget balance [BUD], of the interest rates [T3MUS, T3MAS] and the oil prices [OIL] (Figure 4).

After the transformation of variables, our sample contains 89 observations for the variables adjusted of their trends [CBI, PIBNPRSP and PIBUS] and 88 observations for the other variables [OIL, T3MUS, T3MAS, ΔCPI]. The ADF unit root test and the KPSS stationarity test show that all the transformed variables are stationary (Table 3).

Table 3
ADF unit root test and KPSS stationarity test (transformed variables)

Variables	T3MAS	T3MUS	ΔCPI	PIBNPRSP	PIBUS	OIL	CBI	BUD
Intercept								
ADF-t	-7.76	-5.20	-6.41	-4.46	-3.52	-7,91	-5.10	-2.49
VC 1%	-3.50	-3.50	-350	-3.50	-3.50	-3.50	-3.50	-3.50
VC 5%	-2.89	-2.89	-2.89	-2.89	-2.89	-2.89	-2.89	-2.89
VC10%	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58
KPSS-t	0.06	0.05	0.43	0.07	0.04	0.34	0.05	0.03
VC 1%	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
VC 5%	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
VC10%	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34

Note: « VC X% » denotes the « critical value» at a significance level of X% (X=1, 5 or 10) for the ADF test and « asymptotic critical value » at a significance level of X% (X=1, 5 or 10) for the KPSS test.

C. Selection of Optimal Lag Length

To choose the lag order for each of the selected models, we have used the LR test (likelihood ratio test) and four statistical information criteria (final prediction error [FPE], Akaike Information Criteria [AIC], Schwarz information Criteria [SIC] and Hannan-Quinn information Criteria [HQ]). Table 4 shows the number of lags used for each of the four SVAR models.

Table 4
Optimal lag length for considered SVAR models

Selection criterion of the order of VAR	Optimal lag length			
	System 1	System 2	System 3	System 4
LR	4	2	4	6
FPE	2	2	4	6
AIC	2	2	4	6
SIC	2	1	2	1
HQ	2	2	2	1
Retained lags	2	2	4	6

For system 1, four information criteria (FPE, AIC, SIC and HQ) suggest that the optimal lag order is 2. For system 2, the LR test and three information criteria (FPE, AIC and HQ) suggest that the optimal lag order is 2. For system 3, the LR test and two

information criteria (FPE and AIC) suggest that the optimal lag order is 4. For system 4, the LR test and two information criteria (FPE and AIC) suggest that the optimal lag order is 6.

D. Empirical Results

1. Bank Lending Channel

To analyze the role of total bank lending, i.e. Islamic and conventional, in the transmission process of the monetary policy, we introduce bank credit (CBT) as a transmission variable in systems 1 and 2. Table 5 illustrates the structure of systems 1 and 2 identified in the structural form $A_0 \cdot u_t = B \cdot \varepsilon_t$.

Table 5
Structure of the SVAR-X models to test the total bank lending channel

Total bank lending channel

System 1: $u_t^{SVARX_1} = (u_t^{T_3MAS}, u_t^{CBT}, u_t^{PIBNPRSP})$

$$\begin{pmatrix} 0 & 0 & a_{13} \\ a_{21} & 1 & a_{23} \\ 0 & 0 & 1 \end{pmatrix} \times \begin{pmatrix} u_t^{T_3MAS} \\ u_t^{CBT} \\ u_t^{PIBNPRSP} \end{pmatrix} = \begin{pmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{pmatrix} \times \begin{pmatrix} \varepsilon_t^{T3MAS} \\ \varepsilon_t^{CBT} \\ \varepsilon_t^{PIBNPRSP} \end{pmatrix}$$

System 2: $u_t^{SVARX_2} = (u_t^{T_3MAS}, u_t^{CBT}, u_t^{\Delta CPI})$

$$\begin{pmatrix} 1 & 0 & a_{13} \\ a_{21} & 1 & a_{23} \\ 0 & 0 & 1 \end{pmatrix} \times \begin{pmatrix} u_t^{T_3MAS} \\ u_t^{CBT} \\ u_t^{\Delta CPI} \end{pmatrix} = \begin{pmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{pmatrix} \times \begin{pmatrix} \varepsilon_t^{T_3MAS} \\ \varepsilon_t^{CBT} \\ \varepsilon_t^{\Delta CPI} \end{pmatrix}$$

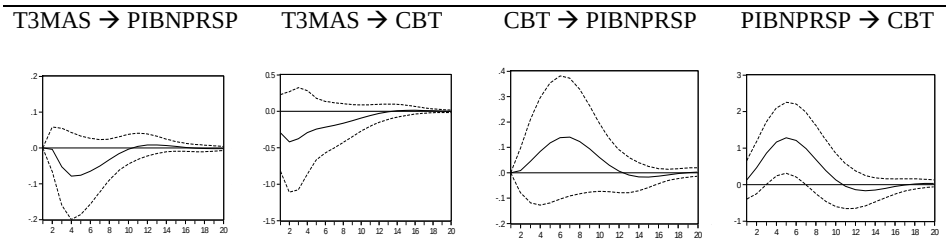
Note: « a_{ij} » is the instantaneous response of the variable « i » to a shock on the variable « j ».

In systems 1 and 2, the Saudi interest rate is assumed to respond contemporaneously to the target variables ($a_{13} \neq 0$). Total bank credit (CBT) is assumed to respond contemporaneously to the short-term interest rate ($a_{21} \neq 0$) and to the target variables of the monetary policy, the output in the system 1 and inflation in the system 2 ($a_{23} \neq 0$). However, we assume that the target variables react to the shocks on the bank credit and on the interest rate with some delay ($a_{31} = a_{32} = 0$).

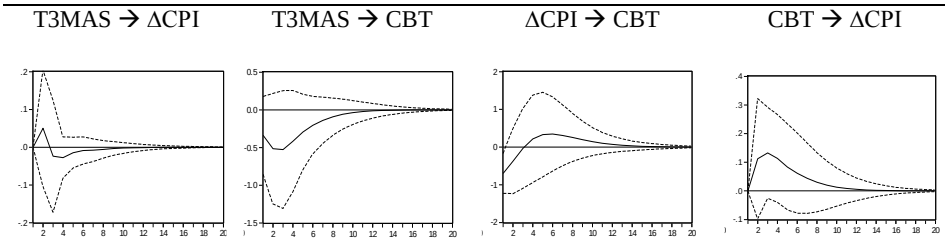
Figures 5a and 5b illustrate the impulse response functions related to systems 1 and 2 respectively: they show the response of target variables (PIBNPRSP and ΔCPI) to a shock on the short-term interest rate (T3MAS) [11].

Figure 5
Bank lending channel – impulse response functions

(a) System 1



(b) System 2



Source: Authors' estimations

Figure 5a shows that a restrictive monetary policy, i.e. a positive shock on the interest rate, translates into an economic decline from the second period that follows the shock. This effect reached its maximum during the fifth quarter after the shock, then it weakened gradually and it vanishes towards the tenth quarter that follows the shock. Indeed, we find that a positive shock on total bank lending affects the economy positively, although it has no contemporaneous impact on the economic activity. Also, bank credit reacts contemporaneously and negatively to the shock on T3MAS. Therefore, it is reasonable to find that, in the context of the bank lending channel, a positive shock on the short-term interest rate affects the economic activity negatively and with some delay.

Figure 5b illustrates the transmission mechanisms when inflation is the target of the SAMA. Indeed, a shock on the interest rate has no contemporaneous impact on inflation, but it increases inflation slightly during the first two quarters, before falling after the third quarter following the shock. This phenomenon, observed for the first time by Sims (1992), commonly known as the "price puzzle", and it may have several explanations. The traditional explanation is related to the econometric specification. In fact, given the limited number of observations that we have, we use parsimonious SVAR models, i.e. involving a reduced number of endogenous variables. Therefore, the probability of having failed variables that could have an effect on the dynamics of inflation is not zero (Sims, 1992). Another possible explanation for this is that, further to tighter monetary policy, domestic borrowers pass on the extra cost that the increase

of interest rates involves on the prices at which they offer their products. This impact is only temporary: the inflation decrease from the third quarter that follows the restrictive shock.

2. Interactions between Islamic and Conventional Banks

To make our vision clearer and more global, we have to examine the interactions that can occur between Islamic bank finance and conventional bank credit. To analyze these interactions and their role in the transmission of the monetary policy, we distinguish the credit granted by conventional banks (CBC) and financing provided by Islamic banks (CBI). Table 6 illustrates the structure of the systems 3 and 4 identified in the structural form $A_0 \cdot u_t = B \cdot \varepsilon_t$.

Table 6

Structure of the SVAR-X models to test interactions between Islamic and conventional banks as part of the bank lending channel

System 3: $u_t^{SVAR-X_3} = (u_t^{T_3MAS}, u_t^{CBC}, u_t^{CBI}, u_t^{PIBNPRSP})$

$$\begin{pmatrix} 1 & 0 & a_{14} \\ a_{21} & 1 & a_{24} \\ a_{31} & a_{32} & a_{34} \\ 0 & 0 & 1 \end{pmatrix} \times \begin{pmatrix} u_t^{T_3MAS} \\ u_t^{CBC} \\ u_t^{CBI} \\ u_t^{PIBNPRSP} \end{pmatrix} = \begin{pmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{pmatrix} \times \begin{pmatrix} \varepsilon_t^{T_3MAS} \\ \varepsilon_t^{CBC} \\ \varepsilon_t^{CBI} \\ \varepsilon_t^{PIBNPRSP} \end{pmatrix}$$

System 4: $u_t^{SVAR-X_4} = (u_t^{T_3MAS}, u_t^{CBC}, u_t^{CBI}, u_t^{\Delta CPI})$

$$\begin{pmatrix} 1 & 0 & 0 & a_{14} \\ a_{21} & 1 & 0 & a_{24} \\ a_{31} & a_{32} & 1 & a_{34} \\ 0 & 0 & 0 & 1 \end{pmatrix} \times \begin{pmatrix} u_t^{T_3MAS} \\ u_t^{CBC} \\ u_t^{CBI} \\ u_t^{\Delta CPI} \end{pmatrix} = \begin{pmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{pmatrix} \times \begin{pmatrix} \varepsilon_t^{T_3MAS} \\ \varepsilon_t^{CBC} \\ \varepsilon_t^{CBI} \\ \varepsilon_t^{\Delta CPI} \end{pmatrix}$$

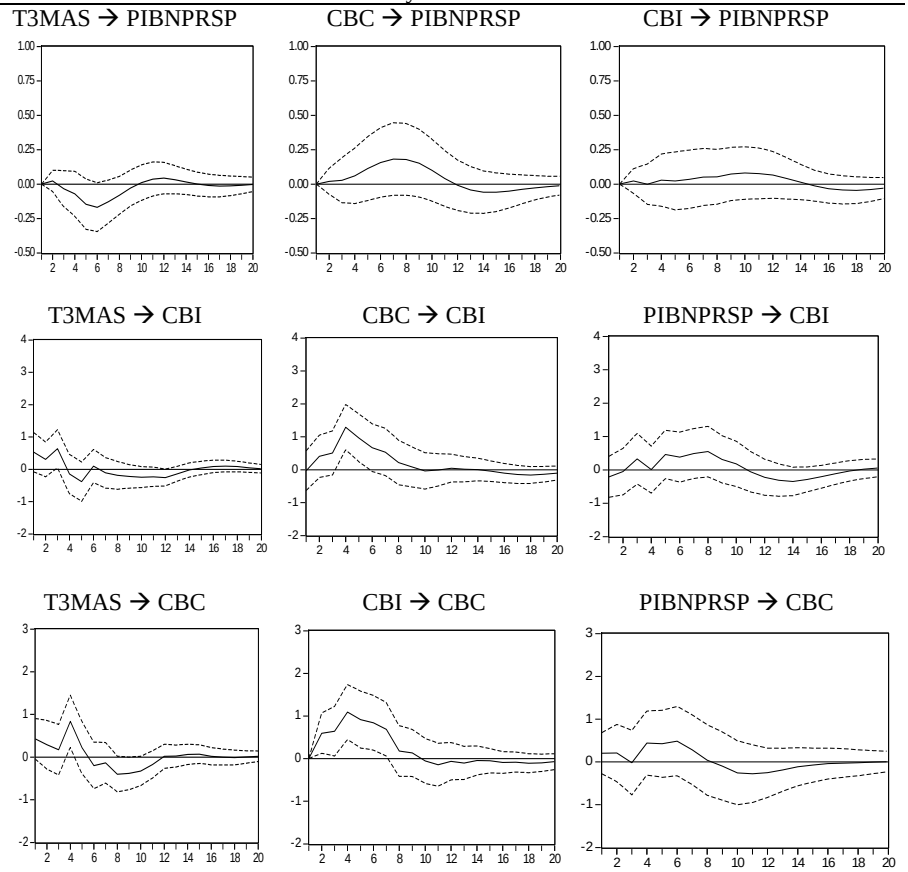
Note: « a_{ij} » is the instantaneous response of the variable « i » to a shock on the variable « j ».

Systems 3 and 4 have the same structure. We assume that the monetary policy responds instantaneously to the target variables (PIBNPRSP in system 3 and ΔCPI in system 4). We also assume that the monetary policy and its targets have contemporaneous impact on both the credit granted by conventional banks ($a_{21} \neq 0$; $a_{24} \neq 0$) and the financing provided by Islamic banks ($a_{31} \neq 0$; $a_{34} \neq 0$), and that the Islamic banks adopt the same behavior as conventional banks in terms of funding policy ($a_{32} \neq 0$).

Figures 6 and 7 illustrate the impulse response functions related to systems 3 and 4 respectively: they show, on one hand, the response of target variables (PIBNPRSP and ΔCPI) to a shock on the short-term interest rate (T3MAS) and on the transmission variables (CBC and CBI), and, on the other hand, the interactions between CBC and CBI in both systems.

Figure 6
Interaction between Islamic and conventional banks – impulse response functions

System 3



Source: Authors' estimations

As shown in Figure 6, a positive shock on T3MAS negatively affects the PIBNPRSP from the third quarter following the shock, and gradually weakened thereafter. Also, positive shock on the transmission variables (CBC and CBI) results in an improvement of the economic activity. However the impact of conventional bank credit on economic activity is more significant than the impact of Islamic bank financing. Symmetrically, a shock on the PIBNPRSP results in an increase in the conventional bank loans and Islamic bank financing.

We also find that conventional and Islamic banks react to each other in the same way. Indeed, an unexpected positive shock on CBC results in an increase in CBI, and vice versa. However, the reaction of the CBC to a shock on the CBI seems to be more significant than the reaction of the CBI to a shock on the CBC.

Figure 7
Interaction between Islamic and conventional banks – impulse response functions

System 4

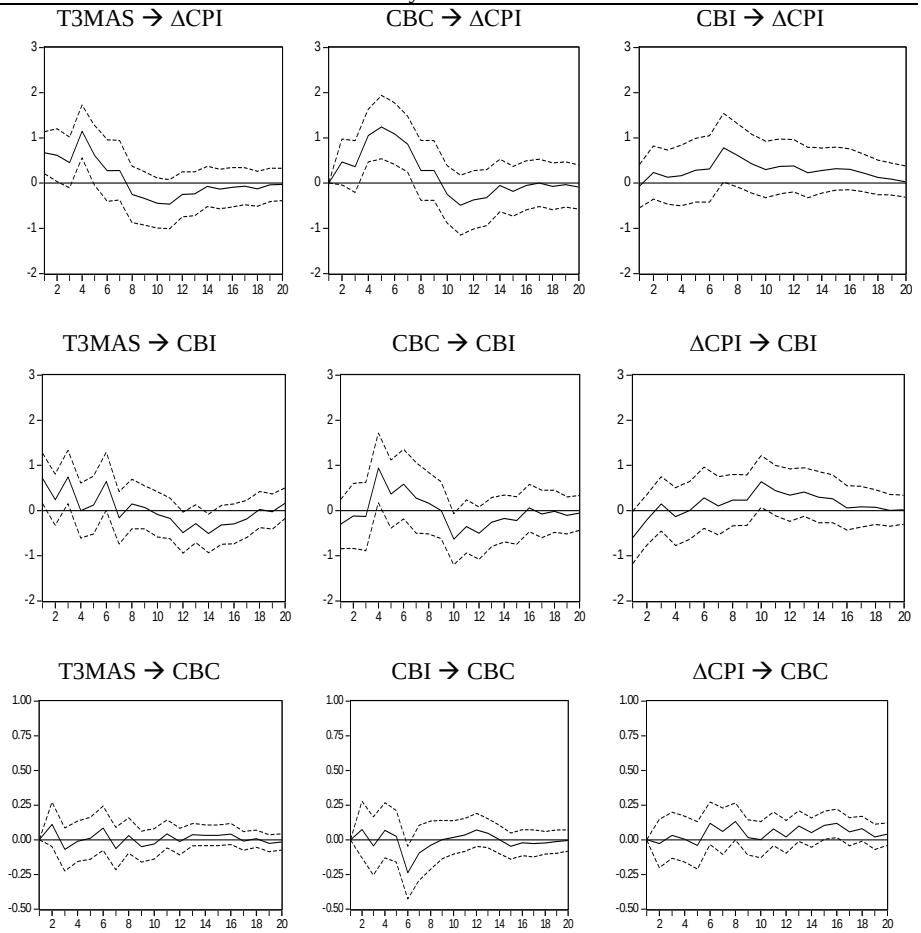


Figure 7 shows that a positive shock on CBC or CBI results in an increase in the inflation. But paradoxically, we find that inflation rises further to a tighter monetary policy. This may be due to the fact that we have used parsimonious models given the fact that we have a limited number of observations, as explained for system 2. Other effects are largely similar to the effects observed in the system 3.

VI. CONCLUSIONS

In this paper we have attempted to empirically investigate the monetary policy transmission channels in the presence of Islamic banks in Saudi Arabia over the period

1990Q4-2013Q3. To do so, we have used SVAR-X models. More precisely, we have built four SVAR-X models: the first two models analyze the (total) bank "lending" channel (i.e. Islamic and conventional), while the latter two models highlight the interactions that can occur between Islamic bank finance and conventional bank credit. The results indicate that bank lending channel is relatively effective in influencing non-oil private output, but less effective in influencing consumer prices. Indeed, a positive shock on bank financing extended by Islamic banks or on loans granted by conventional banks results in an improvement of the economic activity. However the impact of conventional bank credit on economic activity is more significant than the impact of Islamic bank financing. The results also show that conventional and Islamic banks react to each other in the same way, as an unexpected positive shock on CBC results in an increase in CBI, and *vice versa*. However, the reaction of the CBC to a shock on the CBI seems to be more significant than the reaction of the CBI to a shock on the CBC.

As Cevik and Teksoz (2012), Espinoza and Prasad (2012) and Ziaei (2012), we think that strengthening the financial intermediation and facilitating the development of domestic capital markets may improve the efficiency of the transmission mechanisms in this country.

ENDNOTES

1. The Saudi riyal was issued in June 1961, nine years after the establishment of the SAMA.
2. Since May 1977, foreign banks have been forced to sell 60 to 65% of their capital to Saudi institutional units. Under this decision, the Algemene Bank became Bank Al Saudi Al Hollandi, the British Bank of the Middle East became Saudi British Bank, the Banque de l'Indochine et de Suez became Banque Saudi Fransi, the Bank of Cairo became Saudi Cairo Bank, the National Bank of Pakistan became, after a complete nationalization, Bank Al Jazira, the First National Citibank became the Saudi American Bank.
3. In 2003, Saudi Arabia has adopted Anti Money Laundering / Combating the Financing of Terrorism measures.
4. One of the main objectives of banking regulation is to reduce the risk of default, contagion and systemic risk in the financial system, (Ramady, 2009: 236).
5. Obaidullah (2005) also have stressed the point of competition.
6. The demonstration is not submitted in this paper but can be provided by the authors upon request.
7. The increase in food prices pushed the government to introduce a subsidy on rice and baby milk (al-Jasser and Banafe, 2009:425).
8. Over the period 1982-2012, bank credit granted to the private sector to total bank credit ratio vary between 78 and 96%.
9. $[k^2(p+2)]-[k^2p+(k^2+k)/2]=2k^2-[k(k+1)/2]$. If one of the two matrices (A_0 and B) is an identity matrix, then k^2 restrictions will be automatically imposed. In this case, we should introduce $(2k^2-k^2)-[k(k+1)/2]=k(k-1)/2$ restrictions at least.

10. $I(A,B) = \text{cons tan t} + \frac{1}{2}\log\det(A)^2 - \frac{1}{2}\log\det(B)^2 - \frac{1}{2}\text{tr}(A'B'^{-1}B^{-1}A\Omega_u)$.
11. The amplitude of the shock is equal to one standard deviation.

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