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THE MACROECONOMICS OF THE GOLD ECONOMY IN SUDAN

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Abstract

After the secession of South Sudan and the resultant drop in oil exports, Sudan has enjoyed a surge in gold exports, dominated by vast networks of artisanal and small-scale informal mining operations. A combination of fiscally dominated monetary policy and stifling foreign exchange gap prompted the government to pursue a policy of large scale gold purchases by the Central Bank, almost all financed by printing money. We argued in this paper that such policy has resulted in a 'resource curse', manifested by short-term macroeconomic instability and medium-term loss of competitiveness. To substantiate the argument, the paper developed a simple game-theoretic rational expectations macroeconomic model, where the payoffs associated with the strategic behavior of individual gold's traders are used to define the Bank's problem. The results suggested that the Bank's monetary policy was largely influenced by the international gold price, the social tolerance for high inflation and the public sector borrowing requirements that rendered it ineffective for anchoring inflation expectations. Also, we found that higher international gold prices and the probability of successful gold's smuggling lead to higher domestic gold pricing by the Bank. Moreover, we showed that the Bank's gold dealership and the chosen mode of financing has caused short term inflationary spiral, excessive nominal exchange rate devaluation and medium to longer term real exchange rate appreciation. Therefore, we recommend that the gold dealership should be operated by a fiscal authority, rather than the Bank, and be part of a macroeconomic framework based on economic diversification and geared towards stabilization of the economy.

بعد انفصال جنوب السودان وما نتج عنه من انخفاض في صادرات النفط، شهد السودان طفرة في صادرات الذهب تهيمن عليها شبكات من حرفيين يقومون بعمليات تعدين وعمليات أخرى صغيرة وغير رسمية. وتحت وطأة فجوة مزدوجة وخانقة فى الموازنة المالية العامة والنقد الأجنبى، عمدت الحكومة إلى إنتهاج سياسة نقدية أسند بموجبها للبنك المركزى القيام بشراء الذهب على نطاق واسع وبتمويل يكاد يكون كله تقريبا عن طريق طبع النقود. ونبين نحن في هذه الورقة أن هذه السياسة قد أدت إلى تكريس "لعنة الموارد"، والتي تمثلت في عدم استقرار الاقتصاد الكلي في المدى القصير، وفقدان القدرة التنافسية في المدى المتوسط. لإثبات ذلك، أعدت الدراسة نموذجًا اقتصاديًا نظريًا مبسطًا يستند إلى فرضية عقلانية التوقعات، حيث يتم استخدام المكاسب المرتبطة بالسلوك الاستراتيجي الفردي لتجار الذهب لتحديد مشكلة البنك. وتشير النتائج إلى أن السياسة النقدية للبنك تأثرت إلى حد كبير بأسعار الذهب العالمية، وبمدى مرونة القبول المجتمعى للتضخم ومتطلبات اقتراض القطاع العام، الأمر الذى جعل هذه السياسة غير فعالة في كبح جماح توقعات تسارع التضخم من قبل الجمهور. كما وجدنا أن ارتفاع أسعار الذهب العالمية واحتمال نجاح تهريب الذهب يدفعا البنك إلى رفع السعر المحلى للذهب. وعلاوة على ذلك، أوضحنا بأن وكالة شراء الذهب من قبل البنك وطريقة التمويل المختارة قد تسببت في دوامة تضخمية على المدى القصير، وفى تخفيض كبير في سعر الصرف الاسمي، ومغالاة في سعر الصرف الحقيقي على المديين المتوسط و الطويل. وتأسيساً على هذه الشواهد، نوصي بأن يتم تشغيل وكالة شراء الذهب من قبل هيئة مالية تستخدم موارداً حقيقية، وليس البنك المركزي، على أن يكون ذلك جزءاً من إطار شامل للاقتصاد الكلى يستهدف تنويع الاقتصاد واستقراره.

1. Introduction

Gold export by the Republic of Sudan (hereafter referred to as Sudan) has recently become the major foreign exchange earner following the secession of the southern part of the country and the creation of the Republic of South Sudan in July 2011. With most of the oil fields located in the south, the new state took more than 75% of the oil production capacity of the former unified country. However, by 2012, just one year after the secession, Sudan became Africa's third largest gold producer after South Africa and Ghana and among the top 15 global gold miners. It is not surprising, therefore, that gold export has displaced oil export contributing 33% average in 2012-2017, (Figure 1). The new discoveries of gold and its entry, together with other minerals, as major sector in the economy came while industry and agriculture, the traditional mainstay of the economy, continue to suffer from an adverse structure of incentives associated with the Dutch disease effects of the oil era as reflected, among other things, by macroeconomic volatility and overvalued real exchange rate (Suliman, 2016).

The emerging prominence of gold and the mineral sector in general triggered lofty expectations by the government and the public alike that the new resource will likely more than compensate for the loss of oil. Though this remains to be proven, there appears to be preliminary evidence of substantial gold and other mineral deposits in several parts of the country. For example, the Ministry of Mining (2013); Yousif (2015) and Mohamed (2015) estimated the assured gold reserves in concession areas allocated to the working companies at 374.1 thousand tons with potential reserves up to 970 tons, including 200 million tons of mineralizable zinc and copper. Moreover, Sudan and Saudi Arabia have a longstanding agreement to jointly exploit the huge potentials of Atlantis II mining project, which are estimated at 150 tons of gold and over 1 million tons of copper. Also, iron ore deposits are estimated at 2000 billion tons with 45% purity. In addition to its immediate impact on the macro economy of the country, the gold resource has already impacted the life and economic activities of the Sudanese households.

However, so far most of the gold production is generated through informal prospecting. About two million people directly or indirectly engaged in gold extraction, with an estimated four million dependents directly benefiting from these activities, (Ministry of Mining, 2013 and Mohamed, 2015). These are mostly unskilled prospectors, largely drawn from farming communities and other informal sectors, using rudimentary technology and producing small finds. In 2012 the artisanal and small-scale informal gold mining contributed 90% of gold export. On the other hand, there exist about 370 medium and large scale formal companies, of which 102 are foreign, holding land concessions in 120 locations scattered in the 14 out of the 18 Sudanese states using modem technologies. However, gold production from the formal sector remains insignificant contributing less than 10% of total production. In addition, there were 50 formal firms providing diverse services to the mining industry (Yousif, 2015 and Mohamed, 2015). Therefore, despite the presence of these large mining companies, including some partially owned by the government, the gold economy in Sudan is dominated by large and diffused networks of informal prospectors, who, in turn, sell their finds to a small group of traders.

From a macroeconomic perspective, which is the main concern of this paper, the most notable feature of the gold economy in Sudan is that these traders are required to sell the gold to the Central Bank of Sudan, (henceforth the CBOS) which is the exclusive exporter of gold on behalf of the Government. The fact that the CBOS, not the Ministry of Finance and National Economy, is the government agent in this market suggests that domestic credit creation is likely to be the main source of financing the gold purchases, given the country's massive external and internal deficits and dwindling capacity of the government to raise new foreign and domestic debt. As Figure 2

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(A) shows, the trade balance has deteriorated from a surplus of 2% of GDP before the secession of South Sudan to a deficit averaging 8.1% of GDP in 2012-2017. Also, loan disbursements dropped by more than half to 0.5% of GDP average and the mean fiscal deficit is 4.3% of GDP, 2.6 percentage points higher than reported deficit, for the same period reflecting the excessive quasi-fiscal operations of the CBOS[1].

On view of the increasing reliance on gold exports as a source of foreign exchange the CBOS had to offer competitive domestic prices to discourage smuggling to neighboring countries. Moreover, the combination of fiscal dominance and limited options for debt finance forced the recourse to excessive money printing to finance the gold purchases. The proceeds of gold export are, then, used to finance the quasi-fiscal deficit. The IMF report (2017) showed that the CBOS's foreign exchange losses amounted to 2.9% of GDP annually in 2012-2017 due to purchasing gold at parallel exchange rate to cover fiscal transactions at overvalued official exchange rate. As a result, the massive devaluation of the official exchange rate by 67% between 2011 and 2017 has limited revaluation effect on the CBOS's assets because of the huge foreign exchange losses but raised the external debt stock-to-GDP ratio by more than 2.7 times, (Figures 2 A and B). Consequently, this policy has been the main cause of the twin crises of accelerating inflation and massive nominal currency devaluations in the parallel market for foreign exchange. Also, we argue that it has caused real exchange rate appreciation, leading to continued marginalization of agriculture and industry and even more dependency on the resource sector. The central thesis of this paper, therefore, is that the combination of increasing monetization of the fiscal deficit and purchases of gold through money printing by the CBOS have not only been the main source of short-term macroeconomic instability but has also undermined the competitiveness and diversification of exports in the medium to longer runs and worsened the external debt problem.

Moreover, and in the larger scheme of things, it is important to point out that, like oil, unless well managed, the newly found gold resource base that many thinks would be a 'precious boon' for the economy might, instead, turn into a 'precious bane'. Indeed, the development experiences of resources rich countries suggest that dependence on natural resources have been a curse rather than a blessing. However, the literature suggests that the resource curse is conditional on bad governance, but it operates through a combination of extreme economic volatility and real exchange rate overvaluation. The presence of the curse in several of these resource dependent countries is manifest in limited export diversification, smaller shares of manufacturing and ever-increasing dependence on natural resources. Growth in these countries has also been highly volatile, leading to post-boom growth collapses and long-term stagnation in some; and to episodic absolute decline of incomes in a few others (Elbadawi and Gelb, 2010). However, and notwithstanding the importance of these institutional issues, they are beyond the scope of this paper.

Focusing on the macroeconomic aspects of the gold economy and under the plausible assumption that the CBOS expects the public to have rational expectations, this paper analyzes the evolution of the CBOS's key policy instruments used for maximizing the proceeds from gold exports, while combating gold smuggling and ensuring economic stability. The analysis considered the macroeconomic consequences of the monetary financing of gold purchases in the almost completely fiscally dominated monetary policy that characterizes Sudan macroeconomic policy in the post-oil era. We also assessed the impact of the CBOS's policy pass-through on

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[1] The IMF report (2017) under Article IV found that the true fiscal deficit is 2.6 percentage points higher than the 1.7% of GDP average on-budget deficit in 2012-2017.

macroeconomic stability, most notably inflation and the rate of devaluation the nominal exchange rate, including on the competitiveness of the economy.

Section two describes the major features of the gold sector in Sudan: how it evolves; the price setting mechanism and the key actors in the sector. Section three develops a simple model describing the evolution of the CBOS's policy instruments given the major state and intermediate target macroeconomic variables. It also outlines the implications of the CBOS's chosen policies on macroeconomic stability, especially the dynamics of inflation, the nominal exchange rate devaluation as well the real exchange rate appreciation and macroeconomic competitiveness of the economy. Section four estimates some key regressions confirming the impact of the gold pricing and purchasing arrangements on the selected pivotal macroeconomic variables. Section five concludes and discusses some policy recommendations.

2. The Sudanese Gold Sector

Although, informal gold mining through traditional methods has a long history in Sudan, formal large-scale commercial gold production started more recently in early 1990s. Around the same time, the Geological Research Authority of the Sudan was created, within the Ministry of Energy and Mining, to lead and coordinate the exploration and development of mineral resources in the country. In 2010 a dedicated ministry of minerals was established and mandated with the overall guardianship of the minerals resources, including licensing and regulation of mining activities. Between 1991 and 2012, twelve formal gold mining companies operating in concession areas of about 100 thousand square kilometers entered production stage, including *Araib* Mining Company (AMC), the largest company operating in the sector. The AMC was established as a joint venture between the Government of Sudan and the French La Mancha Company, holding 60% and 40% of the shares, respectively. The combined concessions of AMC and *Manop* Company, (a Sudanese Moroccan joint venture), account for 74% of the formal gold production in 2012 (Osman, 2013; Yousif, 2015 and Mohamed, 2015).

The government holds equity ownership in all formal gold companies; however, its interest in these companies varies. Under the current arrangements, the companies pay gold rent in proportion to the government's equity share; in addition to 7% royalties and 30% business profit tax. These ratios are consistent with the international standards adopted in leading mining countries (Table 1). However, the fiscal benefits from the surge in gold export are small as indicated by the low contribution of income from the government equity ownership to the total revenues, which averaged 1.4% during 2008-2012. This low fiscal effort from the gold sector reflects the fact that, unlike oil, the share of the large scale formal companies in gold product and export is still small, at less than 10%; while most of the rent originates from the widely disbursed artisanal and small-scale informal gold miners, which is rather difficult to tax.

Between 2007 and early 2011 the CBOS offered 16% exchange premium to incentivize exporters. As a result, the share of gold export in total exports increased from 1% in 2007 up to 14% for 2011. However, the massive shocks precipitated by the secession of the South Sudan in 2011 and the ensuing collapse of the fiscal and export revenues forced the CBOS to rethink the exchange premium subsidy to exporters. Subsequently, the CBOS abolished the subsidy and engaged in large scale purchases of gold from the domestic markets, conducted through key agents appointed by the CBOS and payable in local currency. In 2012 gold became the major export contributing 53% of total exports, (see Figure 1). Therefore, the pressing need for alternative sources of foreign exchange earnings has contributed to the boom experienced by the informal gold production and trade. Although the size of the informal gold mining sector is difficult to determine with a high

degree of accuracy, the Ministry of Minerals reckons that employment in the informal gold sector almost quadrupled after the secession providing more than 2 million jobs (Ministry of Minerals 2013).

Informal gold mining is performed by individuals, mostly drawn from the same households or same localities. Following the results of initial prospecting and gold ore assaying, drilling and tunneling is performed in about 150 locations in 80 localities, where miners established regular camps. The sector is heterogeneous, however. There are two main methods for informal gold mining, a traditional one using manual ore crushing, panning, dredging and mercury amalgamation in separating gold; and a semi mechanized method with electronic detectors, hand operated drilling machines, stamp mills, and heap leaching plants usually set adjacent to the location of the mines. The purity of the extracted gold varies. Many artisans operate in-house refineries and laboratories for developing the purity of gold including gold dust refining (*shishna*). However, following the inauguration of Khartoum gold refinery in 2012, the in-house refineries and the small scale *shishna's* laboratories are banned. The ban is rationalized as an attempt to combat smuggling and cheating. Moreover, later in the same year, gold exports were banned.

The main actors in the onsite gold market are the miners, the jewelers' agents, the collectors and middlemen who are experienced in gold's assaying. The gold market price is competitive and based on Khartoum jewelers' market rate for 24 karat gold, which is set according to Dubai's bullion market. Thus, gold rate in Dubai is used to proxy the international price. The onside price often includes costs of marketing services. The purchased gold always has great potential for higher resale price; however, the exact premium depends on the cash needs of the prospectors for onsite logistics. The boom experienced by the informal gold mining has led to the establishment of formal supporting firms specializing in the provision of intermediate inputs including electronic metal detectors, hand-operated machines, stamp mills, trommel classifiers and chemicals. The emergence of a second tier of semi-mechanized informal miners aided with specialized inputs and services allowed the Ministry of Mining, in collaboration with local governments, to introduce licensing for the informal semi-mechanized mining as well as a gold sale tax of up to 5%.

The political economy dynamics and social interactions between the informal small-scale miners, indigenous people, the formal large-scale companies including the government are very complex and largely undocumented. In addition, though not sufficiently understood, there are also powerful labor market consequences of the informal gold sector. For example, whether the boom of the informal gold sector has sucked labor from agriculture and industry or created new jobs for the unemployed poor and the extent to which the gold rent is captured by other actors are all important public policy issues that are poorly understood. Moreover, the rise of the informal mining in Sudan could be part of greater move towards informality resulting from the marginalization of agriculture that started with the short-lived oil boom era:1996-2011. During this period, the share of the major agricultural export in total exports dropped from 48% in 1996 to 2% for 2010, (Figure 1). Despite the rebound after secession, the share of cotton, the tradition export, amounted to less than 1% average in 2011-2017. The cotton production and value chain completely collapsed as reflected by the closure of 36 textile factories and 4 spinning factories, (Konandreas, 2009).

The demise of the non-resource tradable sectors of the Sudanese economy was also manifested in the labor market, where labour shortages have been reported in some agrarian localities confirming the existence of a Dutch disease type effect. However, much worse, it was estimated that more than three thousand primary school students in two of the poorest regions of the countries (Darfur and Red See states) have joint the gold rush during the academic year 2012-13 either as child

labour or accompanying their families (e.g. Mohamed, 2015). Moreover, there is mounting evidence of the huge negative environmental footprints as well as the health hazards due to the excessive and uncontrolled application of mercury and explosives for prospecting and production of gold in the informal sector.

Despite the contribution of the informal gold production, it is rarely emphasized as strategic sector in the national plans, including the recently launched Interim Poverty Reduction Strategic paper, 2013. The informal gold mining activities are concentrated in remote localities and compete for the already insufficient services (water and health) therein. Also, the heterogeneity and remoteness of these activities raise the possibility of socio-political marginalization of the miners, could increase corruption in gold-ore rich localities and the likelihood for illegal mining. In part due to poor capacity to control the porous Sudanese borders, it has been reported that in some border localities foreigners from other countries have been illegally mining gold.

The degree to which the informal gold miners could leverage the political space to address the downside risks of the sector largely depends on the miners' motives, which are understandably diverse and complex in such a rush-type of mining booms, as the case of Sudan. Some miners have joined the sector to escape poverty or unemployment others have a business plan and work on permanent basis. The relationship between the miners, the formal companies, local people and the government is often competitive rather than complementary. The informal miners usually work in the companies' concession areas and in some cases bar them from accessing land as in block 24. Also, the violent inter-tribal clashes over gold mines in Jebel Amir's area of the war-ravaged region of Darfur have resulted in 100 deaths and 100000 internally displaced people (UNAMID, 2013). The annual yield of the area is estimated at about 8.6 tons (worth USD 422 million at Jebel Amir local gold prices). The insurgent groups earn at least UDS 54 million per year from levies imposed on prospectors and support businesses in addition to USD 24.6 million exports tax, (United Nations report, 2016).

It appears that despite the loss of most of the oil rents after the secession of the South Sudan in 2011, the 'rentier' mentality remains, as reflected in the public policy pursued regarding the sector. Although much of the gold rent accrues to the miners, the CBOS enjoys a *de jure* monopoly of gold dealership (refining and exporting). As we argue in this paper, financing gold purchases by the CBOS through the printing money, with apparently little regard to the consequences for agriculture and industry, attests to the view that such rentier mentality is alive and kicking on the part of the Sudanese authorities.

The following two sections will show that the mining boom triggered by the CBOS's large-scale gold purchases, almost all financed by printing money, has resulted in a 'resource curse', causing short-term inflationary spiral, excessive nominal exchange rate devaluation and medium to longer term real exchange rate appreciation.

3. The Model

As discussed in the introduction, aside from a few relatively large gold mining companies, most of the Sudanese gold is generated from small finds produced by dispersed networks of small-scale informal producers. In turn, a small number of traders collect the gold from these networks, which they either sell to the CBOS or smuggle abroad, since exporting gold to foreign markets is a monopoly of the Government of Sudan. The gold traders, therefore, have two options: sell the gold, G, to the CBOS for a unit price of P_G in domestic currency; or try to smuggle the gold and sell it abroad. In this case they will sell at the international gold price P_G^* provided that they manage to avoid being caught, which happens at a probability, p. The domestic value of the selling

price under smuggling is equal to $P_G^* E$, where E is the nominal parallel market exchange rate, given by the number of units of domestic currency per unit of foreign currency[2].However, in the event of being caught the smuggler's gold will be confiscated. Moreover, the traders could adopt a mixed strategy, where they could sell a fraction αG ($0 \le \alpha \le 1$) to the CBOS and smuggle the rest $(1-\alpha)G$.

We specify in Diagram 1 below the gold traders' pay-offs under the three scenarios (A) sell to the Central Bank (CB); (B) smuggle and sell abroad (SM); and (C) the mixed strategy of selling to the Central Bank and smuggling to sell abroad.

Diagram 1: Payoff Matrix

	Sell to the CB(A)	Smuggle to Sell Abroad (B)	Sell to the CB and smuggle to Sell Abroad (C)
Traders' Payoff	$p_G.G$	$p_G^*.E.G.(1-p)$	$\alpha p_G.G + (1-\alpha)p_G^*.E.G.(1-p)$

It can be easily shown that if $p_G \ge p_G^*.E.(1-p)$ the traders will pick strategy A over both of B and C.

Instead, if $p_G \le p_G^*.E.(1-p)$ they will prefer strategy B over both of A and C. Hence, for a risk neutral trader, the mixed strategy C will always be dominated by either A or B. The strategy of choice from the perspective of the traders will, therefore, be one of the latter two. In turn, this defines the CBOS's problem:

- The CBOS would choose the gold price to be offered for gold traders so as to minimize the distance between the payoffs for strategy A and B (Diagram 1).

- Given that most of the gold purchases (section 2) will likely be funded by domestic credit creation, the CBOS has to choose the rate of monetary growth that will not only guarantee a competitive price for the traders but also keep actual inflation close to the inflation rate expected by the public.

- Finally, the value of gold sales to the CBOS should be subject to the government budget constraint, given by the fraction of change in the stock of domestic credit, where we realistically assumed that no public debt financing of gold purchases is available to the authorities. This is the major reason for assigning the gold purchase dealership to the CBOS rather than to the Ministry of Finance and National Economy or any other public fiscal authority.

Taking the above choices facing the CBOS into account we posit the CBOS's optimization problem as follow:

(1) $Min \; \ell(p_G, g_M) = \left(p_G.G - p_G^*.E(1-p).G\right)^2 + \theta\left(M(\pi - \pi^*)\right)^2$
$+ \lambda\left(p_G.G - \phi \, g_M.M\right)$

Where g_M is the money supply growth rate; and θ is the degree of aversion to departure from the targeted deficit (or expected inflation rate by the public π^*), given the stock of money. The assumed one-period optimization model, admittedly, presumes myopic behavior on the part of the Sudanese Central Bank. However, this is not necessarily unrealistic on view of the crisis-like environment that characterizes economic policy making since the secession of the South Sudan and loss of more than 75% of the oil resources. Hence, the planning horizon is understandably short. However, we will show in the empirical section that, under unit root non-stationarity and co-integration, the underlying steady state solutions of equation (1) is consistent with a dynamic infinite horizon optimization problem.

The first term in the right-hand side of equation (1) minimizes the squared difference between the CBOS's value of gold purchases and the corresponding domestic value that could be earned by smuggling the same amount of gold abroad and selling it at the international prices (adjusted for the probability of successful gold's smuggling $(1-p)$. The second term minimizes the square distance between current and expected inflation, given the stock of money, M. Finally, the last term in the right-hand side of equation (1) states that the value of the gold purchases by the CBOS is equal to a fraction of the seniorage revenue: $\phi\, g_M.M$, where $\emptyset < 1$.

The link between targeted fiscal deficit and inflation can be derived from the government budget constraint, where seigniorage revenue must satisfy the below Cagan-type inflation function:

(2) $\pi = \frac{Gov - T}{M}$ [3]

Where, Gov stands for government expenditure (including interest payments on public debt) and T stands for tax and other sources of public revenues. This specification is motivated by the fiscal dominance model of Sargent and Wallace (1981), where, under fiscal dominance, fiscal deficit determines seignorage revenue (πM) in the long run[4].

And, financing the fiscal deficit is given by the following identity:

(3) $\Delta M = (Gov - T) - \Delta PubDebt = (Gov - T) - (\Delta L_{pub} + E.\,\Delta F_{pub})$

Where ΔL_{pub} is the change in the stock of domestic debt and ΔF_{pub} is the change in the stock of foreign debt net of official reserves (in foreign currency) and, E, here, stands for the free (parallel) market exchange rate[5]. Equations (2) and (3) allow writing the following expression for the rate of inflation:

(4) $\pi = \dfrac{\Delta M + \Delta L_{pub} + E.\Delta F_{pub}}{M} = g_M + \dfrac{\Delta L_{pub} + E.\Delta F_{pub}}{M}$

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[3] A more general formula is given by, where β is a positive parameter. To simplify the algebra, without loss of generality, we set this parameter to 1.

[4] However, in the short-run the relationship between the fiscal deficit and inflation cannot be predicted a priori on theoretical grounds, due to the feedback effects from inflation to the fiscal balance (Catao and Terrones, 2001).

[5] The parallel exchange rate is used to express foreign debt in domestic price. For simplicity we abstract from the valuation effect in the change of the stock of foreign debt ($\Delta E.F_{pub}$).

Using equations (2) to (4) in the simple optimization model of equation (1), the first-order conditions (FOCs) solution allows the derivation of the following expressions, respectively, for the money supply growth rate and CBOS's price of gold:

$$(5)\ \tilde{g}_M = \left(\frac{-\theta}{\varphi^2+\theta}\right)\left(\frac{\Delta L_{pub}+E.\Delta F_{pub}}{M}\right)+\left(\frac{\varphi}{\varphi^2+\theta}\right)\left(\frac{G}{M}\right)E.p_G^*(1-p)+\left(\frac{\theta}{\varphi^2+\theta}\right)\pi^*$$

$$(6)\ \tilde{p}_G = \left(\frac{-\theta\varphi}{\varphi^2+\theta}\right)\left(\frac{\Delta L_{pub}+E.\Delta F_{pub}}{G}\right)+\left(\frac{\varphi^2}{\varphi^2+\theta}\right)E.p_G^*(1-p)+\left(\frac{\varphi\theta}{\varphi^2+\theta}\right)\left(\frac{M}{G}\right)\pi^*$$

First, the above two equations suggest that the monetary policy is determined by the CBOS's gold price setting and that money supply growth is, among other factors, determined by the domestic currency value of the international gold price. In particular, the model predicts both policy variables to rise:

(i) The higher the domestic currency value of the international gold price $(E.p_G^*)$, which has experienced substantial growth due to the exogenous increase in the international prices as well as the precipitous weakening of the Sudanese pound in the free market.

(ii) The higher the probability of successful gold's smuggling $(1-p)$, due to the large and geographically disbursed network of miners and lack of state capacity to police gold smuggling, which is expected in view of the long and porous borders of the country.

(iii) The higher the rate of the expected inflation (π^*) that the society (or the authorities) are willing to tolerate.

Second, on the other hand, the two monetary policy instruments tend to decrease in response to rising public debt ratios $(\frac{\Delta L_{pub}+E.\Delta F_{pub}}{M})$, which suggests that:

(i) A higher ratio of debt inflows to stock of money reduces the need for monetary financing of the deficit by the CBOS; hence, leading to a lower optimum money supply growth rate.

(ii) The availability of domestic debt finance reduces the need for money creation to finance the domestic purchases of gold, while the availability of foreign debt reduces the foreign exchange-driven demand for gold; with both channels depressing the CBOS's gold price.

Third, while the rate of monetary growth is increasing in the stock of gold to money ratio $(\frac{G}{M})$, the CBOS's price of gold is decreasing in this ratio. Also, it follows that:

(i) The above ratio magnifies the aggregate effect of the domestic value of the international price of gold, adjusted for the probability of successful smuggling ($E.p_G^*(1-p)$), on the money supply growth rate.

(ii) Instead, the volume of gold to money supply ratio depresses the effect of inflation expectations (π^*) in the CBOS's gold price's equation.

Finally, the orders of magnitudes of the above effects are conditioned by the extent of aversion to inflation in the CBOS's loss function (θ) - i.e. the weight the CBOS's assign to the objective of

keeping actual inflation close to the inflation expectations of the public; and the share of the CBOS's money supply used for financing the purchases of gold (ϕ).

3.1 Implications of the CBOS's choices for inflation, nominal and real exchange rates

The policy of maximizing the foreign exchange proceeds of gold export assumes that the CBOS finances gold purchases almost exclusively by money creation. This assumption is justifiable because of the large fiscal deficit and the limited opportunity to raise new debt to finance the gold purchasing operations. Moreover, the low capacity for enforcing surrender of gold under low purchasing prices forces the authorities to offer a highly competitive price to contain the incentive for smuggling. These considerations have major effects on the monetary policy as shown by the model. In turn the ensuing monetary policy has implications for the macroeconomic outcomes; in particular, inflation and the exchange rate. To highlight the role of the gold purchasing and exporting policy on these two pivotal macroeconomic outcomes we derive expressions for domestic inflation and nominal exchange rate developments as functions of the ratio of the (optimum) value of gold purchases to stock of money $(\frac{\tilde{p}_G.G}{M})$.

From the budget constraint (third right-hand side term of equation 1) we have the following expression for the rate of growth of money supply:

$$(7) \quad \tilde{g}_M = \frac{1}{\phi}.\frac{\tilde{p}_G.G}{M}$$

Therefore, the money supply growth rate is proportional to the ratio of the (optimum) value of gold purchases to the stock of money, with the constant of proportionality being the reciprocal of the share of the change in domestic credit to total money supply used to finance the gold purchases by the CBOS. Now substituting for $\tilde{g}_M$ in equation (4) we have the below simple expression for the rate of inflation:

$$(8) \quad \tilde{\pi} = \frac{1}{\phi}.\frac{\tilde{p}_G.G}{M} + (\frac{L_{pub}}{M} g_L + \frac{E.F_{pub}}{M} g_F) = \frac{1}{\phi}.\frac{\tilde{p}_G.G}{M} + \sigma_1$$

Where g_L and g_F are, respectively, the rates of growth of domestic and foreign debt. And, the rate of inflation is equal to the rate of growth of money supply plus the weighted rates of growth of domestic and foreign debt (σ_1), which we assume to be very small.

To derive an expression for nominal exchange rate devaluation, we consider a basic version of the open economy money market equilibrium under currency substitution (Dornbusch, 1986 and Elbadawi, 1997):

$$(9) \quad \log \frac{M_t}{E_t.F_t} = -\eta_t \Delta \log E_{t+1}$$

Where $_t\Delta\log E_{t+1}$ is the one-step ahead forecast of the rate of change of the nominal exchange rate at time t+1, given information at time t. Now, by discrete differentiation, and dropping the time index, we have the following expression for nominal exchange rate devaluation $(\hat{E})$:

$$(10)\ \hat{E} = \frac{1}{1+\eta}(g_M - g_F) + \frac{\eta}{1+\eta}\hat{E}^e_{+1}$$

Where $\hat{E}^e_{+1}$ is the future expected rate of change of the nominal exchange rate; given current information. The above equation suggests that the extent of exchange rate devaluation increases with the excess of the rate of growth of domestic credit over the rate of growth of foreign debt as well as with the expected rate of devaluation. The latter effect is magnified by the extent of currency substitution in the economy (i.e. larger η), while the monetary growth effect is dampened by the substitution elasticity.

Now substituting for g_M from equation (7), we have the ultimate expression for nominal exchange rate devaluation:

$$(11)\ \hat{E} = \frac{1}{\varphi(1+\eta)}\cdot\frac{\tilde{p}_G.G}{M} + \frac{1}{1+\eta}\left(\eta\hat{E}^e_{+1} - g_F\right) = \frac{1}{\varphi(1+\eta)}\cdot\frac{\tilde{p}_G.G}{M} + \sigma_2$$

As for the case of inflation (equation 8), the above equation shows that the rate of nominal devaluation is proportional to the ratio of the value of gold purchases to the stock of money. However, the corresponding coefficient is smaller and is equal to the reciprocal of the product of the share of the change in domestic credit to total money supply used for financing the gold purchases and one plus the elasticity of the currency substitution. Therefore, as function of $(\frac{\tilde{p}_G.G}{M})$, the nominal devaluation curve, (equation 11) is flatter. The two curves intersect when $\tilde{\pi} = \hat{E}$, which defines an important threshold level for $\frac{\tilde{p}_G.G}{M}$:

$$(12)\ \frac{\overline{\tilde{p}_G.G}}{M} = \frac{\varphi(1+\eta)}{\eta}(\sigma_2 - \sigma_1) = \frac{\varphi(1+\eta)}{\eta}\left(\frac{(1+\eta)}{\eta}E^e_{+1} - \frac{L_{pub}}{M}.g_L - \frac{E.F_{pub}}{M}g_F - \frac{(1+\eta)}{\eta}g_F\right)$$

Therefore, the threshold of gold purchases- at which the rates of inflation and nominal devaluation are equalized- is increasing in the rate of expected future devaluation and decreasing in the sum of the weighted rate of growth of domestic and foreign debt.

The validity of the above expression requires that $\sigma_2 - \sigma_1 > 0$. This is likely to hold under the environment in question, with positive expectation of nominal devaluation and negative or near zero rates of growth in stocks of domestic debt or foreign assets. Under the assumption that $\sigma_2 - \sigma_1 > 0$. Figure (3) depicts the relationship between inflation and the rate of nominal devaluation. Noting that the inflation's curve will always be steeper than the rate of nominal

devaluation's curve, the figure suggests two important policy implications associated with the above threshold:

$$(13) \ if \ \frac{\tilde{p}_G.G}{M} < \frac{\overline{\tilde{p}_G.G}}{M}, \ \hat{E} > \tilde{\pi}$$

And,

$$(14) \ if \ \frac{\tilde{p}_G.G}{M} > \frac{\overline{\tilde{p}_G.G}}{M}, \ \hat{E} < \tilde{\pi}$$

Accordingly, when the ratio of gold purchases to money is higher than the threshold ratio, nominal deprecation of the currency is more than matched by higher inflation, which, in turn, would lead to real currency appreciation. This can be seen by noting that a simple concept of the non-gold tradable sector-oriented real exchange rate (RER$_{NG}$) can be represented by the following equation:

$$(15) \ RER_{NG} = \frac{E.p^*_{NG}}{p}$$

Where p^*_{NG} is the aggregate foreign price level of the non-gold tradable exports (e.g. agricultural and industrial exports) and p is the domestic price level. The rate of change of the RER can then be stated as follows:

$$(16) \ \hat{RER}_{NG} = \hat{E} + \hat{p}^*_{NG} - \tilde{\pi}$$

Thus, to the extent that the rate of change in the foreign price of non-gold price level can be assumed to be relatively small, the RER for the non-gold tradable sector will appreciate (i.e $\hat{RER}_{NG} < 0$) when the ratio of gold purchases exceeds the threshold (i.e when $\hat{E} < \tilde{\pi}$). In this case the macroeconomic policy associated with the gold resource would not only lead to macroeconomic instability (high inflationary pressures and continued nominal exchange rate devaluation) but it might also appreciate the real exchange rate, which will surely render the agricultural and industrial exports non-competitive in foreign markets. Previous results showed that Sudan's dependence on oil during 1999-2011 has been associated with real currency appreciation, high terms of trade volatility, low fiscal effort and resource misallocation, resulting, in turn, in low total factor productivity growth, (Suliman, 2016).

To recapitulate, this paper's model suggests that, due to the CBOS's policy of purchasing gold through money printing, the ratio of gold purchases to money has become a major determinant of inflation and the rate of nominal devaluation. Also, the model shows that the CBOS's gold purchasing and pricing policy influences the real side of the economy as well, through its appreciationary impact on the real exchange rate for the non-gold tradable sector, which impedes overall growth and economic diversification and further reinforces the dependency on gold and other extractive industries.

We turn next to assessing the empirical significance of the model's predictions.

4. Taking the Model to Data

The econometric analysis is based on the solution of an infinite horizon version of the optimization model of equation (1) which explicitly links the policy instruments (g_M, p_G) to the state and intermediate target macroeconomic variables, (M, P_G, E. p_G^*, L/M, E.F/M, G/M, $1-p$, π^*), denoted as vector y'_t. Therefore, the dynamic optimization of equation (17) below assumes that the CBOS chooses the domestic price of gold that maximizes the foreign exchange proceeds from gold purchases, while also choosing the rate of growth of money supply that accommodates this objective. The CBOS also takes into account the socially acceptable rate of inflation, given the stock of money supply and the exogenously determined state variables including the probability of successful gold's smuggling; the foreign price of gold and the parallel market exchange rate. Thus, CBOS objective is to choose a path for the policy instruments at the beginning of period t conditional on the information in the previous period, which leads to the following intertemporal loss function in period t:

$$(17) \quad \underset{\{p_{Gt}, g_{Mt}\}_{t=0,....,\infty}}{Min} \quad E_{t-1} \sum_{t=0}^{\infty} \delta^t \ell_{t+1}$$

Where, E is the expectations operator and δ is the discount factor. As in Binder and Pesaran (1997 and 1995) the solution to equation (1) as expressed in (17) in intertemporal setting, can be had in the following reduced form canonical multivariate rational expectations model;

$$(18) \quad Ay_t = By_{t-1} + CE(y_{t+1}|I_t) + \mu_t$$

Where, as defined above, y'_t is an $n \times 1$ vector of the two CBOS's policy instruments (the rate of money growth and the price of gold), the state and intermediate target macroeconomic variables, μ_t is an $n \times 1$ vector of 'unobservable' forcing variables assumed serially uncorrelated with zero means, and I_t is the information set available to the CBOS at time t, containing current and lagged values of y'_t, and μ. The coefficient matrices A, B and C depend on the medium-term structural parameters of the underlying optimization model, and E is the expectation operator.

Assuming the variables in vector y'_t are first difference stationary, equation 18 can be solved and represented by the following reduced form vector error-correction model (VECM); the coefficients of which can be estimated and used to identify the structural parameters, subject to some identifying restrictions (see Appendix A for a full derivation).

$$(19) \quad \Delta y_t = b_0 - \alpha_0 a_0 - \alpha_1 [\beta' y_{t-1} - a_1(t-1)] + \sum_{i=1}^{s-1} \gamma_i \Delta y_{t-1} + \mu_t, i = 1,2,.....,s-1$$

The numerical solution of the model can be carried out using the structural modelling approach explained in Pesaran and Pesaran (I996), Pesaran and Smith (1997), Pesaran and Shin (2002), and Pesaran et al (2000), which is based on a modified and generalized version of Johansen's (1991, 1995) maximum likelihood approach to estimation of VECMs.

This approach requires the variables in y'_t = (M, P_G, E. p_G^*, L/M, E.F/M, G/M, $1-p$, and π^*)'- expressed in logarithmic form- to be integrated of the same order (measurements of the y'-variables are provided in Appendix B). All variables are observable except the expected inflation

rate by the public (π^*), which is not; hence, it needs to be estimated using an appropriate procedure (see the Appendix A).

Appendix B Table B.1 contains the summary statistics of the basic variables used in the estimation of the model. Figures (4) to (7) display the variables of interest. As seen the logarithms of all variables are trending. In Figure (4) the logarithm of gold to money supply ratio is very volatile and swings upward around mid-2010 reflecting the rise of the gold economy. Similarly, Figure (5) reflects that the logarithms of the ratios of the domestic and foreign debt to money are unstable particularly during the first and second global credit crunch, respectively in 2007 and 2008. Also, foreign debt declined after the secession of South Sudan in June 2011 and further dropped since 2012 reflecting the tightening of the USA's economic sanctions. Moreover, though the ratio of the stock of domestic debt to money slightly increased during 2013, its average rate of growth essentially remained stationary during the last three years since the session of the South[6].

Figures (6) and (7) make clear that gold purchases account for the much of the monetary expansion particularly after the secession of South Sudan. All the series are not adjusted in order to preserve information; however, dummies are used in the estimation to account for these developments.

The standard augmented Dickey-Fuller unit root test (not reported) does not reject the null hypothesis of a unit root in all series in logarithmic levels but rejects the null of a unit root in first difference. Hence, we conclude that the series are first difference stationary. Moreover, the standard co-integration tests confirm the existence of two cointegrating vectors in the system of state and intermediate target macroeconomic variables in y_t' in line with the predictions of our model (see Appendix A. Table A.1). Therefore, subsequent analysis assumes that the cointegration rank is two in the system. The two cointegrating vectors can be interpreted as a steady state solution for the CBOS's optimization model. Table (2) shows the exactly identified estimates using the following restrictions: coefficients for LM and LP$_G$ are, respectively, set equal to 1 (0) and 0 (1) for the first (second) co-integration vector. The asymptotic standard errors are reported beneath the estimated coefficients.

The signs of coefficients derived from the solution of the optimization model are consistent with the short-run dynamics of equations (5) and (6). These coefficients can be viewed as long-run parameters of the equilibrium steady state relations; however, the statistical significance of the individual parameters varies, (Table 2 Part A). We use over identifications restrictions to test whether or not the CBOS's policy actions are consistent with equations (1), as expressed in (18). That is, each period, the Bank takes a plan of action $f(y_t')$ regarding its policy instruments independent of the expectational error μ_t and that these plans are time-invariant. As implied by (1) and (18) the CBOS chooses the values of the policy instruments that minimize the weighted sum of the economic shocks and fluctuations in y_t'. Thus, this test amounts to testing the co-trending hypothesis, that is, the trend coefficients are zero in the two steady-states; Table (2) presents the result.

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[6] The evolution of external and internal debt over the latter period together with the expectation of future devaluation seem to confirm the validity of the assumption that ($\sigma_2 - \sigma_1 > 0$), which underpins the construction of Figure 3.

The log-likelihood ratio statistic for imposing zero restrictions on the trend coefficients is 2(757.973-752.832) = 10.282, which is below the 0.05 bootstrapped critical value of the chi-squared distribution with 2 degrees of freedom; but significant at 10% level. Hence the co-trending hypothesis is rejected implying that the variables in y_t' are driven by nonlinear deterministic trends because the (common trends) driving these variables do not cancel out. This result implies that the CBOS's assessment of the significance of the stochastic signals of the variables in y_t' is subjective and time-varying.

The theoretical model predicts that the CBOS's gold price and money supply respond positively to the growth of the international gold price in domestic currency; the rise in the probability of successful gold's smuggling and the rise in expected inflation. The findings in Table 2 (Part A) significantly corroborate the model's predictions, except that the coefficient on expected inflation is correctly signed but is insignificant, which might perhaps be explained by a high tolerance to inflation on the part of monetary authorities and the public. The model also predicts that, higher ratios of domestic and foreign loans to money supply should reduce the rate of money supply growth and the CBOS's gold price. Moreover, a higher ratio of gold purchases to money supply would increase money growth and decrease the CBOS's gold price. The estimated parameters on this variable are correctly signed, but statistically significant only for the money supply cointegrating relation.

Before examining the short-run dynamics of the empirical model, we assess the robustness of the estimated long-run relationships. Following Pesaran and Shin (1996 and 1998) we examined the persistence profiles of the steady-state equilibrium relations in response to unknown system-wide shock, which provide information about the robustness of the estimated long-run relationships and about the speed of convergence to these equilibrium relations. If the long-run relationships are cointegrating then these profiles, which by construction take the value of unity on impact of the shock, should die over time. The authors also defined the generalized impulse response functions (GIRFs) for the VERM process to describe the responses of the equilibrium relationships to shocks in the model equations as well as the responses of the model variables to variable-specific shock. The effects of the former shocks are temporary and should die out over time. which provide information about the equilibrating dynamics embedded in the model, while the effects of the latter persist. The GIRFs are used here to illustrate the time profile of the CBOS's policy variables in response to shocks in the variable-specific error-correction equations (henceforth ECEs) which are of more interest. The effects of these shocks would provide testing for the predictions of equations (5) and (6) derived from the FOCs for the CBOS's optimization model.

Figure (8) pictures the persistence profiles of the two steady-state relations. As seen both profiles decline to their steady-states, with cointegrating relation of the CBOS's gold price declining faster. About 59% and 68% of the adjustments, respectively, for the CBOS's gold price and money, occur in the first four months, while full convergence takes about six months to complete. These patterns of convergence suggest that the model is reasonably specified. We also examined the effects of positive shocks (measured by one standard error) to the individual equations of the model on the steady-state values of the policy instruments. The results (not shown) indicate that the effects of these shocks die out as the policy instruments revert to steady-state equilibrium further confirming the robustness of the cointegrating relations suggested by theoretical model. However, the speed of adjustments to the equilibrium varies. In all the cases the impacts of the shocks are much stronger on the CBOS's gold price than on money supply.

Figures (9) to (14) depict the generalized impulse responses (GIRs) of the CBOS's policy instruments to positive shocks (measured by one standard error) in the variable-specific ECEs. Overall, the responses of the CBOS's policy instruments are in line with predictions of equations (5) and (6). Firstly, as Figure (9) shows, a one standard error increase in the international gold price in domestic currency raises the CBOS's gold price on-impact by 0.04 basis points, followed by further increase in the second month before it settles to long-run growth at 0.05 basis points above the baseline value. Money supply initially rises by 0.003 basis points in response to the shock and then accelerates in about two years to grow by 0.016 basis points above the base value. Secondly, the CBOS's gold price and money supply initially increase by about 0.007 basis points each following a unit shock to the probability of successful smuggling and in the long-run they grow by 0.04 and 0.02 basis points, respectively, (Figure 13). Thirdly, the CBOS's gold price rises on impact following a positive shock to expected inflation and remains persistent, while money supply swings between negative and positive values in the first three months before adjusting to higher steady-state growth in the fourth month, (Figure 14). Fourthly, a unit shock to, respectively, the ratios of domestic and foreign debt flows to money supply sets both policy instruments into lower steady-state growth-path, (Figures 10 and 11). Finally, as predicted, a shock to the gold to money ratio reduces the CBOS's gold price on impact before it converges to negative steady-state growth. Correspondingly, money supply initially rises in response to the shock, then it adjusts to higher positive steady-state growth in about two years, (Figure 12).

The patterns of responses to system-wide and variable-specific shocks showed that the empirical model is reasonably specified and confirmed the predictions implied by the FOCs of the CBOS's optimization problem. Overall, the setting of the CBOS's gold price and money supply rule are significantly determined by the domestic currency value of the international gold price; the probability of successful smuggling; the social tolerance for high inflation; and public sector borrowing requirements. The next section reviews the empirical model of CBOS's policy pass-through, which illustrates the consequences of the CBOS's gold-purchases maximizing behavior on the developments of inflation, the exchange rate and completeness.

4.1 The CBOS's policy pass-through to inflation, nominal and real exchange rates

The implications of the gold's export maximizing behavior of the CBOS on inflation (π) and the rate of nominal exchange rate devaluation $(\hat{E})$, highlighted by the CBOS's policy pass-through model (equations 8 and 11) can be assessed at their equilibrium values consistent with the steady state ratio of gold purchases to money $(\overline{\tilde{p}_G.G/M})$. Assuming that the set of variables $(\pi, E$ and $\tilde{p}_G.G/M)$, denoted as vector, x'_t are first difference stationary, their common movements in levels in the medium to long run that characterize the distribution of the different shocks, can be analyzed using a VECM similar to (19). As in the case of the CBOS's optimization model, the variables in vector x'_t are expected to be integrated of the same order.

As before, the standard augmented Dickey-Fuller unit root test (not reported) does not reject the null hypothesis of a unit root in all the variables in x'_t, but rejects the null of a unit root in first difference. Hence, we conclude that the series are first difference stationary. Moreover, the standard co-integration tests, with restricted intercept[7], confirm the existence of two cointegrating vectors, which are in line with the predictions of our CBOS's policy pass-through model, (Appendix A. Table A.2). Table 3 presents the results of the two co-integration vectors, where

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[7] The presence of the intercept is in accordance with theoretical model.

coefficients of LE and Lπ are, respectively, set equal to 1 (0) and 0 (1) for the first (second) co-integration vector.

The slope parameters are correctly signed and statistically significant and the slope of the inflation equation is steeper, which corroborates the model's prediction. Moreover, while the intercept of the exchange rate's equation is significant, we could not reject the hypothesis of a zero intercept for the inflation equation[8], again corroborating another key prediction of the model.

Figure (15) shows that the persistence profiles rapidly converge to steady-state equilibrium following a system-wide shock, with the nominal exchange rate adjusting faster than inflation before full convergence to equilibrium in about five months. Also, the profiles of the GIRs of the steady-state values of these variables to a positive shock in the gold purchases to money ratio, including to own shock, (not shown) converge to steady-state; but in all the cases the impacts of the shocks are much stronger on inflation.

The patterns of the GIRs of the exchange rate and inflation to a positive shock in the gold purchases to money ratio are displayed in Figure (16). As seen, the on-impact effect of the shock raises inflation by 0.055 and depreciate the value of the currency by 0.006 basis points. In the medium to long-run the effect of the shock increases inflation and exchange rate devaluation, by 0.05 and 0.02 basis points. This result is in accordance with the predictions of the CBOS's policy pass-through model; that a positive shock to the threshold ratio would cause the nominal devaluation of the currency to be more than matched by higher inflation, which, in turn, would lead to real currency appreciation.

Figure (17) depicts the ratio of gold purchases to money supply against the threshold level that equates the rate of nominal devaluation to inflation obtained from the estimation of the CBOS's policy pass-through model under just identifying restrictions as well as over identification restrictions in line with our two hypotheses noted earlier, (see section 3.1). As shown in Figure (3) therein, when gold purchases to money ratio is higher than this threshold, the inflation curve is steeper that of nominal devaluation; suggesting real exchange rate appreciation. On view of the fact that the actual gold purchases ratios overshoot the horizontal threshold ratio since 2011, as shown in Figure (17), the CBOS's gold pricing and financing policy appears to have led to an extended episodes of real exchange rate appreciation. This result suggests that the CBOS's gold dealership has not only caused short term macroeconomic instability but has serious negative consequences for the competitiveness of the economy in the medium-term.

5. Conclusions and Policy Implications
Gold export by Sudan has recently become the major foreign exchange earner following the secession of South Sudan in 2011 and the loss of about 75% share in the oil productive fields. We postulated a simple game-theoretic model where the CBOS maneuvers money supply and the gold purchase price to maximize the foreign exchange proceeds from gold dealership and combat gold smuggling, while minimizing economic fluctuations, given that agents form their expectations rationally. It is assumed that the CBOS needs to restrain domestic credit creation for financing gold's purchases and the budget deficit to avoid high inflation. We also considered the consequences of the chosen policy on inflation, the rate of nominal exchange rate devaluation and

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[8] The log-likelihood ratio statistic for imposing the zero restriction on the intercept of the inflation equation is 2(131.325-131.254) = 0.143, which is well below the 0.05 bootstrapped critical value of the chi-squared distribution with 1 degree of freedom, (Table 3). On the other hand, the joint zero intercepts restrictions could be rejected at less than 5% significance level.

overall competitiveness. The following conclusions and policy recommendations can be drawn from the analysis:

First, as briefly discussed in the introduction, the informal gold mining in Sudan boomed on the back of the large-scale gold purchases by the CBOS following the shortfall of oil revenues and foreign exchange earnings after the secession of South Sudan. In 2012 gold contributed 53% of exports and overtook the other exports including oil. Notwithstanding the potential contribution of the informal artisanal and small-scale gold mining (SSGM) to exports, job creation, poverty reduction and crowding in of formal large-scale gold miners, the activities of the informal miners are prone to the Dutch disease. Labour shortages and school children' leakages have been reported in some gold ore-rich agrarian localities. The political and economic linkages between the miners, the formal gold companies, local people and the government are often competitive rather than complementary. Additionally, the unwarranted consumption of mercury could significantly worsen the local environment. More important, the remoteness and diffused activities of the SSGM sector raise the possibility of corruption, illegal mining and smuggling. This conclusion suggests that, a multi-pronged approach is needed to deal with the legal, social, economic and environmental aspects of gold mining in Sudan including all vested interests in the venture. Especially the small-scale and large-scale miners; the federal, state and local authorities, and the indigenous people.

Second, the results of the estimation are consistent with the assumptions of our model. The findings showed that the CBOS's monetary policy is largely determined by the international gold price in domestic currency, the social tolerance for high inflation and the public sector borrowing requirements. Although the model assumes that smuggling entails punishment and gold's traders are risk averse, indeed factors contributing to the probability of successful smuggling, e.g., weak government institutions and oversight over the gold sector, corruption and a sustained dual exchange rate system would oblige the CBOS to raise the values of its policy instruments. In addition, the findings suggest that the CBOS's assessment of the significance of the stochastic signals of the main state and target variables in the economy is subjective and time-varying. Also, gold traders and the public correct their expectational errors very rapidly implying that the CBOS's ban on gold export including its gold pricing and the associated money supply setting are ineffective for the maximization of proceeds from gold exports.

Third, the analysis confirmed that the CBOS's direct dealership in gold has caused the real exchange rate to misalign. In this regard, it appears that a 'gold curse' impact has set in through a combination of high volatility of the international gold price in domestic currency, high inflation and the appreciationary effects of the real currency value, which in turn could limit export diversification and discourage manufacturing leading to ever increasing dependence on this resource. Hence, entrusting the gold's dealership with the Ministry of Finance and National Economy (MoFNE) would allow the Back to focus on its charted objectives: stabilization of the general price and par value of the Sudanese Pound. More importantly, the MoFNE should assign the management of gold, and for that matter oil, to an independent public institution with aim of isolating the economy from volatility in the prices of these resources. Such a measure would allow the MoFNE to focus more on tax-and-transfer programs geared towards poverty reduction, diversification and stabilization of the economy.

Finally, while the analysis focussed on the macroeconomic impacts of the CBOS's gold dealership, we believe that the public policy and development issues presented by the nascent gold sector in Sudan are much more than macroeconomic policy. Indeed, there are grave political economy

issues as well as health and environmental challenges that are crucial; but, are beyond the scope of this paper awaiting future research.

References

Binder, M. and Pesaran, M. H. 1995. Multivariate rational expectations models and macroeconomic modelling: a review and some new results, in M.H. Pesaran and M. Wickens [eds.], Hand-book of Applied Econometrics: Macroeconomics, pp. 139-187. Oxford: Basil Black-well).

Binder, M. and Pesaran, M. H. 1997. Multivariate linear rational expectations models. Characterization of the nature of the solutions and their fully recursive computation, Econometric Theory, vol. 13, 877-888.

Catao, Luis and Marco Terrones. 2001. Fiscal Deficits and Inflation: A New Look at the Emerging Market Evidence, IMF Working Paper No. WP/01/74. The International Monetary Fund, Washington DC 20433, USA.

Dornbusch, Rudiger. 1986. Special Exchange Rates for Capital Account Transactions, World Bank Economic Review, Vol. 1, no.1: pp. 1-33.

Elbadawi, Ibrahim and Alan Gelb. 2010. Oil, Economic Diversification and Development in the Arab World, Policy Research Report No. 35: The Economic Research Forum for the Arab World, Iran & Turkey, Cairo, Egypt.

Elbadawi, Ibrahim. 1997. The parallel Market Premium for Foreign Exchange and Macroeconomic Policy in Sudan, in Miguel Kiguel, Saul Lizondo and Stephen O'Connell (editors). Parallel Exchange Rates in Developing Countries. P: 221-246. St. Martin's Press, Inc., New York; and McMillan Press, Inc., London.

International Monetary Fund (IMF). 2017. Sudan: Article IV Consultations; Country report No. 17/364. IMF, Watsontown DC.

Konandreas, Panos. 2009. Assessing Sudan's Export Diversification Potential in Agricultural Products, European Commission and the Ministry of Foreign Trade, Government of Sudan, study undertaken on behalf of Maxwell Stamp PLC, London.

Ministry of Mining Report 2013. Ministry of Mineral, Khartoum Sudan.

Mohamed S. Ibrahim. 2015. Artisanal Mining in Sudan - Opportunities, Challenges and Impacts. United nations Conference on Trade and development presentation at the 17th Africa Oil, Gas and Mines Trade and Finance Conference and Exhibition, Khartoum, Sudan.

Norian, Majdi, A, Alzain,M. I., Margani, N. M and M. A. Al Bagir. 2012. The Economic Impacts of Gold Dealership in Sudan, Research and Studies Series No 20, Central Bank of Sudan, (in Arabic).

Osman M. S M. 2013. The contribution of Minerals to the GDP in Sudan, Ministry of Mining Working papers on the Role of Mining Sector in the GDP, Khartoum Sudan, (in Arabic).

Pesaran, M. H. 1987. The Limits to Rational Expectations", Oxford: Basil Blackwell (reprinted with corrections, I 989).

Pesaran, M.H. and Y. Shin. 1996. Cointegration and Speed of Convergence to Equilibrium, Journal of Econometrics, 71, 117-143.

Pesaran, M. H. and Y. Shin. 1998. Generalized Impulse Response Analysis in Linear Multivariate Models, Economics Letters, vol. 58, pp. 17-29.

Pesaran, M. H. and Y. Shin. 2002. Long-run Structural Modeling, Econometric Reviews, vol. 21.

Pesaran, M. H. and R. J. Smith. 1998. Structural Analysis of Cointegrating VARs, Journal of Economic Surveys, vol. 12, pp. 471-506.

Pesaran, M.H., Shin, Y., and R. J. Smith. 2000. Structural Analysis of Vector Error Correction Models with Exogenous I(1) Variables,*Journal of Econometrics*, 97:293-343.

Pesaran, B., and M.H. Pesaran, 2009. Time series Econometrics using Microfit 5.0 A User's Manual:, Oxford University Press, Oxford.

Peseran, M.H. 1990. An Economic Analysis of Exploration and Extraction of Oil on the UK Continental Shelf'. Oxford Institute for Energy Studies. EE7.

Pesaran, M.H. and R.P. Smith. 1997. New Directions in Applied Dynamic Macroeconomic

Modelling, in R. Dahel and I. Sirageld (eds.) Models for Economic Policy Evaluation:

Theory and Practice, JAI Press Inc, Greenwich.

Sargent, Thomas and Neil Wallace. 1981. Some Unpleasant Monetarist Arithmetic, Federal Reserve Bank of Minneapolis Quarterly Review, Fall.

Suliman, K. M. 2016. Understanding and Avoiding the Oil Curse in Sudan. In I. Elbadawi and H. Selim (Authors), Understanding and Avoiding the Oil Curse in Resource-rich Arab Economies (pp. 421-460). Cambridge: Cambridge University Press.

United Nations. 2016. Final report of the Panel of Experts on the Sudan established pursuant to resolution 1591 (2005) (S/2017/22). http://www.un.org/ga/search/view_doc.asp?symbol=S/2016/805&referer=/english/&Lang=E

United Nations African Union Mission in Darfur, (UNAMID). 2013. UNAMID's publication for the people of Darfur, Voices of Darfur, Vol. 4. No. 3, UNAMID. https://issuu.com/vodarfur/docs/vod_may_2013_-_lores.

Yousif Elsamani. 2015. Minerals potentials and resources in Sudan: United nations Conference on Trade and development presentation at the 17th Africa Oil, Gas and Mines Trade and Finance Conference and Exhibition, Khartoum, Sudan.

Table 1: Comparison of Sudan's Gold Mining Fiscal Regime with Other Countries (In percent)

Country	Royalty Rate	Orate Income Tax	State Equity	
Australia	2.5	29	None	
Ghana	5	35		10
Indonesia	3.75	25	None	
Mongolia	5 (plus price based progressive royalty)	25	Up to 34	
South Africa	7	Variable rate	None	
Sudan	7	30	Varies	
Tanzania	4	30		5

Source: IMF's Sudan: 2013 Article IV IMF country report No. 13/317, p.11.

Table 2: The Identified Steady State Relations for the Variables in the CBOS's Optimization Model

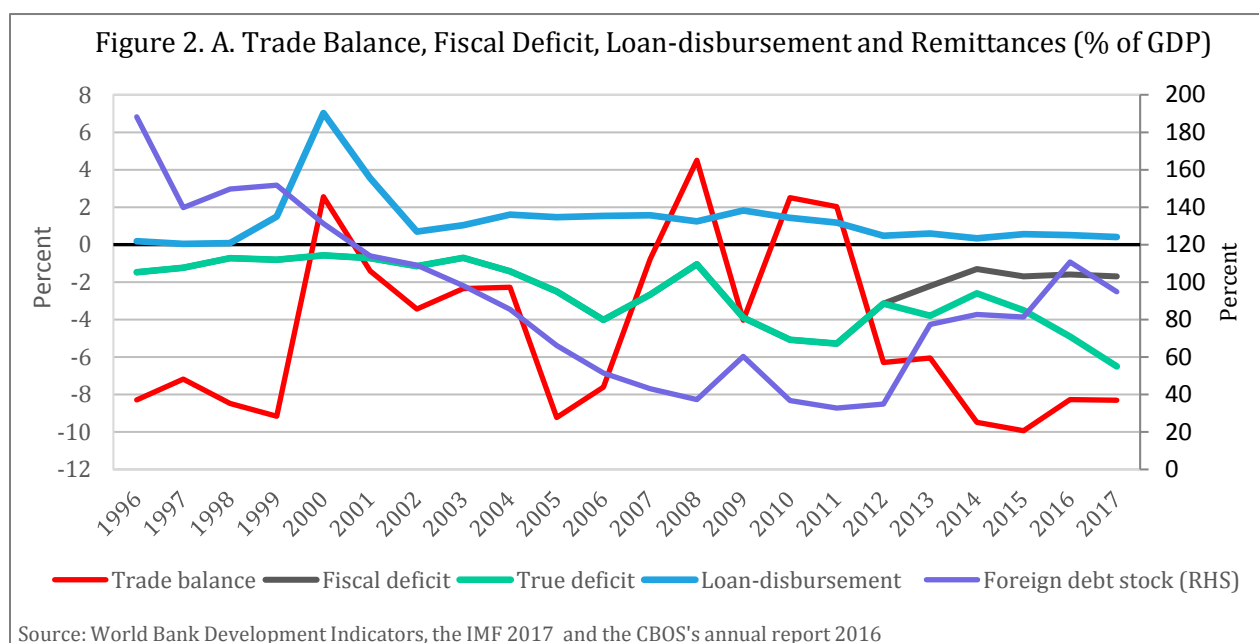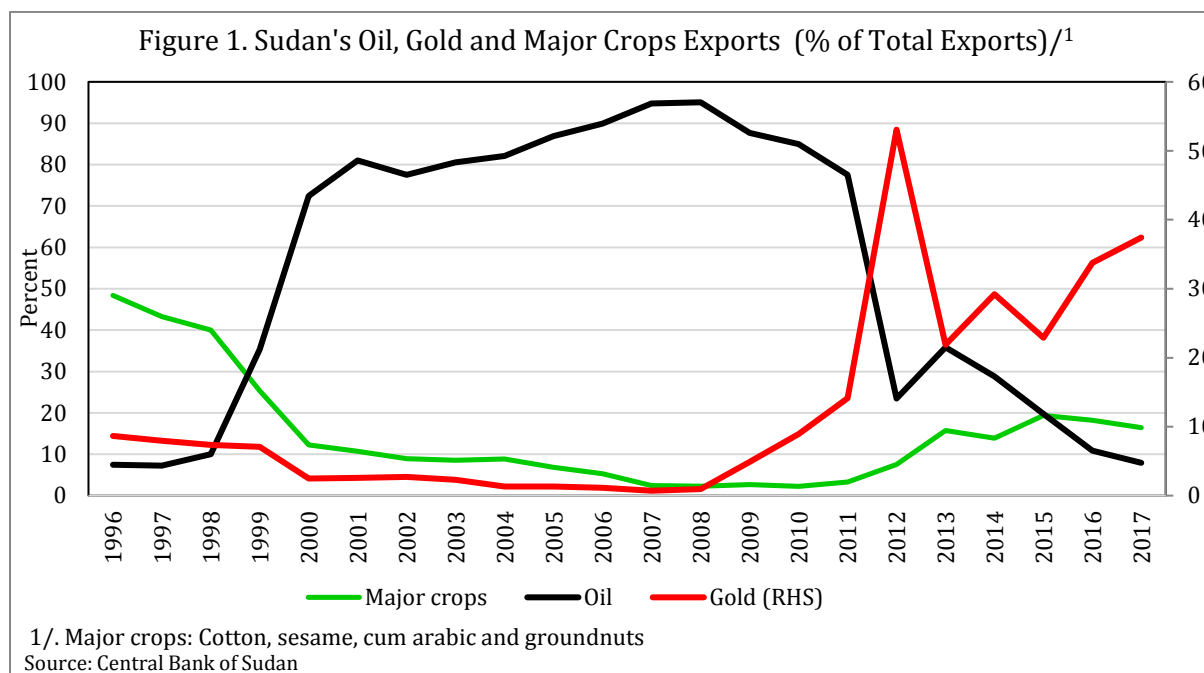| Panel A: co-integrated vector with time trend/[1 to 10]								
Dep. variables		Explanatory variables						
LM	Lp_G	LE. p_G*	LL/M	LE.F/M	LG/M	$L(1-p)$	$L(\pi^*)$	Trend
1	0	-0.214 (0.077)	0.009 (0.008)	0.004 (0.012)	-0.017 (0.006)	-0.588 (0.184)	-0.006 (0.040)	-0.009 (0.002)
0	1	-0.510 (0.204)	0.027 (0.020)	0.013 (0.028)	0.014 (0.014)	-2.144 (0.490)	-0.098 (0.097)	-0.002 (0.004)
The value of the maximized log-likelihood: 757.973								
Panel B: co-integrated vector without time trend								
Dep. variables		Explanatory variables						
LM	Lp_G	LE. p_G*	LL/M	LE.F/M	LG/M	$L(1-p)$	$L\pi^*$	Trend
1	0	-0.208 (0.072)	0.009 (0.008)	0.004 (0.012)	-0.017 (0.006)	-0.598 (0.176)	0.004 (0.041)	-0.009 (0.001)
0	1	-0.594 (0.093)	0.029 (0.019)	0.012 (0.027)	0.013 (0.014)	-1.990 (0.348)	-0.119 (0.086)	0
The value of the log-likelihood: 757.811								

Notes:

1. All estimates use Microfit 5.5 (see Pesaran and Pesaran 2009) with monthly Sudanese macroeconomic data over 2007M1- 2013M6.

2. LM denotes the log of money supply.

3. Lp_G is the log of the domestic price of gold set by the CBOS.

4 LE. p_G* is the log of the domestic value of the international market price of gold in US dollar multiplied by the parallel market exchange rate in Sudanese pound per dollar.

5 LL/M is the log of the ratio of the stock of domestic loans to money supply.

6. LE. F/M is the log of the domestic value of the stock of foreign debt to the money supply.

7. LG/M is the log of gold purchase to the money supply.

8. $L(1-p)$ is the log of one minus the probability of successful gold's smuggling.

9. $L\pi^*$ is the log of expected inflation rate by the public.
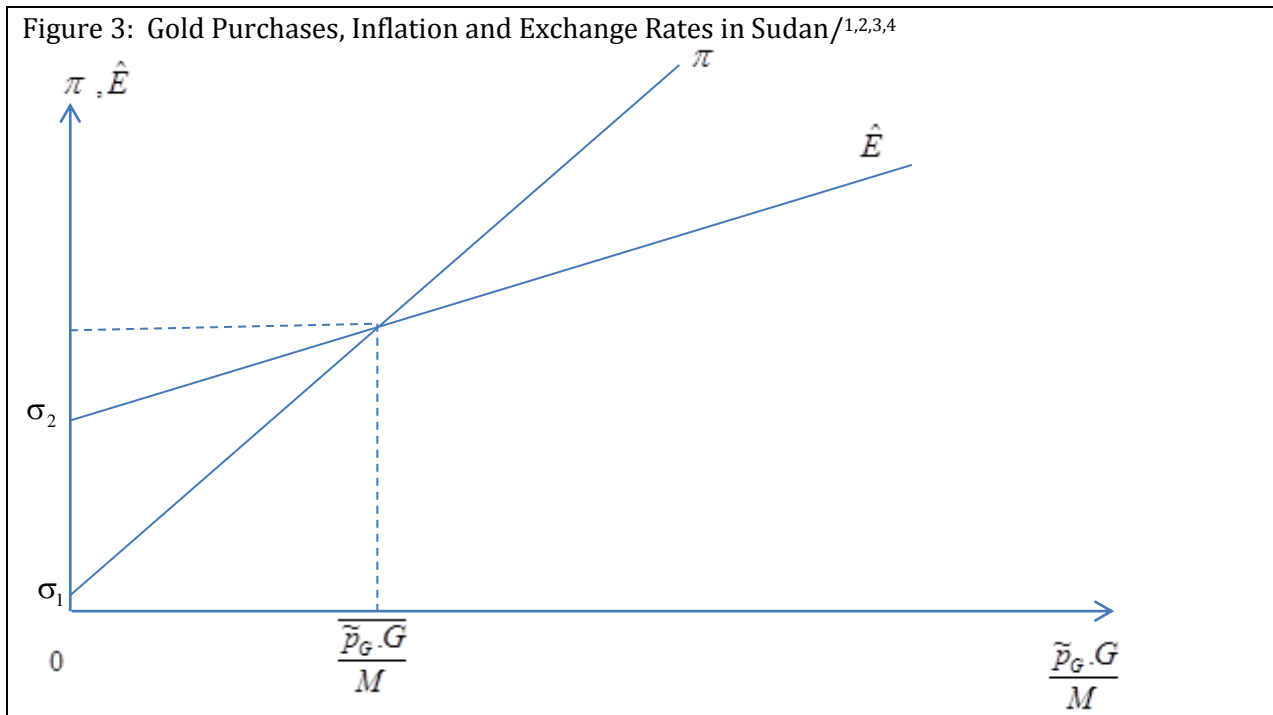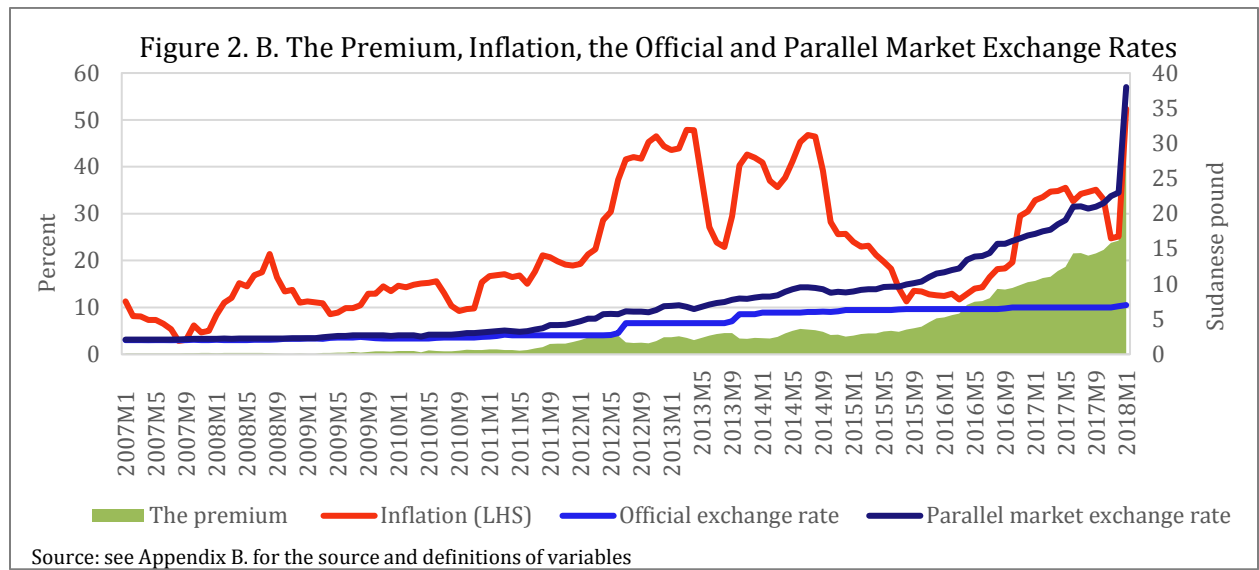
10. Trend is a time trend.

Table 3. The Results of Estimation of the CBOS's Threshold ratio of Gold Purchases/[1,2,3]

Model A				Model B			
LE	$L\pi$	LG/M	Intercept	LE	$L\pi$	LG/M	Intercept
1	0	-0.765 (0.318)	-2.899 (1.586)	1	0	-0.741 (0.286)	-2.547 (1.192)
0	1	-1.486 (0.700)	-1.330 (3.524)	0	1	-1.422 (0.657)	0
The value of the maximized log-likelihood: 131.325				The value of the maximized log-likelihood: 131.254			

Notes:

1. LE is the log of parallel market nominal exchange rate (measured in Sudanese pounds per US dollar).

2. $L\pi$ is the log domestic of inflation (measured in percentage rate).

3. LG/M is the log of the ratio of gold purchase to the stock of money supply.

Figure 1. Sudan's Oil, Gold and Major Crops Exports (% of Total Exports)/1

1/. Major crops: Cotton, sesame, cum arabic and groundnuts
Source: Central Bank of Sudan

Figure 2. A. Trade Balance, Fiscal Deficit, Loan-disbursement and Remittances (% of GDP)

Source: World Bank Development Indicators, the IMF 2017 and the CBOS's annual report 2016

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Figure 2. B. The Premium, Inflation, the Official and Parallel Market Exchange Rates

Source: see Appendix B. for the source and definitions of variables

Figure 3: Gold Purchases, Inflation and Exchange Rates in Sudan/[1,2,3,4]

Notes: 1/. π is the rate of domestic inflation.

2/. $\hat{E}$ is the rate of nominal exchange rate's devaluation.

3/. $\dfrac{\widetilde{p}_G.G}{M}$ is the ratio of the value of gold purchases to the stock of money supply.

4/. $\dfrac{\overline{\widetilde{p}_G.G}}{M}$ is the threshold of the ratio of the value of gold purchases to the stock of money supply, such that $\pi = \hat{E}$.

5/. $\sigma's$ are the intercepts of the $\hat{E}$ and π curves (see equation 11).

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Figure 4. Logarithms of Gold Market and CBOS's Prices per gram, the Gold to Money ratio and the Probability of Sucessful Gold's Smuggling
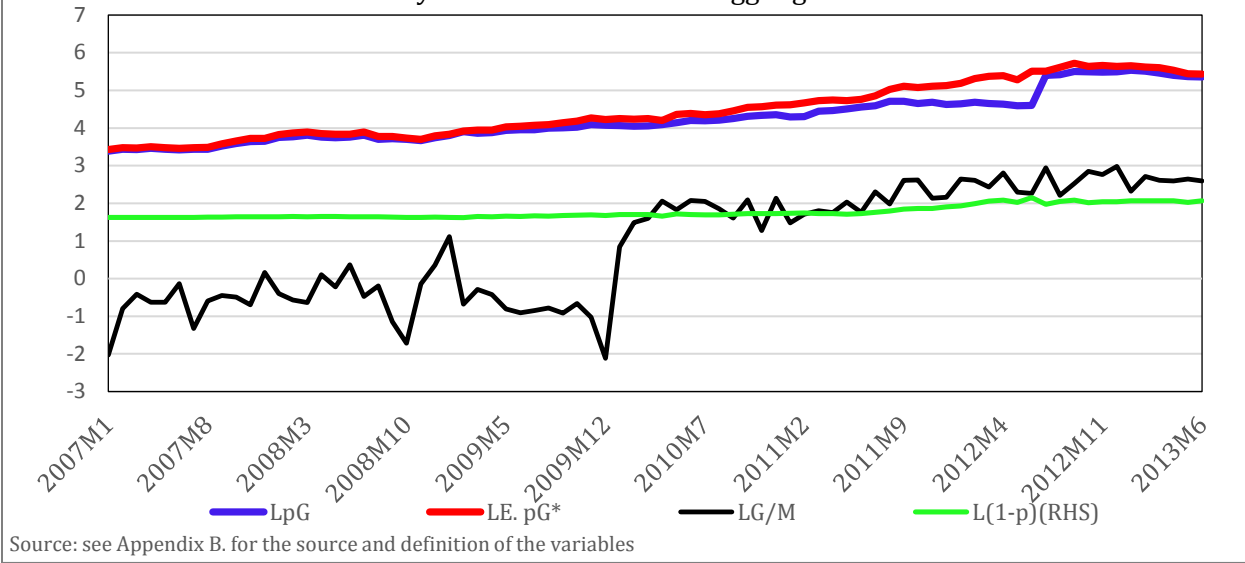
Source: see Appendix B. for the source and definition of the variables

Figure 5. Logarithms of the Ratios Domestic and Foreign Debt to Money

Source: see Appendix B. for the source and measurements of the variables
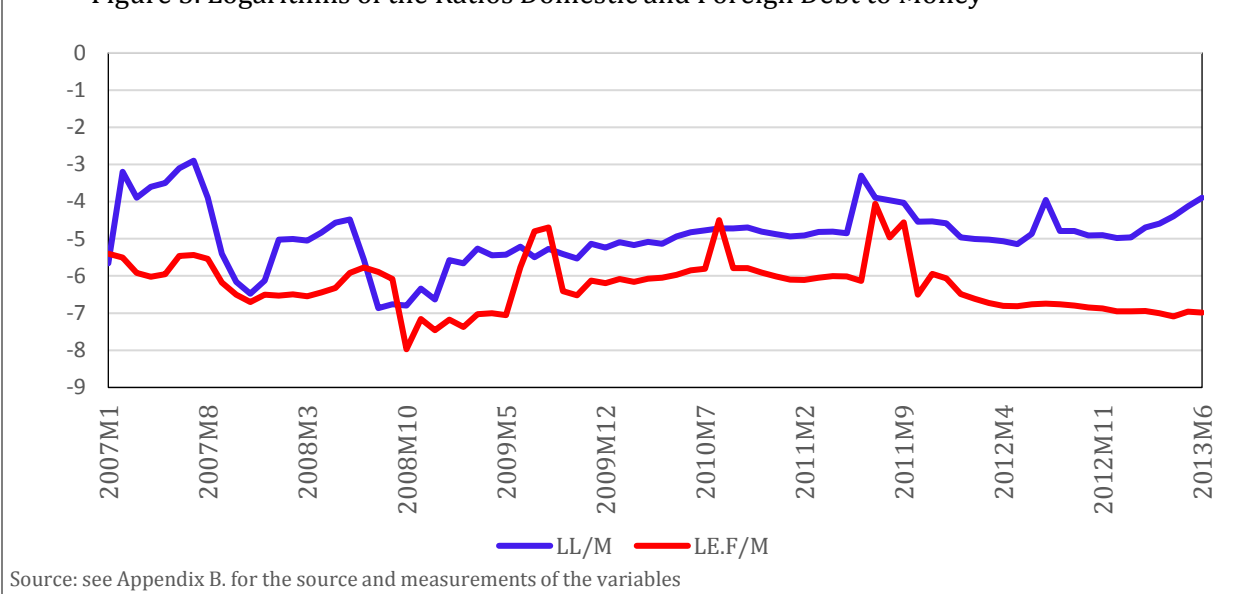
Figure 6. Logarithms of Actual and Expected Inflation, the Exchange Rate and Money Supply
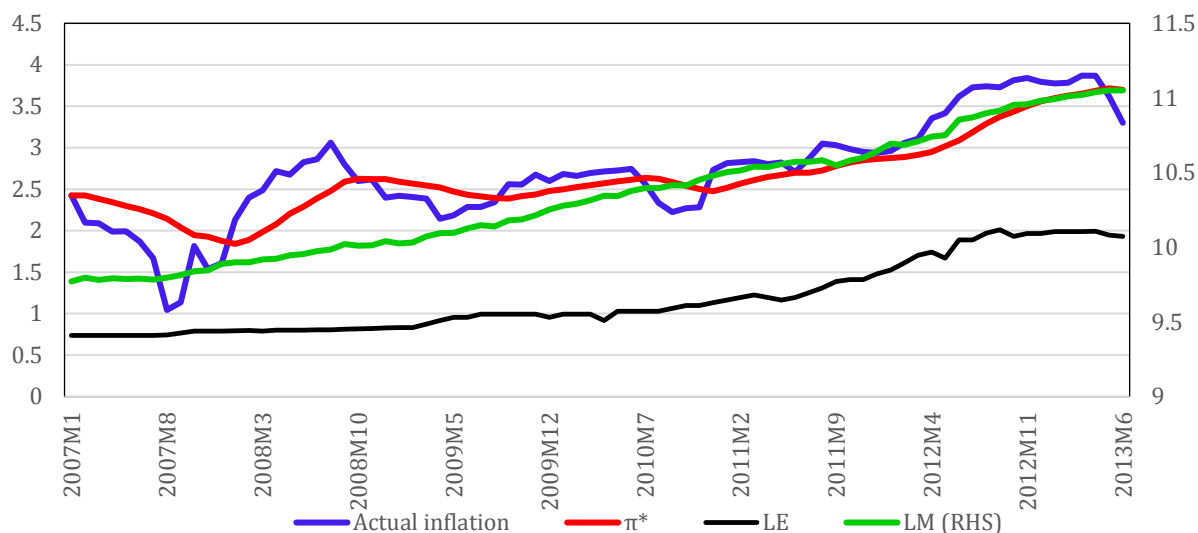
See Appendix B. for the source and measurements of the variables

Figure 7.Monthly Money Supply Growth and the Value of Gold Purchases
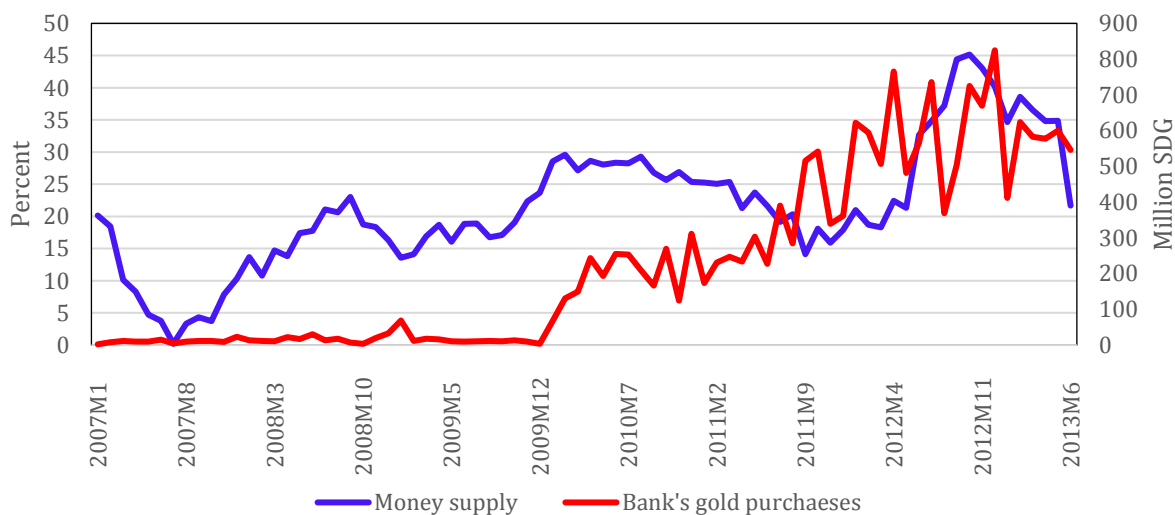
Source: ses Appendix B. for the source and measurements of the variables

Figure 8. Persistence Profile of the Effects of System-wide Shock the Steady State Relations of the Policy Instruments in the CBOS's Optimization Model
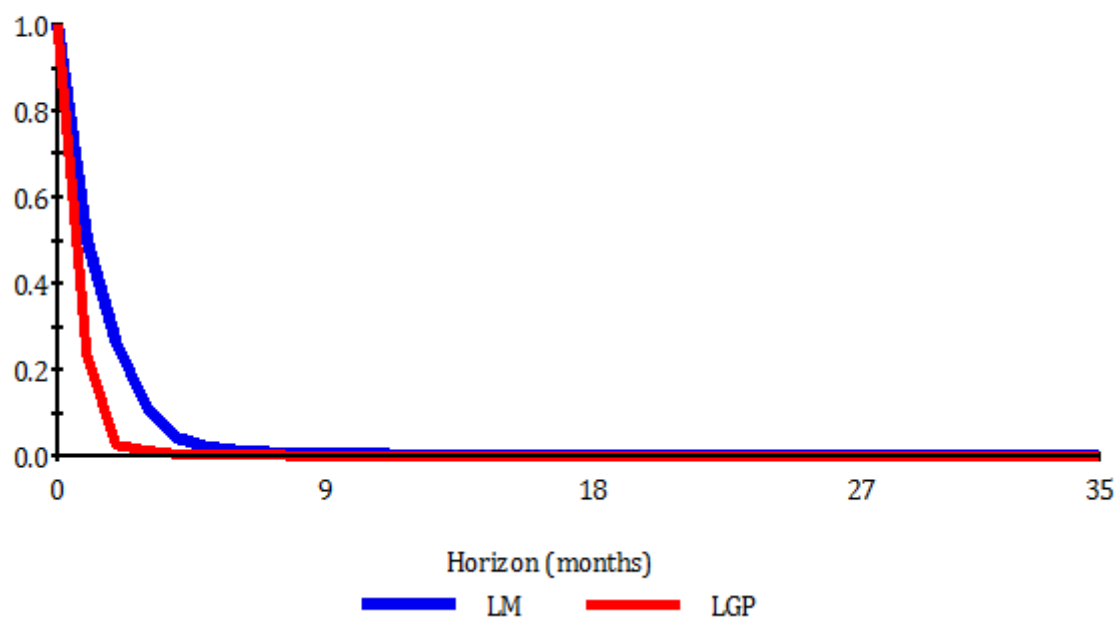
Horizon (months)

LM   LGP

Figure 9. GIRs of the CBOS's Policy Instruments to One S.E. Shock in the International Gold Price in Domestic Currency's ECE

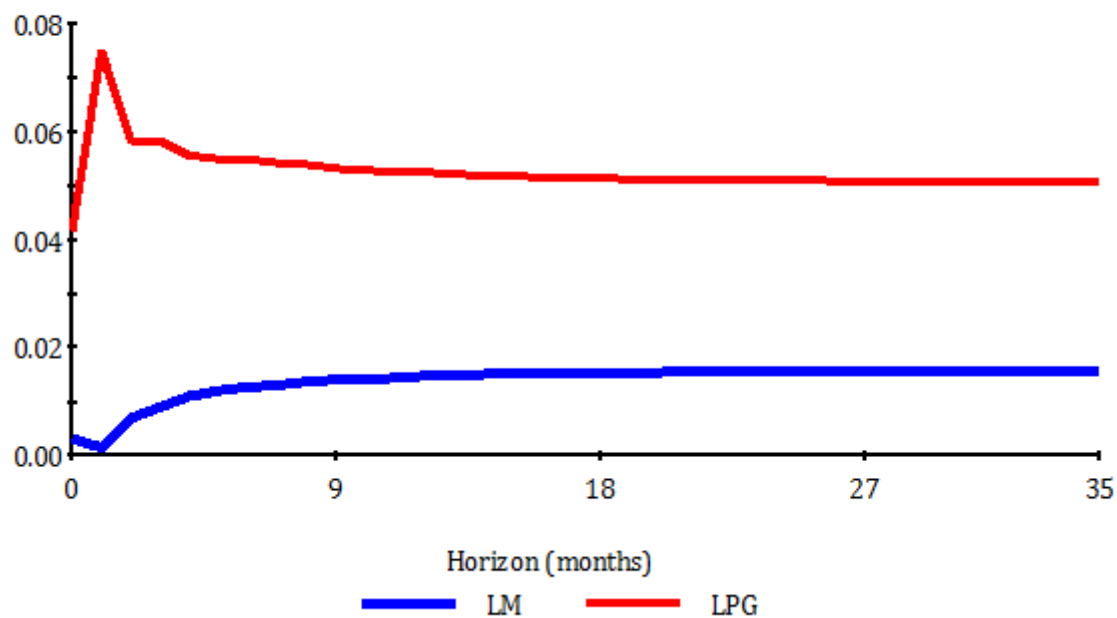Horizon (months)

LM   LPG

Figure 10. GIRs of the CBOS's Policy Instruments to One S.E. Shock in the Domestic Debt to Money Ratio's ECE
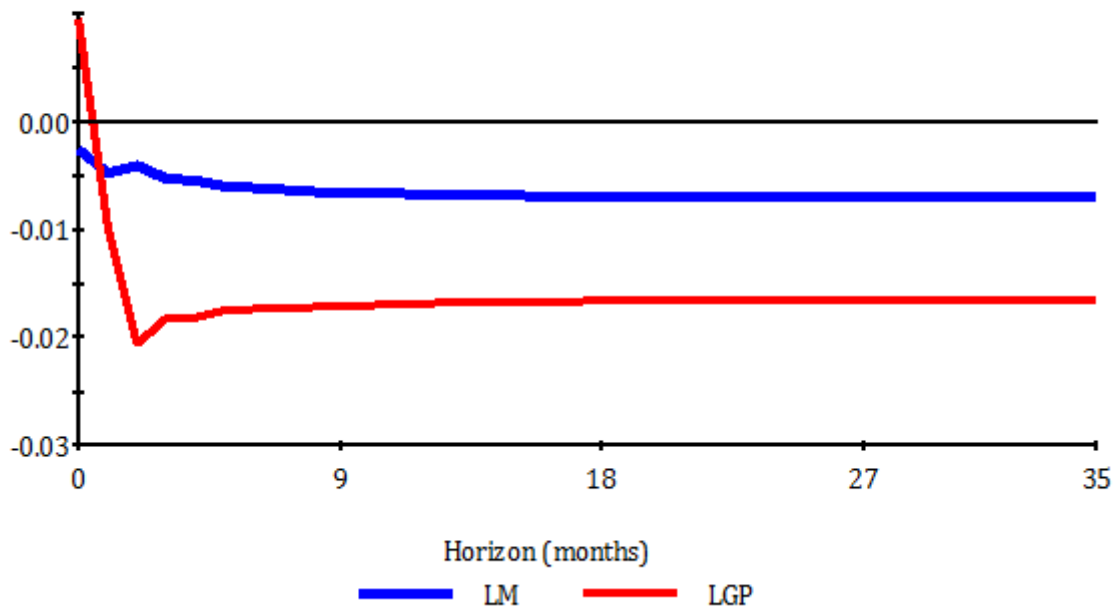

Figure 11. GIRs of the CBOS's Policy Instruments to One S.E. Shock in the Foreign Debt to Money Ratio's ECE
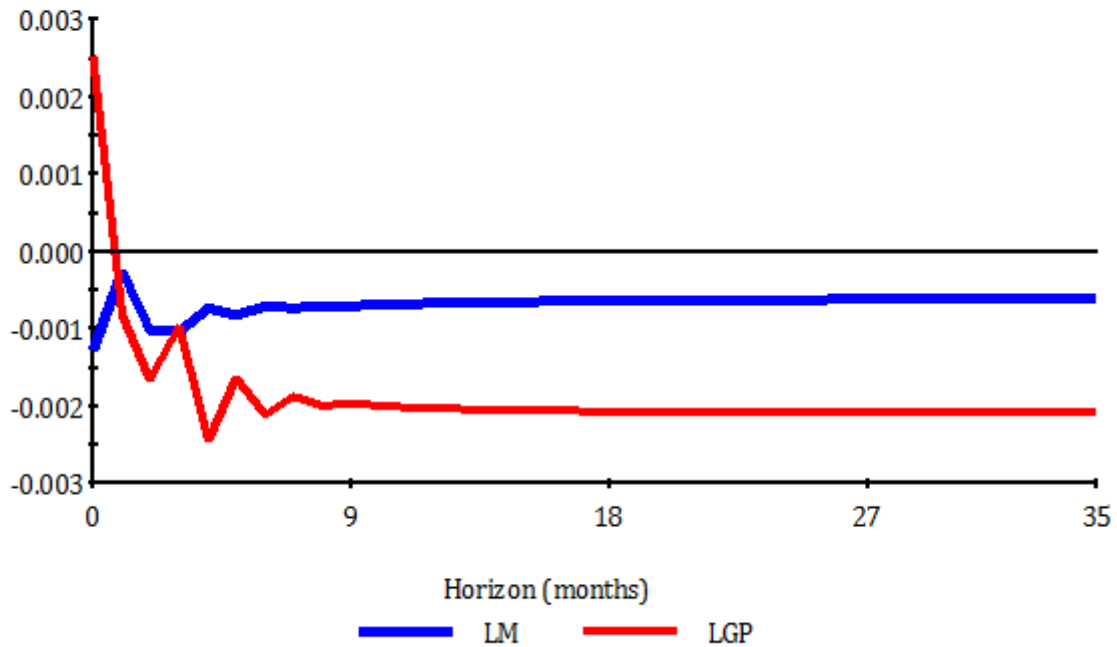
Figure 12. GIRs of the CBOS's Policy Instruments to One S.E. Shock in the Gold to Money Ratio's ECE
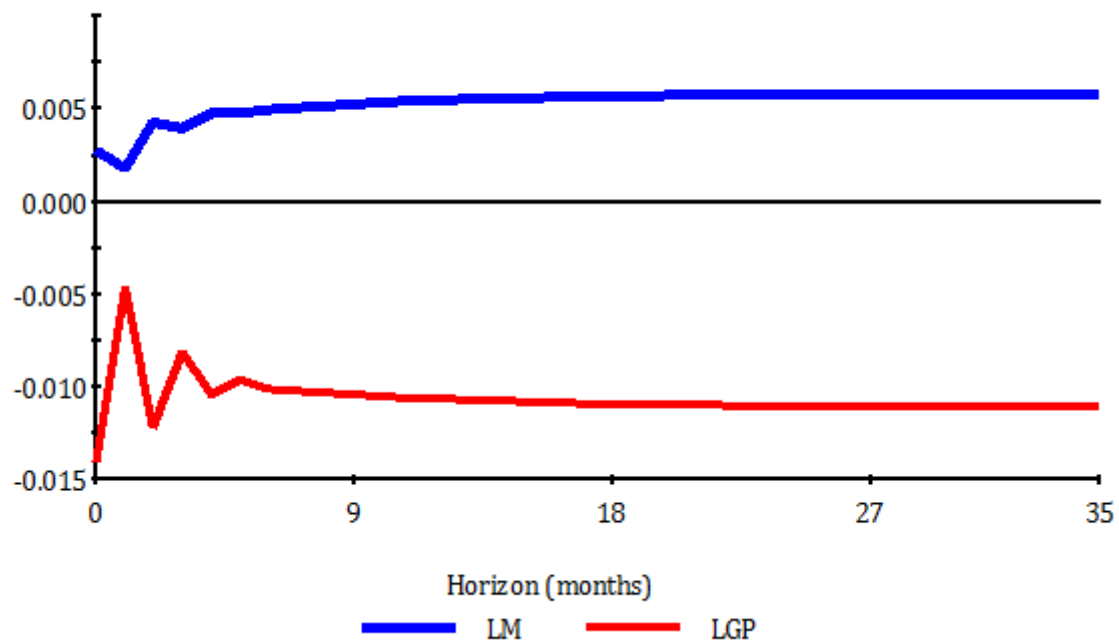

Figure 13. GIRs of the CBOS's Policy Instruments to One S.E. Shock in the Probability of Successful Gold Smuggling's ECE
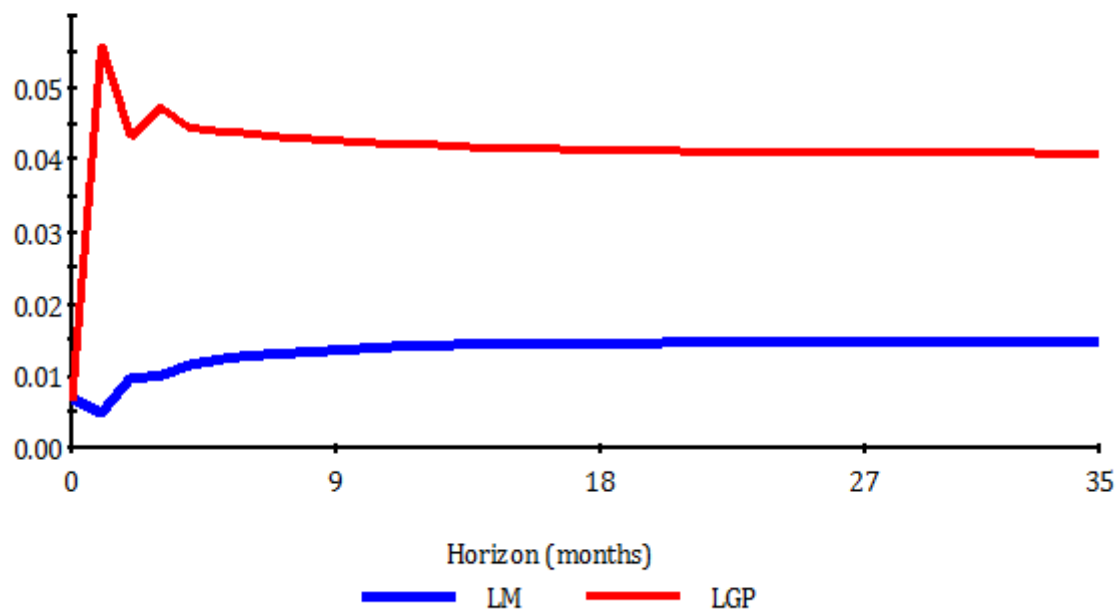
Figure 14. GIRs of the CBOS's Policy Instruments to One S.E. Shock in the Expected Inflation's ECE

Horizon (months)

LM   LGP
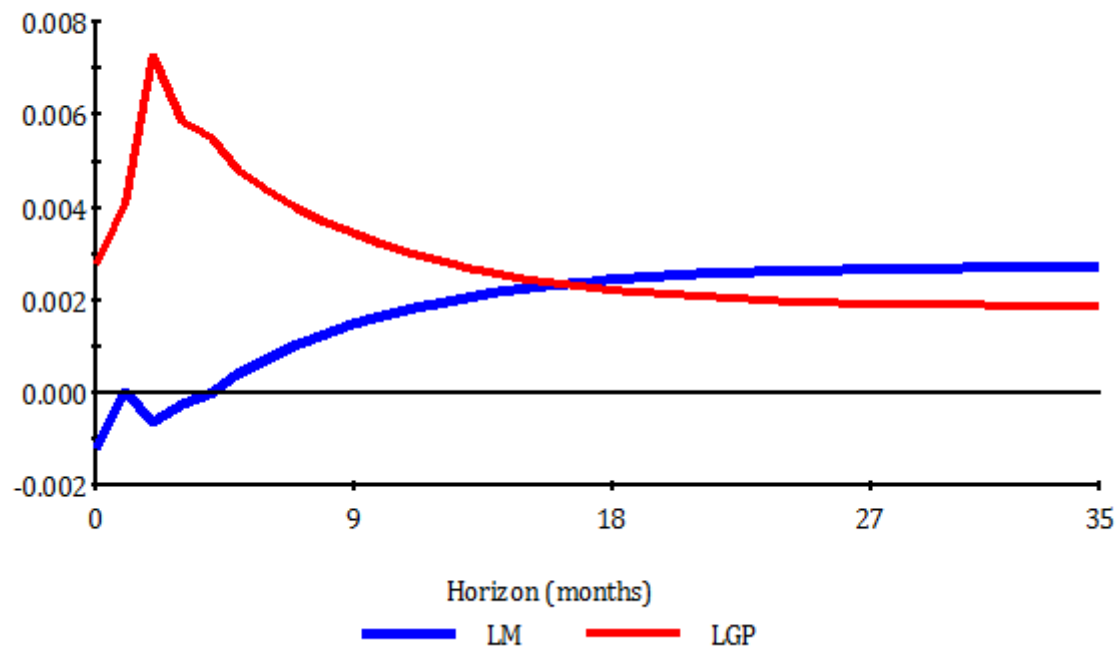
Figure 15. Persistence Profiles of the Effects of System-wide Shock to the Exchange Rate and Inflation Consistent with the CBOS's Gold Purchases to Money Stock Ratio

Horizon (months)

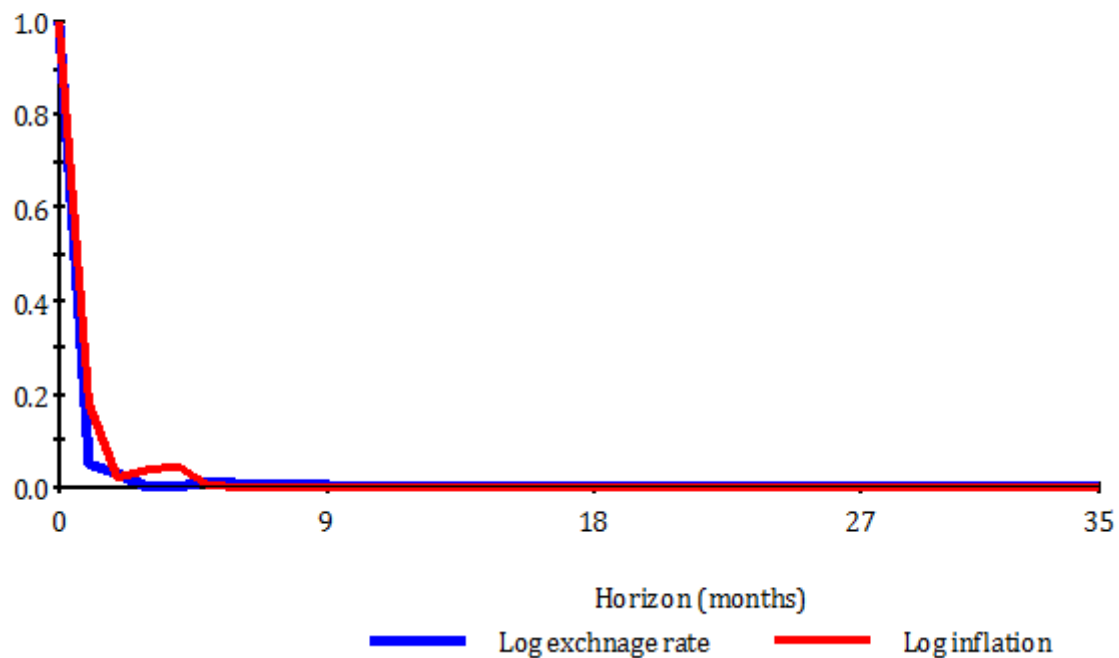Log exchnage rate   Log inflation

Figure 16. GIRs of the Exchange Rate and Inflation to One S.E. Shock in CBOS's Gold Purchases to Money Ratio's ECE
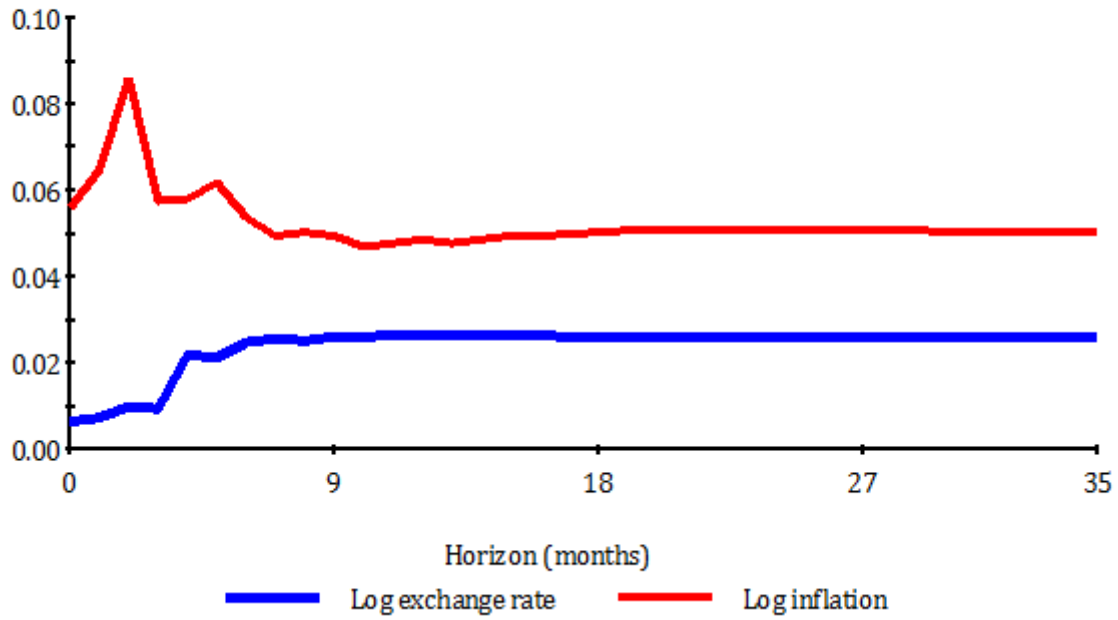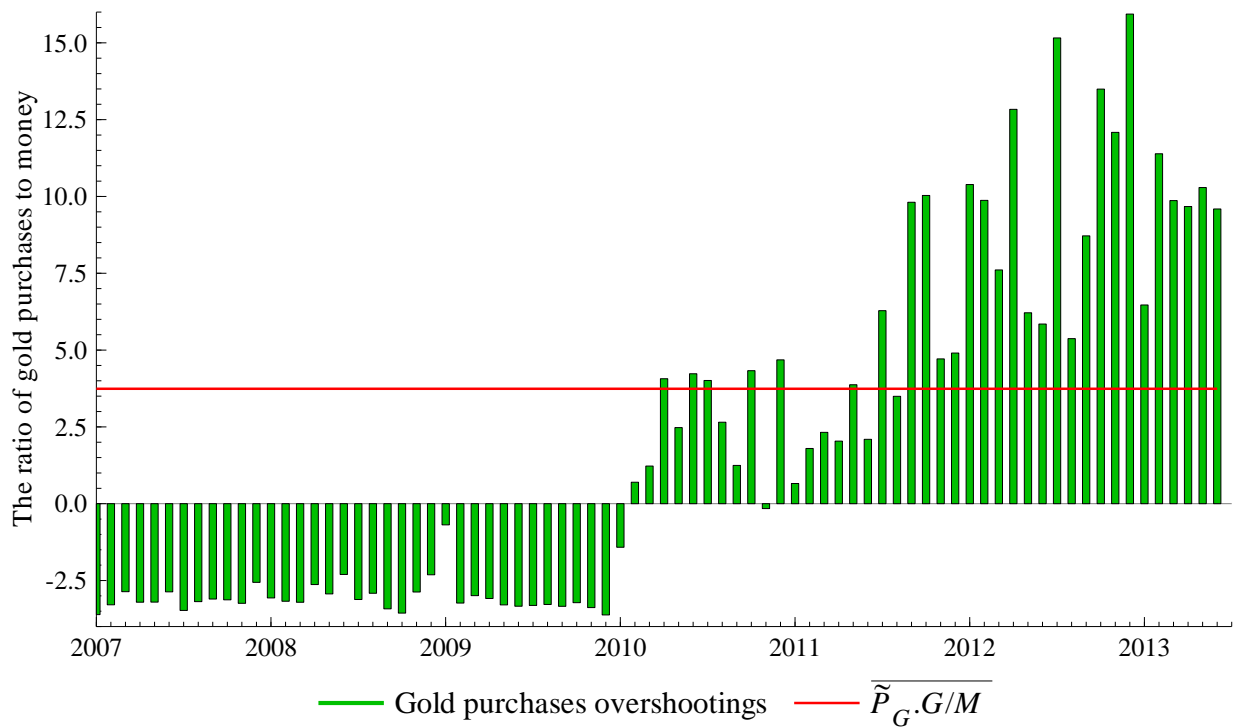

Figure 17. Gold Purchases' Threshold and Overshootings of Actual Gold Purchases (as ratios of money)

Appendix A: Econometric Methodology

The solution set of (18) can be determined by the following quadratic determinantal equation method due to Binder and Pesaran (1997, 1995);

A.1 (19) $\quad \det(C\lambda^2 - A\lambda + B) = 0$

Where a unique and stable solution requires that for each pair of roots corresponding to nonzero eigenvalues of C and A, one root will fall inside the unit circle and the other outside it. Assuming these requirements are met, the medium-term structural equilibrium relations, (denoted by '*'), underlying (18) can be expressed as;

A.2 (20) $\quad (A - B - C)y_t^* = \mu_t^*$

Under the postulate that these steady state relations are identifiable, their estimation can be carried out within the following n x I vector of $I(1)$ variables, y_t ;

A.3 (21) $\quad A_0 y_t = a_0 + a_1 t + A_1 y_{t-1} + ... + A_p y_{t-p} + v_t, t = 1, 2...T$

Where a_0 and a_1 are m x 1 vectors of unknown coefficients, $A_i, i = 0,1,..., p$, are m x m matrices of unknown parameters, A_0 is non-singular matrix of contemporaneous structural coefficients and v_t is an m x 1 vector of errors. For identification and estimation, equation (A.3) can be reparameterized in the following structural cointegrating vector autoregressive model;

A.4 (22) $A_0 \Delta y_t = a_0 + (\Pi a_1)t - \Pi y_{t-i} + \sum_{i=1}^{p-1}\gamma_i \Delta y_{t-i} + v_t, t = 1, 2...T$

with $\gamma_i = \sum_{j=i+1}^{p} A_j$, $\Pi = \alpha\beta' = A_0 - \sum_{i=1}^{p} A_i$, α and β are m x r matrices of full rank $(0 < r < m)$. And $\beta' y_t$ gives the linear combinations in y_t that are steady-state-stationary. The variance of the structural shocks v_t is denoted by Ω; which is a diagonal matrix with the diagonal elements containing $var(v_t)$.

Associated with the structural (VAR) model (A.4) is the following reduced form vector error correction model (VECM):

A.5 (23) $\Delta y_t = b_0 + (\Pi b_1)t - \Pi y_{t-i} + \sum_{i=1}^{p-1}\delta_i \Delta y_{t-i} + \varepsilon_t, t = 1, 2...T,$

where $b_0 = A_0^{-1}a_0, b_1 = A_0^{-1}b_1, \delta_i = A_0^{-1}\gamma_i, \tilde{\Pi} = A_0^{-1}\Pi = \tilde{\alpha}\beta'$, with $\tilde{\alpha} = A_0^{-1}\alpha$ and $\varepsilon_t = A_0^{-1}v_t$, which is a nx1 vector of serially uncorrelated reduced form errors with $var(\varepsilon_t) = \Sigma.$

At least exact identifying restrictions are needed for recovering the structural equilibrium parameters of the VAR model (A.4) from the estimable reduced form coefficients of model (A.5). By normalizing m diagonal elements of A_0 to ones, at least $m[(m-1)/2]$ restrictions are needed for exact identification.

We motivate these restrictions in terms of the decision problem of the CBOS articulated in equation (1), which implies that it chooses the values of monetary growth (g_M) and the CBOS's gold price (p_G) that minimize the weighted sum of the fluctuations in the level of domestic currency value of the international gold price $(E.p_G^*)$ conditioned by $(1 - p)$, the level of price as well as the levels of the ratios of domestic and foreign debt to the stock of money and the ratio of gold to

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money. The deviations from planned values of g_M and p_G (respectively in logarithmic form $lg_M - l\tilde{g}_M$ and $lp_G - l\tilde{p}_G$) are driven by unanticipated changes in the levels of target macroeconomic variables (y'), hence all variables are likely to be contemporaneously determined. Given the expectations formation mechanisms of the reduced form VECM (A.5), the deviations of the policy instruments (g_M and p_G) from planned values implies the existence of two equilibrium relations in the medium to long run in the expectational variables (y') including (g_M and p_G) assuming that the CBOS's monetary programme is known and believed by the public. Using (A.4) these equilibrium relations can be written as; $v_t = \beta' y_{t-1} - (a_0 - a_1) - a_1 t$, where β' is 2x1 vectors giving the steady state evolution of the CBOS's control variables. Thus, exact identification of the medium-term structural equilibrium relations requires two restrictions per cointegrating vector. Assuming the expectational variables vector (y') are first difference stationary (A.5) can be expressed as,

A.6 (24) $\quad \Delta y_t = b_0 - \alpha_0 a_0 - \alpha_1 [\beta' y_{t-1} - a_1(t-1)] + \sum_{i=1}^{s-1} \gamma_i \Delta y_{t-1} + \mu_t, i = 1,2,.....,s-1$

Estimation of Expected inflation

The adaptive expectations and the rational expectations approaches are developed in the literature to explain the expectations formation. According to the former approach expected inflation one period ahead is linked to actual and expected inflation for the current period by the following equation: $\pi^* = \pi_{t-1}^* + \lambda(\pi - \pi_{t-1}^*)$, with $0 \prec \lambda \succ 1$. And for all periods $\pi^* = (1-\lambda)\sum_{t=0}^{\infty}(\lambda^t \pi_t)$. The latter approach assumes that (in simple rational expectations setting) agents minimize conditional expectation errors $\varepsilon_t = \pi_t - E[\pi_t / I_{t-1}]$, where (I_{t-1}) is the information available at the time of the forecast. It has been argued in the literature that the adaptive expectations approach is not necessarily in conflict with the rationality approach, as shown by Muth (1960) and Pesaran (1987 and 1990). The former approach will give statistically optimal price forecasts if the process generating π can be represented by a first-order moving average, MA(1), such as $\pi_t = \varepsilon_t - \delta\varepsilon_{t-1}$, with δ being the same as λ . Estimates of the MA (1) of Sudan's inflation measured, respectively, in log difference of the consumer price index (denoted by $\Delta LCPI$) and in year-on-year in log percent (denoted by π) over 2007M1-2013M6 with (t-statistic in brackets) are summarized by the following equations:

$\Delta LCPI_t = 0.014 \quad + \quad 0.307\, \hat{\varepsilon}_{t-1} + \hat{\varepsilon}_t$; $\overline{R}^2 = 0.10$, DW-statistic = 1.807.
$\qquad\qquad (4.589)(3.322)$

$\Delta\pi_t = \quad\quad 0.010 \quad + \quad 0.223\, \hat{\varepsilon}_{t-1} + \hat{\varepsilon}_t$; $\overline{R}^2 = 0.02$, DW-statistic = 1.997.
$\qquad\qquad (0.381) \quad (1.614)$

As seen in the first equation δ is statistically significant, but with the opposite sing. The second equation suggests that the MA (1) for the year-on-year inflation in log percent is integrated of the first order. Further estimates (not shown), using Akaike selection criterion, indicate that the year-on-year inflation in Sudan follows an integrated autoregressive-moving average of the second order. Filature to confirm the MA (1) process could be due to the high volatility of inflation rate.

Also, Sudan's Central Berea of Statistics publishes the monthly inflation with lags. It appears that agents resort to less information demanding alternatives such as the adaptive expectation mechanism to form their expectations. The adaptive method is applied to the year-on-year inflation series, which is used in the empirical model. The value of λ weight is set at (0.8), which best minimizes the sum of residual standard errors obtained from the actual and forecasted inflation for various values of λ. Figure (6) shows the plots of the logarithms of the actual inflation rate and our proxy for expected inflation.

The co-integration tests:

The Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SBC) are used for the selection of the lag order of the VECM underlying the cointegration analysis. The results of testing (not shown) for vectors y_t' and x_t' using monthly data over 2007m1-2013m6, respectively, with seven and twelve lags are inconclusive. The AIC selects 7 and 4 lags for the first and second model, respectively; while the respective lag order according to BSC are one and 4. In view of the relatively small sample size and that the damage of selecting higher order is less compared to low order, we estimate the first model with two lags and the second model with four lags. For the CBOS's optimization model, in terms of equation 19, the trend coefficients are restricted such that $\alpha_0 a_1 = \eta \alpha_1 \beta'$, where ή is an 9 x 1 vector of unknown confidents, while the intercept terms are unrestricted. In the second model, which illustrates the CBOS's policy pass-through to inflation, the nominal and real exchange rates, the intercepts are restricted to ensure that there exist steady state values for inflation and nominal exchange rate at the mean ratio of the value of gold purchases to the stock of money. Though the threshold value of $\overline{(\tilde{p}_G.G/M)}$ is endogenously determined, the model allows the analysis of the response of inflation to nominal exchange rate devaluation. According to our theory, if the degree of pass-through from exchange rate to inflation is high, the exchange rate devaluation would not have much impact on competitiveness and trade balance. Hence, given the steady state values we can assess the extent to which changes in the nominal exchange rate and inflation, due to the CBOS's optimization behavior, could lead to changes in real exchange rate that might be misaligned.

Tables (A.1) and (A.2), respectively, report the cointegration rank test under λ -*max* and λ -*trace* statistics for the variables in the CBOS's optimization model and the variables in the pass-through relation associated with this optimization.

Table A.1. Cointegration Test Statistics for the Variables in the CBOS's Optimization Model[1]

		λ -Max			Trace		
H_0	H_1	Statistic	95% cv	90% cv	Statistic	95% cv	90% cv
r=0	r=1	114.748	55.140	52.080	282.873	182.990	176.920
$r\leq 1$	r=2	53.973	49.320	46.540	168.126	147.820	141.820
$r\leq 2$	r=3	37.405	43.610	40.760	114.153	115.850	110.600
$r\leq 3$	r=4	29.457	37.860	35.040	76.748	87.170	82.880
$r\leq 4$	r=5	23.942	31.790	29.130	47.292	63.000	59.160
$r\leq 5$	r=6	12.105	25.420	23.100	23.350	42.340	39.340
$r\leq 6$	r=7	9.6164	19.220	17.180	11.245	25.770	23.080
$r\leq 7$	r=8	2.081	12.390	10.550	2.081	12.390	10.550

1/. Vector y' = (MS, p_G, E. p_G, L/M , E.F/M, G/M , $(1-p)$, π^*), denoted in logarithms as, (LM, LpG, LE. pG*, LL/M,   LE.F/M,

LG/M, $L(1-p)$ and $L(\pi^*)$ ' . The VECM underlying the analysis is estimated with two lags and restricted trend. See Appendix B for the definitions of the variables. Also, five dummies are included unrestricted; motivated as follows: two dummies taking the value of one over 2007M5-2007M8 and 2008M6-2008M11 and zero otherwise are used to account for the global credit crunch over these periods. Similar a dummy over 2011M6-2013M6 is used to account for the rise of the gold economy and secession of South Sudan. The other two dummies over 2012M2-2012M8 and 2012M9 account, respectively, for the first post-secession budget of 2012 amended in July and the consequent riot of September 2012 following the removal of subsidies. The estimation period is 2007M1-2013M6.

Table A.2. Cointegration Test Statistics for the Variables in the CBOS's Policy Pass-through Model[1]

		λ -Max			Trace		
H_0	H_1	Statistic	95% cv	90% cv	Statistic	95% cv	90% cv
r=0	r=1	35.555	22.04	19.86	62.381	34.87	31.93
$r\leq 1$	r=2	18.300	15.87	13.81	26.826	20.18	17.88
$r\leq 2$	r=3	8.526	9.16	7.53	8.526	9.16	7.53

1/. Vector $x'=(E,\pi,\tilde{p}_G.G/M)$ denoted in logarithms as, (LE, L $L\pi$ and LG/M)'. The VECM underlying the analysis is estimated with four lags and restricted intercept. See Appendix B for the definitions of the variables. Also, three step dummies are included unrestricted to account, respectively, for the rise of the gold economy and the instability associated first post-secession budget of 2012 as well as a dummy to account for the step devaluation of the official exchange rate taking the value of one over 2012M6-2013M6 and zero otherwise. The estimation period is 20o7M1-2013M6.

As seen in both tables, the λ -*max* statistic confirms the existence of two cointegrating vectors per system in line with the predictions of our model. The testing for cointegration among the variables in the CBOS's policy pass-through model indicates that the cointegrating rank is 3 with λ -*max* statistic significant at 10% suggesting that the gold threshold ratio forms a linear combination that is stationary with the other included variables. However, we assume the rank is 2 in accordance with the postulated model.

Appendix B: Sources of the variables and their measurements

Money supply (measured in M2). Source: International Financial Statistics (IFS), the International Monetary Fund.

The CBOS's gold price (measured in Sudanese pound, SDG, per gram). Source: Norian et al (2012) and the Central Bank of Sudan.

The international gold price (measured in SDG per gram using the parallel market exchange rate). Source: Based on the average monthly's Dubai rates of the 99.5% fine gold; https://www.bullion-rates.com/.

The domestic debt (measured in SDG). Source: The Central Bank of Sudan.

Change in the stock of foreign debt net of official reserves (measured in SDG using the parallel exchange rate). Source: The Central Bank of Sudan.

Ratio of the market value of gold to money supply. Source: The IFS and the Central Bank of Sudan.

Inflation (measured by year-on-year change of CPI in percent over 2007M1-2013M6). Source: Sudan Central Bureau of Statistics.

The parallel market and official exchange rates: The official rate is compiled from the Central Bank of Sudan. The parallel exchange rate is compiled from the archives of daily newspapers that publish parallel market values of major currencies in SDG (namely *Alsahafa*; *Alnilin* and *Sudantribune*, including AL-ansaree Exchange Company Ltd and the African Exchange Company Ltd. The data is in daily frequency; the monthly frequency is obtained by averaging excluding weekends.

Probability of successful gold's smuggling. Source: (Norian at el 2012). The authors estimated the proportion of the smuggled gold at 5% in 1996 and adjusted just this ratio by the month-on-month spread between the parallel exchange rate and the CBOS's exchange rate for gold purchases for 1996-2011. We used the same method to estimate the probability of successful gold's smuggling for 2007M1 -2013M6.

Table B.1. Summary Statistics of the Primary Variables

Variable	mean	Maximum	Minimum	St. D./[1]	C.V./[2]
Money supply (in million SDG)	33420.3	63004.5	17523.9	13801.6	0.413
CBOS's price of gold per gram (in SDG)	88.2	252.9	29.5	66.7	0.756
International gold price per gram (in SDG)	111.6	304.6	30.8	84.1	0.753
Domestic debt (in million SDG)	334.9	1439.4	22.6	293.2	0.876
Foreign debt (in million SDG)	81.4	672.6	7.7	94.5	1.161
Gold market value (in million SDG)	351.5	1629.1	2.4	428.5	1.219
Probability of successful gold's smuggling	0.059	0.086	0.051	0.01	0.178
Monthly inflation (in percent)	18.3	47.9	2.84	12.1	0.660
Official exchange rate per SDG	2.907	4.420	2.000	0.801	0.303
Parallel market exchange rate per SDG	3.574	7.470	2.090	1.782	0.499

Notes:
1. St. D. is the standard deviation.
2. C. V. is the coefficient of variation.