Monetary Policy and the Informal Sector

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Abstract

In this paper we argue that the effects of monetary policy on informal economic activity can be very different from those on the officially reported one. To this point, we consider a two-sector monetary business cycle model in which one of the sectors, which we call the formal sector, is affected positively by the liquidity effects generated by monetary policy actions. The other sector, which we call the informal sector, shrinks from expansionary monetary policy since the pickup of inflation acts as a tax on the transactions of this sector's participants. The model is consistent with the evidence presented on UK informal sector. According to our estimates an increase in the interest rate causes an expansion of informal sector activity while the official sector contracts.

Keywords : Informal sector; Shadow economy; Monetary policy.

JEL classification : O17; O23; E52

1 Introduction

Few would deny that unregistered economic activity is a fact in every country although there is a general disagreement about its size. Diversity of opinion is nevertheless understandable as it is clear that obtaining information about unregistered economic activity is very difficult due to the unwillingness of those engaged to admit it. Arguably,

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knowing more about shadow sectors of the economy, is of great importance to policy makers for various reasons:

(i) Large informal sectors imply that the statistics on which policy decisions are made are wrong or, at least incomplete, thus rendering ineffectiveness and unwanted side-effects that may question the usefulness of such policies.

(ii) There is interaction between the formal and informal sectors that is at least twofold. The informal sector withdraws resources from the formal economy and enjoys certain public goods without paying for them. At the same time, as Schneider and Enste (2000) point out, nearly two-thirds of the income earned in the informal sector is spent on goods and services provided by formal economic activity.

(iii) In the absence of information about the informal sector policy makers do not have feedback on the policies implemented. In other words, since the effects of policies on the informal sector are generally unobserved it might be the case in many situations that despite observed desired effects in the formal sector, the overall economy is worse off. An example can be the design of social security systems. Previous studies have found that social security and unemployment insurance are desirable, however these can be designed in such a way that give people incentives to look for jobs in the informal sector while receiving unemployment benefits and at the same time can provoke lower net job creation in the formal sector due to high social security contributions. Thus, ill designed social welfare system may increase the share of the informal sector in the economy.

In the literature on informal economic activities there exist different definitions of the informal sector of an economy. We find the most relevant for our purposes the definition given by Schneider and Enste (2000). In particular, *we call informal sector all legal value-added activities that avoid taxation and remain unregistered by official statistics.* In this paper we argue that the effects of monetary policy on informal

economic activity can be very different from those on the officially reported one. To this point, we consider a two-sector monetary business cycle model in which one of the sectors, which we call the formal sector, is affected positively by the liquidity effects generated by monetary policy actions. The other sector, which we call the informal sector, shrinks from expansionary monetary policy since the pickup of inflation acts as a tax on the transactions of this sector's participants.

There is a general agreement among economists that changes in monetary conditions influence aggregate economic variables. In particular, after a monetary contraction output, employment, and inflation decrease. See, for example, Christiano, Eichenbaum and Evans (1996), Leeper, Sims and Zha (1996) for studies of the US economy, and Kim (1999), Canova and de Nicoló (2003) for studies of G-7 economies. Of course, all studies analyze the effects of money on officially measured variables such as GDP, industrial production, employment, etc. According to various studies, however, in most economies around the world there might be a fairly large informal sector, i.e. unregistered economic activity. Estimates vary a lot across studies and countries but all reveal that a non-trivial portion of the economy is not included in the officially reported statistics. For example, in a comprehensive recent study Schneider and Klinglmair (2004) find that the informal sector (IS) in 21 OECD countries is on average about 18 per cent of the officially estimated GNP and that this share has been growing for the past 20 years. The estimates for individual countries range from 8.6 percent in US to 28.3 percent in Greece. These values are much higher for developing and transition countries, averaging 41 percent and 38 percent respectively. It is, of course, difficult to imagine government policies that affect only the officially registered economic activity and this motivates us to pursue a better understanding of the effects of monetary policy on the informal sector.

The idea that policy has effects on the informal sector is not new. Various authors analyze such problems from different perspectives. Loayza (1996) constructs a simple endogenous growth model with a production function that uses congestible public services as inputs and in which the government cannot enforce compliance with the

tax code. This model is used to study the determinants and the effects of taxes and regulation on the informal sector. Its analysis shows that changes in policy and quality of government institutions that increase the size of the informal sector affect negatively the rate of economic growth. Johnson, Kaufman and Shleifer (1997) analyze a model of allocation of labor between the official and the informal sectors of the economy. The government levies taxes on the official sector to provide public goods that increase productivity. The informal sector neither pays taxes nor has access to public goods. Instead, it pays fees to private agencies to provide them. The quality of these goods depends on the revenue these agencies raise. The key prediction of this model is that economies can be in either of two distinct equilibria. In one, the government offers a sufficiently attractive combination of tax rates, regulation, and public goods and most firms choose to stay in the official sector. In the other equilibrium private agencies out-compete the government in providing public goods and hence many firms stay in the informal sector. Antunes and Cavalcanti (2004) construct a general equilibrium model with credit-constrained heterogeneous agents that make occupational choices over formal and informal businesses, contractual imperfections and a government that imposes taxes and regulations on formal-sector firms. In this model the return from being in the formal sector is better access to outside finance. The numerical results suggest that regulation costs rather than financial market imperfections account for the difference in the sizes of the informal sectors of US and the Mediterranean Europe, but this is exactly the opposite for countries with very weak enforcement systems. In summary, excessive taxes, social security contributions, bad institutions and regulations, especially on the labor market, tend to stimulate the unreported economic activity.

Unlike fiscal policy and regulation, effects of monetary policy are not well studied. Koreshkova (2003) documents a strong positive relationship between the size of the informal sector and inflation. Using a quantitative general equilibrium monetary model she shows that a theory of optimal taxation can rationalize government incentives to inflate in the presence of an informal (tax-evading) sector. This paper, however, has somewhat different perspective than ours since it justifies certain types of monetary

policy in the presence of informal sector but does not analyze what are the effects of such a policy on it. Caballé and Panadés (2004) analyze the effects of inflation on tax compliance and government revenues in a monetary economy where households face cash-in-advance constraints on consumption purchases and are exposed to random audits by the tax enforcement agency. One of their findings is that higher inflation stimulates tax evasion.

As a first step in tackling our problem we estimate a time series index of the informal sector in UK. We report some evidence suggesting that monetary policy affects the informal sector quite differently from the formal one. Based on this observation we build an equilibrium monetary business cycle model that attempts to explain why this might be so.

The rest of the paper is organized in six sections. Section 2 describes our empirical study of the British informal sector. Sections 3 and 4 describe a model that accounts for the observations in the previous section. The following two sections, Section 5 and Section 6, discuss the calibration, numerical solution and results for the model in Section 3. Section 7 concludes.

2 Estimating the informal sector in UK

In general it is very difficult to estimate the informal sector as pointed out by Schneider and Enste (2000) who review the existing methods of estimation. The authors suggest that an approach called Multiple-Indicator Multiple-Cause (MIMIC) modeling is the least prone to the critiques directed to existing estimation strategies. We follow this advice and use a dynamic version of this approach (DYMIMIC) to estimate the informal sector in UK. Using the time series index resulting from this estimation we then analyze the statistical relationships between this estimate and aggregate variables such as GDP, the interest rate set by the monetary authority, various monetary aggregates, etc. with the intention to infer the effects that changes in monetary conditions exert on the informal sector.

The empirical method that we use is based on the statistical theory of unobserved variables, which considers various causes and various indicators of the phenomenon of interest. For the estimation, a factor-analytic approach is used to measure an index of the unobservable variable over time. The coefficients are estimated in a system of structural equations in which the unobserved variable cannot be measured directly. The DYMIMIC model consists of two general parts, the measurement model and the structural equations model. The structural model specifies the relationship between the unobserved variable, in our case the informal sector, and the set of variables that are assumed to influence it, see equation (1a). The measurement model links the unobserved variable with another set of variables that are assumed to be indicators for the shadow economy's development, thus capturing the structural dependence of the informal sector on variables that may be useful in predicting its size and movements over time, see equation (1b). Nowadays, there is a large literature on the causes and indicators of informal activity. Summarizing, causes can be among the following types,

(i) The tax burden is pointed out in almost all studies, both empirical and based on theoretical models, as the main cause for the existence of an informal sector. The argument is that increasing tax payments and social security contributions give incentives both to workers and employers to avoid stating the (full scale) economic activity they are engaged in. Thus we expect estimated coefficients for variables representing tax burden in the structural equation to have positive signs. As proxies of the tax burden we use the ratio of total direct and indirect taxes to GDP, the ratio of social security contributions received by the government to GDP, and total government receipts to GDP. A note of caution should be added. In some cases this positive correlation is reversed as in Italy where relatively low tax burden co-exists with high informal sector and the Scandinavian countries, where the tax burden is high but the informal sector is relatively small.

(ii) Generous social welfare systems give incentives for people to work in the informal sector since by accepting a formal-sector job they lose their (potentially large)

welfare benefits and in addition pay income taxes on newly earned incomes. Thus the alternative of working in the informal sector and keeping the benefits plus non-taxed earnings can easily have a higher payoff. To account for this we use the amount of social benefits paid by the government as a fraction of GDP. As with the tax burden we expect the estimated coefficients on these variables in the state equation to have positive sign.

(iii) Koreshkova (2003) points out that larger informal sectors co-exist normally with higher inflation. At the same time since price inflation acts as a tax on cash holdings it can decrease the motivation of people to participate in the informal sector or at least to use cash transactions. In the presence of these two counterbalancing effects the expected sign on inflation-related variables is ambiguous. We include CPI as one of the causes in our estimation.

A change in the size of the informal sector over time may be reflected in the following indicators:

(i) Developments of the product market. Changes in size of the informal sector mean that inputs, particularly labor, are redirected from or to the formal sector which most likely has effects on formal GDP size and fluctuations. Other, complementarity effects are also likely. For example, a considerable part of the income earned in the informal sector is spent on goods and services produced by the formal sector. As production market indicator we use real GDP and as noted above it is difficult to determine the expected sign of the estimated coefficient.

(ii) Developments of money markets. Informal sector transactions are paid mostly in cash in order to avoid being registered by tax authorities and thus changes in the informal sector introduce changes in the demand for cash, other things equal. Therefore we expect positive sign of the estimated coefficient on IS in the measurement equation that represents developments on money markets. Our indicators are currency in circulation or currency in circulation divided by M2.

(iii) Developments of labor markets. Increases in informal sector activity requires more labor input and therefore leads to decreases in the participation in registered economically active population. We use as an indicator on this market the rate of economically inactive male population. We choose to work only with male population since female labor force participation in the last forty years has been predominantly driven by factors unrelated to shadow economic activity. To achieve identification of the model we fix to unity the coefficient on IS in this measurement equation.

Table 1 reports the variables used in the present study.

Name	Description
CPI	CPI, Harmonized Consumer Price Index
GDP	Real GDP, chained volume measures, 2001 prices
CURR	Currency outside banks
Taxb1	Government receipts
Taxb2	Total direct taxes
Taxb3	Total indirect taxes
Taxb3	Social security contributions to Government
URATE	Unemployment rate, registered
RUWC	Real unit wage costs
EIAM	Economic inactivity rate, males 16 years and more
Sben	Social security benefits paid by Government
BR	The interest rate set by the Bank of England
M2	M2 monetary aggregate

Table 1: Variables used in the estimation. Data sources: OECD Economic Outlook, OECD Paris; International Financial Statistics, IMF Washington, D.C.; Office of National Statistics, London UK.

2.1 The econometric model

Let the latent variable x_t denote the time-t index of the informal-sector output. Let $Z_t = [z_{1,t}, z_{2,t}, \ldots, z_{k,t}]'$ denote a vector of k time-t causal variables, and $Y_t = [y_{1,t}, y_{2,t}, \ldots, y_{p,t}]'$ denote a vector of time-t observations of p indicator variables. We consider the following state space model,

$$x_t = Fx_{t-1} + GZ_t + v_t, \tag{1a}$$

$$Y_t = H'x_t + A'Z_t + w_t, \tag{1b}$$

for $t = 1, \ldots, T$ and with independently, normally distributed, mean zero errors,

$$\begin{pmatrix} v_t \\ w_t \end{pmatrix} \sim \mathbf{N}\left[\mathbf{0}, \begin{pmatrix} \sigma_v^2 & \mathbf{0} \\ \mathbf{0} & R \end{pmatrix}\right] \tag{2}$$

where F, G, H, and A are conformable matrices of coefficients. We estimate the model using a combination of the EM algorithm and scoring as discussed by Watson and Engle (1983). The unobserved component is handled via the Kalman filter. We have tested all variables for non-stationarity starting with the hypothesis of I(3) against the alternative of I(2) and going down to I(1) against I(0). Those variables for which tests do not reject I(1) are transformed into percent growth rates. Table 2 reports the results from the Augmented Dickey-Fuller tests for non-stationarity.

We should underline that the estimation method allows us to recover only a unit-free index of the informal sector. This is, however, sufficient for our purposes since we are interested only in the co-movements with other variables over the business cycle and not in the particular size of the informal sector.

2.2 Estimation results

After trying various specifications for the state variable (informal sector) process and using different causal variables we pick a model with an AR(2) process for the informal sector and five causes: the unemployment rate, the consumer price index, the share of government receipts in GDP, the social benefit payments by the Government as a

Variable	I(3) vs. I(2)	I(2) vs. I(1)	I(1) vs. I(0)
CPI	Reject I(3)	Reject I(2)	I(1)
GDP	Reject I(3)	Reject I(2)	I(1)
CURR/M2 (CM2)	Reject I(3)	Reject I(2)	I(1)
Taxb1/GDP	Reject I(3)	Reject I(2)	I(1)
URATE	Reject I(3)	Reject I(2)	I(1)
RUWC	Reject I(3)	Reject I(2)	I(1)
EIAM	Reject I(3)	Reject I(2)	I(1)

Table 2: Results from Augmented Dickey-Fuller tests. All variables are transformed in logarithms and tested down for stationarity starting with H_0 : Integration of third order.

fraction of GDP, and real wages. Table 3 contains the estimates of the coefficients of the model in (1). All causal variables, except the unemployment rate, are statistically significant and have the expected sign. According to our estimation increases of inflation, the tax burden, and social benefits all influence positively the size of the informal sector. High wages in the official sector, however, tend to reduce the size of the informal sector, i.e. as the opportunity cost to working in the informal sector rises, perhaps more workers decide to look for job in the formal sector.

For the purpose of comparison with other studies Figure 1 presents our estimate of the informal sector as percentage of the official GDP estimate. To obtain this graph, however, we need an estimate not only of an index of the informal sector but, in addition, we need an estimate of the *actual size*. To this point we take the estimate of Schneider and Klinglmair (2004) of the *size* of the British informal sector in 1990 and use it to calibrate our index. Our estimate proves to be roughly consistent with the literature. Using the currency demand approach, Bhattacharyya (1990), estimates that the share of the informal sector in official GDP has risen from 6.4 percent in 1971:1 to 8.18 percent in 1984:4 whereas our estimate for the period is an increase from 4.48 to 9.78 percent. Table 4 compares our estimate with those of Schneider and Klinglmair

State equation			
Parameter	Estimate	St. error	p-value
Informal Sector(-1)	0.1654	0.1394	0.2382
Informal Sector(-2)	0.5489	0.1496	0.0004
URATE	-0.0212	0.0254	0.4057
CPI	0.1534	0.0673	0.0249
Taxb1/GDP	0.0622	0.0371	0.0969
Sben/GDP	0.1897	0.0823	0.0232
RUWC	-0.1808	0.1088	0.0997

Table 3: Parameter estimates of the state equation (matrices F and G) of the DYMIMIC model defined by (1) and (2). The coefficient of the informal sector in the first measurement equation is normalized to one to achieve identification.

(2004) who pursue the same estimation approach as we do.

Study	Average 1989/90	Average 1994/95	Average 1997/98	Average 1999/00	Average 2001/02	Average 2002/03
SK (2004)	9.6	12.5	13.0	12.7	12.5	12.3
This study	9.5	11.1	11.2	10.9	10.6	10.5

Table 4: Comparison between our estimates and those reported by Schneider and Kliglmair (2004).

To get an idea about the statistical relationship between our informal sector estimate and various monetary variables we estimate a five variable VAR using quarterly observations from the first quarter of 1971 to the fourth quarter of 2004 for the following variables: our estimate of the informal sector, real GDP, CPI, the interest rate set by the Bank of England, and M2. Table 5 reports results from the 15 step-ahead forecast error variance decomposition, computed with Choleski decomposition and variables in the order above. A brief inspection of this table confirms that the policy-set interest

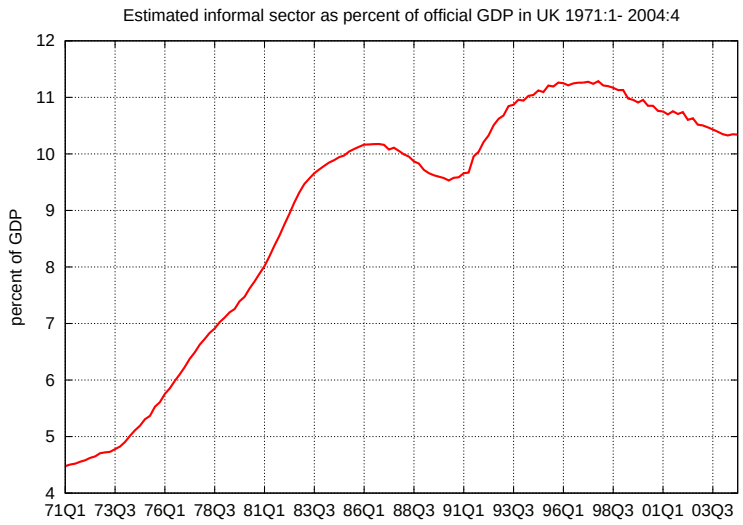

Figure 1: Estimate of the UK informal sector as percentage of GDP.

Period	IS	GDP	CPI	BR	M2
5	68.32	20.49	6.31	2.98	1.90
10	41.30	29.59	14.06	14.12	0.93
15	30.61	28.67	19.64	19.51	1.58

Table 5: Variance decomposition of 15 step-ahead forecast error of the growth rate of the informal sector resulting from a 5 variable VAR containing besides the estimate of the index of the informal sector, GDP, CPI, the policy rate set by the Bank of England, and M2.

rate plays an important role for our estimate of the British IS. As long as the Bank of England's policy rate reflects its monetary policy stance we cannot deny that there is an interesting statistical relationship between our estimate of IS and monetary policy. Figure 2 gives us further information about this relationship. We estimate that a one standard-deviation (orthogonalized) positive shock in the interest rate causes a statistically significant increase in our informal-sector estimate and this is exactly the opposite to the estimated response of official output. These two results are present in VARs estimated with variables both in levels and percent growth rates. According to our estimates an increase in the interest rate causes an expansion of informal sector

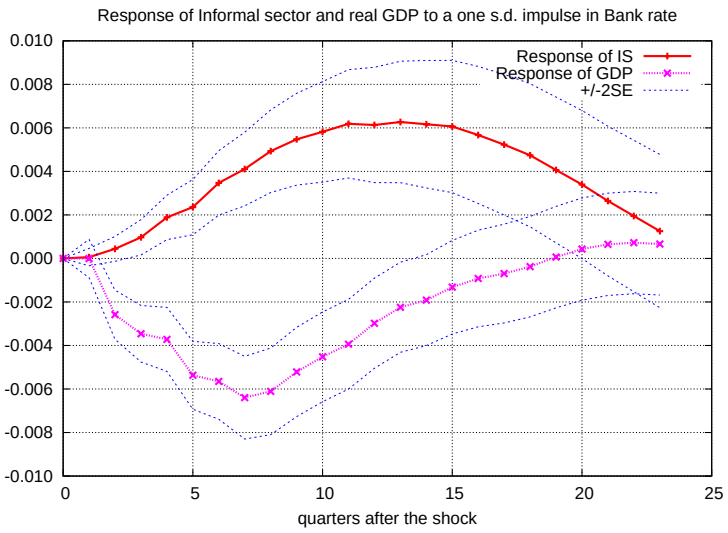

Figure 2: Impulse responses of the estimate of the index of UK informal sector and real GDP to a shock in the Bank of England policy rate resulting from a 5 variable VAR containing besides the estimate of the index of the informal sector, GDP, CPI, the policy rate set by the Bank of England, and M2.

activity while the official sector contracts. How could one justify such a finding? We think that a possible explanation could be the following. It is widely accepted that informal economic activity is not financed by banks and other official credit institutions and financial transactions are made mostly in cash. Thus a liquidity effect created by a monetary policy action does not have the direct consequences that it has on formal business activity, rather the effects can be indirectly passed through the official sector. For example, if a monetary contraction decreases output, employment, and inflation there would be more workers that in the face of unemployment would choose to work in the informal sector. Further, since inflation acts as a tax on cash transactions, such a policy action reduces this tax and this spurs the economic activity in the informal sector.

3 A Theoretical Model

To study the effect of monetary policy on informal economic activities, we incorporate an informal sector into a monetary general equilibrium business cycle model proposed by Cooley and Quadrini (1999). In the model there are two types of frictions. Labor market frictions that generate unemployment, and a cash-in-advance constraint that generates demand for money. Business cycle fluctuations are driven by a monetary policy shock. The labor market frictions allow us to study the effect of monetary policy on the creation and destruction of jobs, as well as on the allocation of time between formal and informal activities.

There are three sectors in the economy: a household's sector, a production sector, and a banking sector. There is also a monetary authority that controls the supply of liquidity (money) available for transactions in the economy. In the production sector there are two types of firms: industrial or formal firms and informal or extralegal firms. Both types of firms produce the same good, but they use different technologies. Households own two types of assets, liquid and illiquid, and are the ultimate owners of firms. Households enjoy leisure and the consumption of a single-type good produced in both sectors. Due to frictions on the labor markets, an individual works only if he or she is matched currently with a formal-sector firm. Otherwise such an individual divides his or her time between job-search and informal economic activity.

In the beginning of the period households observe their current employment status, employed in the formal sector or unemployed, and buy deposits from the banking sector. The monetary authority trades government bonds with the financial intermediaries, which determines the amount of liquidity available for formal firms' loans, $L = \text{Deposits} - \text{Bonds}$. Formal firms use these loans to advance wages to their employees. When workers receive their wages in the formal sector, production begins, the labor market opens, and firms post vacancies. Unemployed individuals divide their time between searching for a job in the formal sector and working in informal activities. Once production have taken place the labor market closes, new matches are formed

and firms carry their production to the goods market. Formal employees carry their cash and current period wages to the goods market, and unemployed individuals carry only their cash, since proceeds from production in the informal sector are not available for consumption until next period. This last assumption gives expected inflation a role in determining the allocation of hours to informal activities since inflation acts as a tax on informal production. At this stage consumption takes place.

In the end of the period firms repay the loans to the financial intermediaries, the government collects taxes to pay for the interests on bonds, and workers receive the return of their deposits and the profits of formal firms. In the remaining of this section we explain in detail the problem faced by each of the participants of the economy.

3.1 The monetary authority and the intermediation sector

The monetary authority controls the supply of liquidity (money) available for transactions by conducting open market operations, that is, by purchasing and selling government bonds. We assume that the total nominal stock of public debt is constant. What changes is the fraction of it that is in the hands of financial intermediaries, i.e. part of this stock is owned by the monetary authority and part is owned by the banking sector. The nominal value of public debt or government bonds owned by the banks is denoted by B. Transactions in government bonds take place between the monetary authority and the banks. For simplicity we assume that the interest paid on bonds owned by the private sector (banks) is financed with non-distorting taxes.

The quantity of liquid funds, M, available in the economy is constant. Part of these funds are held by households for transactions and the remainder is deposited with banks. Banks collect these deposits from households and use them to buy government bonds and to make loans to firms. Consequently, in each period, an amount $M - D$ of money, where D denotes the aggregate stock of nominal deposits, is available to the households for transaction and an amount $D - B$ is available to the firms. The sum of these two stocks gives the total amount of money used for transactions, that is, $M - B$.

Although we assume that M is constant, the monetary authority is able to modify the stock of money used for transactions by changing the stock of public debt outstanding with open market operations. When the monetary authority purchases public bonds from the banks, the quantity of loanable funds $D - B$ available to the intermediation sector increases (for a given stock of deposits D), and this increase in the supply of loanable funds has the potential to drive the interest rate down.

To insure that open market operations change the supply of loanable funds, we need to impose some rigidity in the ability of the individuals to adjust their stock of deposits. We assume that individuals are able to change their stock of deposits at any moment but there is a readjustment cost associated with doing so. We denote this cost by $\tau(d, d')$ where d is the current holding and d' the new chosen stock. The adjustment cost function is continuously differentiable in both arguments and convex in the absolute change of the initial stock. We also assume that $\tau(d, d) = \tau_1(d, d) = \tau_2(d, d) = 0$, that is, the cost and the partial derivatives are zero when the $d = d'$.[1] The advantage of this approach over the standard limited participation model is that liquidity effects of monetary shocks are more persistent even though they may be smaller in the current period.[2]

The monetary authority controls the growth rate of the aggregate stock of money $M - B$ with open market operations. Monetary policy shocks are innovations to the targeted growth rate g. We formalize the monetary policy rule with the AR process

[1] As Cooley and Quadrini (1999) note this cost can be justified by penalties that banks charge on earlier withdrawals and by lower interest rates earned in the first period in which a new deposit is made. Such penalties are justified by the costs that banks incur for readjusting their loan portfolio. Of course, in this model, deposits should not be understood as checking deposits but rather as less liquid assets that earn higher interest.

[2] Under the assumptions of the standard limited participation model, even if the transfers from the monetary authority are persistent, the greater availability of funds in subsequent periods will be mostly compensated for by a reduction in the stock of deposits owned by households. With adjustment costs, households do not completely adjust their nominal stock of deposits in the following period either, and this induces a more persistent effect of monetary policy shocks.

$\log(1+g') = \rho_g \log(1+g) + \epsilon'_g$, where the prime denotes the next period values and ϵ'_g is the monetary policy shock.

3.2 Households

In the household's sector there is a continuum of individuals in the interval $[0, 1]$. Households maximize the expected present discounted value of the sum of per period utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(c_t - \chi_t \frac{l_{f,t}^{\gamma}}{\gamma} - (1-\chi_t) \frac{l_{i,t}^{\gamma}}{\gamma} \right), \tag{3}$$

where c is consumption of market produced goods, l_f is the time spent working in the formal sector, l_i is the time spent working in the informal sector if the individual is unemployed, and χ is an indicator function taking the value of one if the individual is employed in the formal sector and zero otherwise. Only unemployed individuals can work in the informal sector. In order to work in the formal sector, an unemployed individual needs to search for a job. However, there is no direct cost of searching and the probability of finding a job in the formal sector depends positively on the time allocated to search. The opportunity cost of searching for a job in the formal sector is the forgone gain from working in the informal sector.

Households are the owners of all firms in the economy and besides own two types of assets: cash and nominal deposits. Households maximize expected utility subject to two constraints. First, they face a cash-in-advance constraint that takes the form:

$$p(c + \tau(d, d')) \leq m - d' + \chi \; p \; w_f \tag{4}$$

where primes denote the next period value, m is the household's nominal holdings of money, $\tau(d, d')$ is the cost of readjusting the nominal portfolio of deposits, p is the nominal price level, and w_f is the wage received at the beginning of the period in cash if the individual is employed in the formal sector. Nominal deposits receive a nominal interest rate r at the end of the period. The second constraint households face is the

budget constraint, which can be written as

$$p(c + \tau(d, d')) + m' = m + rd' + \chi\ p\ w_f + (1 - \chi)p\ w_i + p\bar{\pi} - rB, \tag{5}$$

where w_i is the real labor income from informal activities, $\bar{\pi}$ is it share of aggregate profits from firms, and rB are the taxes that the household pays. Note that the income earned in the formal sector is available for purchasing current market consumption, while the income earned in the informal sector is received at the end of the period and is available for consumption in the next period. As pointed out before, this feature affects workers incentives to work in the informal sector when expected inflation is high since inflation acts as a tax on informal activities.

3.3 The production sector

In the production sector there are formal and informal firms. The production technologies in both sectors take labor as the only input. These technologies differ across sectors. The technology in the formal sector exhibits constant returns to scale, and the technology in the informal sector is assumed to exhibit decreasing returns to scale. In particular the production of an unemployed individual who allocate l_i units of time operating an informal business is $y_i(l_i) = \delta_p A l_i^{\nu}$, where A is the technology in the formal sector and δ_p represents the relative productivity of the informal sector with respect to the formal. We assume that $\delta_p < 1$ which guarantees that in equilibrium the informal sector size is well defined: a positive amount of labor is allocated to informal businesses since $\lim_{l_i \to 0} y_i'(l_i) = \infty$. The assumption of a decreasing marginal product of labor in the informal sector is motivated by the empirical finding of Lemieux, Fortin and Fréchette (1994) that after-tax wages earned in the formal sector are negatively correlated with the hours worked in the informal sector.

The production in the formal sector requires firms and workers to be matched. The current aggregate state of the economy is $s = (g, B, D, N)$, where N is the number of workers that at the beginning of the period are matched with a firm. The production of a match in the formal sector is $y_f = Al_f - \varphi$, where φ is the non-labor

cost of production. The cost φ is idiosyncratic to the firm and is assumed to be independently and identically distributed across firms and time with distribution function $F : [0, \infty] \to [0, 1]$. Both the firm and the worker observe the cost shock at the beginning of the period and decide whether to continue the match. If the realization of the cost shock is high enough, it would be unprofitable for the match to continue. The value of φ above which the firm decides to shut down is denoted by $\bar{\varphi}(s)$ and it is a function of the state of the economy s. The aggregate technology level is assumed constant $A = \bar{A}$.

3.4 Matching process and the dynamics of employment

At the beginning of the period there are N matches in the formal sector, and the measure of workers employed in the formal sector that produce in the current period is equal to $F(\bar{\varphi}(s))N$. Thus, a total of

$$u(s) = 1 - F(\bar{\varphi}(s))N, \tag{6}$$

workers will not produce in the formal sector during the period. Individuals who do not produce in the formal sector during the period allocate l_i hours of their time operating an informal business and the rest in searching for a job in the formal sector. The measure of hours allocated to informal activities is then $l_i u(s)$ and the measure of hours devoted to search is $(1 - l_i)u(s)$.

The number of matches in any period is given by a constant return to scale matching function $\Psi(v_p, u_h)$, where v_p is the total measure of vacancies posted by formal firms during the period and u_h is the total measure of hours devoted to search. In the present case $u_h = (1 - l_i)u(s)$. We also assume that $\Psi(v_p, u_h)$ is strictly increasing in

both arguments and satisfy some standard regularity conditions.[3] The probability that a searching firm finds a worker is denoted by $\lambda_f(s)$ and it is equal to $\Psi(v_p, u_p)/v_p$, while the probability that an unemployed worker who allocates one unit of time seeking for a job in the formal sector finds a job is denoted by $\lambda_w(s)$ and it is given by $\Psi(v_p, u_p)/u_h$.

The total number of matches, therefore, evolves according to

$$N(s') = F(\bar{\varphi}(s))N + \Psi(v_p, (1 - l_i)u(s)). \tag{7}$$

3.5 Wage and labor supply determination

To determine wages and working hours firms and workers solve a Nash bargaining problem in which workers bargaining power equals η. The Nash bargaining problem is defined as

$$\max_{w(s,\phi)} J(s,\phi)^{1-\eta}(W(s,\phi) - U(s))^{\eta}. \tag{8}$$

where $J(s,\varphi)$ denotes the value of a match for the firm, $W(s,\varphi)$ the value of a match for a worker, and $U(s)$ the value of being unemployed.

Firms implement optimal production plans to maximize the welfare of their owners. They have to pay wages in advance in cash, and they finance these advance payments by borrowing from a financial intermediary at the nominal interest rate r. Since dividends are paid at the end of the period, individuals need to wait until the next period to transform this cash into consumption. This implies that the current value in terms of consumption of one unit of cash received at the end of the period is $\delta(s) = \beta E(p(s)/p(s'))$. The value of a match for the firm measured in terms of current

[3] These conditions are:

$$\begin{aligned}
\Psi(0, u_h) &= \Psi(v_p, 0) = 0, \\
\lim_{v_p \to \infty} \Psi_{v_p}(v_p, u_h) &= \lim_{u_h \to \infty} \Psi_{u_h}(v_p, u_h) = 0, \\
\lim_{v_p \to 0} \Psi_{v_p}(v_p, u_h) &= \lim_{u_h \to 0} \Psi_{u_h}(v_p, u_h) = \infty.
\end{aligned}$$

consumption is given by

$$J(s,\varphi) = \delta(s)\pi(s,\varphi) + \beta E \int_0^{\bar{\varphi}(s)} J(s',\varphi')dF(\varphi'), \tag{9}$$

where $\pi(s,\varphi) = Al_f - \varphi - (1+r)w(s,\varphi)$ is the profit of a type (s,φ) firm at the end of the period. This profit equals the output produced by the firm minus the non-labor cost φ and the labor cost $(1+r)w(s,\varphi)$, which consist of the wage $w(s,\varphi)$ plus the interest paid by the loan used to financed the advanced payment of the wage.

Unmatched firms, or firms whose matches terminated, may choose to enter the labor matching market and post vacancies. The cost of posting a vacancy is k per period. If $\lambda_f(s)$ is the probability that a vacancy is filled, free entry ensures that firms post vacancies until the expected return of posting a vacancy equals k. That is until

$$\beta\lambda_f(s)E \int_0^{\bar{\varphi}(s')} J(s',\varphi')dF(\varphi') = k. \tag{10}$$

With respect to workers we have that the value of a match and the value of being unemployed in terms of current consumption are defined as

$$W(s,\varphi) = w(s,\varphi) - \frac{l_f^\gamma}{\gamma} + \Gamma\left[\bar{\varphi}(s')\right] + \beta E U(s'), \tag{11}$$

$$U(s) = \max_{l_i}\left\{\delta(s)y_i(l_i) - \frac{l_i^\gamma}{\gamma} + (1-l_i)\lambda_w(s)\Gamma\left[\bar{\varphi}(s')\right] + \beta E U(s')\right\}, \tag{12}$$

where the function Γ is defined as,

$$\Gamma\left[\bar{\varphi}(s')\right] = \beta E\left\{\int_0^{\bar{\varphi}(s')} \left[W(s',\varphi') - U(s')\right]dF(\varphi')\right\}.$$

First, notice that the values $W(s,\varphi)$ and $U(s)$ are defined in terms of consumption net of the disutility from working. Having in mind that these two functions represent the value of being employed in the formal sector and the value of being unemployed, one can interpret Γ as the expected discounted surplus of a worker from working in the formal sector in the next period. The first two terms on the right-hand side of equation (11) represent the net value for a worker from working in the current period, while the last term denotes the expected discounted value of being unemployed from next period

on. Equation (12) represents the value of being unemployed as the sum of the net gain from working in the informal sector (the first two terms on the right-hand side), the expected surplus from working next period conditional on devoting $(1 - l_i)$ units of his or her time on searching (the third term), and finally the expected discounted value of being unemployed from next period on.

The first order condition of the Nash bargaining problem (8) can then be written as

$$\eta J(s, \phi) = (1 - \eta)(1 + r)\delta(s) \left[W(s, \phi) - U(s) \right]. \tag{13}$$

Using equations (9) to (13) we derive the wage $w(s, \phi)$ as a function of the labor inputs l_i and l_f. This is given by

$$\begin{aligned} w(s, \varphi) = \frac{\eta}{1 + r(s)}(A l_f - \varphi) + (1 - \eta) \left(\delta(s) y_i(l_i) - \frac{l_i^\gamma}{\gamma} + \frac{l_f^\gamma}{\gamma} \right) \\ + \frac{k\ \eta}{\lambda_f(s)} \left\{ \frac{1}{\left[1 + r(s)\right] \delta(s)} - \left[1 - (1 - l_i)\lambda_w(s)\right] E \left[\frac{1}{\delta(s') \left[1 + r(s')\right]} \right] \right\}. \end{aligned} \tag{14}$$

The solution of problem (12) implies that the optimal input of labor allocated to informal activities, l_i, is implicitly defined by the equation

$$\delta(s) y_i'(l_i) - l_i^{\gamma - 1} = \frac{k\ \eta}{1 - \eta} \frac{\lambda_w}{\lambda_f} E \left\{ \frac{1}{\delta(s') \left[1 + r(s')\right]} \right\}. \tag{15}$$

To determine the optimal input of labor in the formal sector workers maximize the surplus $W(s, \phi) - U(s)$ with respect to l_f, which implies that

$$l_f(s) = \left(\frac{A}{1 + r} \right)^{1/(\gamma - 1)}. \tag{16}$$

This equation implies that the labor input, and therefore, firm's output, is decreasing in the nominal interest rate r. This is because the interest rate increases the marginal cost of labor. This has important implications for the impact of monetary policy shocks on real activities.

A successful match is endogenously discontinued when the realization of the shock makes the value of workers' surplus zero or negative, i.e., $W(s, \phi) - U(s) \leq 0$. This condition implicitly defines the upper bound shock $\bar{\varphi}(s)$ as the solution of $W(s, \bar{\varphi}(s)) -$

$U(s) = 0$. By equation (13) the value of a firm at $\bar{\varphi}(s)$ equals zero. This means that workers and firms allways agree on wheather to form or maintain a relationship.

3.6 The household's problem and general equilibrium

In this section we describe the household problem written in recursive form after normalizing all nominal variables, (B, D, m, d, p), by M. To keep notation relatively simple we do not change the names of these variables. Recall that the aggregate state of the economy was: the growth rate of money g, the normalized stock of government bonds B owned by the intermediaries, the normalized stock of nominal deposits D, and the number of workers N that at the beginning of the period are matched with a firm. The individual states are the occupational status χ, the stock of liquid assets m, and the stock of nominal deposits d. We will denote the set of individual states with $\hat{s} = (\chi, m, d)$.

Let $\bar{\pi}$ denote the share of aggregate profits of the formal sector that is equally distributed at the end of the period to households and let the function $H(s)$ define the law of motion for the aggregate state vector, s. Then denoting with $\Omega(s, \hat{s})$ the household's value function, the household's problem becomes:

$$\Omega(s, \hat{s}) = \max_{c, m', d'} \left\{ c - \chi \frac{l_f^\gamma}{\gamma} - (1 - \chi) \frac{l_i^\gamma}{\gamma} + \beta E \Omega(s', \hat{s}') \right\} \tag{17}$$

subject to

$$c = \frac{m - d'}{p} + \chi w - \tau(d, d'), \tag{18}$$

$$m' = (1 + r)d' + p\bar{\pi} + p(1 - \chi)y_i(l_i) - rB, \tag{19}$$

$$\bar{\pi} = \int_0^{\bar{\varphi}} \pi(s, \varphi) dF(\varphi), \tag{20}$$

$$s' = H(s), \tag{21}$$

After substituting the cash-in-advance constraint, equation (18), and the budget constraint, equation (19), in the household's utility, the household's problem reduces to the choice of the variable d'. Differentiating with respect to d' we get

$$\beta(1 + r)E\left(\frac{p}{p'}\right) - p[\tau_2(d, d') + \beta E(\tau_1(d', d''))] = 1. \tag{22}$$

Without the presence of the adjustment cost the equation would reduce to the usual Euler equation $1 = \beta(1 + r)E(p/p')$.

4 Equilibrium and the steady state

A recursive competitive equilibrium is defined as a set of functions for (i) household decisions $c(s, \hat{s})$, $m'(s, \hat{s})$ and $d'(s, \hat{s})$; (ii) labor inputs $l_f(s)$ and $l_i(s)$, wage in the formal sector $w(s, \varphi)$ and exit decision $\bar{\varphi}(s)$; (iii) aggregate deposits $D(s)$, banks' holding of government bonds $B(s)$, loans $L(s)$ and employment N; (iv) interest rate $r(s)$ and nominal price $p(s)$; (v) law of motion $H(s)$ for the aggregate state. Such that: (i) the household's decisions are the optimal solutions to the household's problem (17); (ii) the labor input in the informal sector satisfies equation (15), the labor input in the formal sector satisfies equation (16), and the exit condition maximizes the surplus of the match; (iii) the market for loans clears, that is $D(s) - B(s) = L(s)$, and $r(s)$ is the equilibrium interest rate; (iv) the law of motion of aggregate states $H(s)$ is consistent with the individual decisions of households and firms.

In a steady-state equilibrium all variables are constant. The steady-state interest rate can be derived from equation (22) and it is given by $r = 1/\beta - 1$. Once we know the interest rate r, we are able to determine the steady state labor input in the formal sector l_f from equation (16). Then the steady state equilibrium can easily be characterized using the following system of six equations in the six unknowns v_p, l_i, u,

N, D, p, and $\bar{\varphi}$. All nominal variables are normalized by M.

$$\beta^2 \int_0^{\bar{\varphi}} \pi(\varphi) dF(\varphi) + \beta \frac{kF(\bar{\varphi})}{\lambda_f(v_p, (1-l_i)u)} = \frac{k}{\lambda_f(v_p, (1-l_i)u)}, \tag{23}$$

$$\nu \delta_p A l_i^{\nu-1} - l_i^{\gamma-1} = \frac{k\ \eta}{1-\eta} \frac{v_p}{(1-l_i)u}, \tag{24}$$

$$\beta(Al_f - \bar{\varphi}) + \frac{l_i^\gamma}{\gamma} - \frac{l_f^\gamma}{\gamma} + \frac{k\ (1-\eta(1-l_i)\lambda_w(v_p, (1-l_i)u))}{(1-\eta)\lambda_f(v_p, (1-l_i)u)} = \beta y_i(l_i), \tag{25}$$

$$N \int_0^{\bar{\varphi}} (A_f l_f - \varphi) dF(\varphi) - k v_p + u\ y_i(l_i) = \frac{(1-D)}{p} + N \int_0^{\bar{\varphi}} w(\varphi) dF(\varphi), \tag{26}$$

$$p\ N \int_0^{\bar{\varphi}} w(\varphi) dF(\varphi) = D - B, \tag{27}$$

$$(1-l_i)\lambda_w(v_p, (1-l_i)u)u = (1-F(\bar{\varphi}))N, \tag{28}$$

$$u = 1 - F(\bar{\varphi})N. \tag{29}$$

Equation (23) is the free entry condition for firms. Equation (24) is the first order condition for the supply of labor in the informal sector, and equation (25) is the exit condition. Equation (26) is the aggregate cash-in-advance constraint for the households and equation (27) is the equilibrium condition in the market for loans. Equation (28) is the flow of workers in and out of employment, and equation (29) is the measure of workers that do not produce in the formal sector.

5 Calibration

The parameters that describe household preferences are the discount factor β and the disutility parameter γ. Choosing the time period to correspond to a quarter of a year, β is set to 0.98, implying a steady state interest rate of approximately 2% per quarter. Since in the economy there is no growth in nominal variables, the steady state nominal interest rate is equal to the steady state real interest rate. As in Cooley and Quadrini (1999), we assume that the disutility function is quadratic and, therefore, we set $\gamma = 2$.

We follow Cooley and Quadrini in choosing a Cobb-Douglas matching function of the form $\Psi(v_p, u_h) = \mu v_p^\alpha u_h^\zeta$. We set $\alpha = 0.4$ and $\zeta = 0.6$ based on the estimates

of Blanchard and Diamond (1989). Cooley and Quadrini (1999), Walsh (2003), and den Haan, Ramey and Watson (2000), fix $\lambda_f = 0.7$. Based on Cole and Rogerson (1996) , we set the average duration of unemployment at 1.67 quarters, which implies $\lambda_w = 0.6$. With the values of λ_f and λ_w we are able to determine the last parameter of the matching function μ. We set the sharing parameter $\eta = 0.5$. The value of this parameter is important for the volatility of employment but not for the shape of the response of employment to shocks.

The production functions are characterized by the stochastic properties of the idiosyncratic shock and by three parameters: the aggregate technology level $\bar{A}$, the return to scale parameter of the informal sector ν, and the relative productivity of the informal sector with respect to the formal sector δ_p. Given the steady state interest rate r and using equation (16), the parameter $\bar{A}$ is determined by imposing the condition that each employed worker in the formal sector spends, on average, one third of the available time working. Lemieux et al. (1994) estimated the return to scale parameter of the informal sector for Canada to be 0.74, with standard error 0.1. Based on the survey by Schneider and Enste (2000), which argues that the U.S. and Canada have similar informal sector size, we consider this estimate of the degrees of scale is reasonable to be used as our benchmark parameter v. The relative productivity between informal and formal firms δ_p is the one that matter most for the allocation of time between the sectors. This parameter controls the size of the informal sector. Alternative estimates of the size of the underground economy in the U.S. range from 6.7% to 13.9%, with an average of 10% of GDP (Schneider and Enste (2000)). Based on this observation we determine δ_p by imposing that the production of the informal sector equals 10% of the production in the formal sector.

For analytical simplicity, we assume that the non-labor cost φ is distributed exponentially with distribution function $\varphi \sim e^{-\varphi/\theta}/\theta$. The parameter θ is determined jointly with the parameter k by imposing that the steady state measure of individuals that do not produce in the formal sector equals 18%, and that the arbitrage condition for the creation of new vacancies is satisfied. Notice that we define the measure of indi-

viduals that do not produce in the formal sector as the sum of unemployed individuals, which is assumed to be 6%, plus the informal labor.

The ratio of the stock of public debt to aggregate final output is assumed to be 0.5. This value, however, does not affect the properties of the economy.

The growth rate of money follows the process $\log(1+g') = \rho_g \log(1+g) + \epsilon'_g$, with $\epsilon_g \sim N(0, \sigma_g^2)$. The parameter values are $\rho_g = 0.49$ and $\sigma_g = 0.00623$, which are those used by Cooley and Hansen (1989).

Finally, the adjustment cost function is specified as $\tau(d, d') = \phi((d'-d)/d)^2$ and the value of the parameter ϕ is determined to obtain the desired volatility of the nominal interest rate: the higher ϕ is, the higher the volatility of the interest rate. The value chosen for the baseline model is $\phi = 3$.

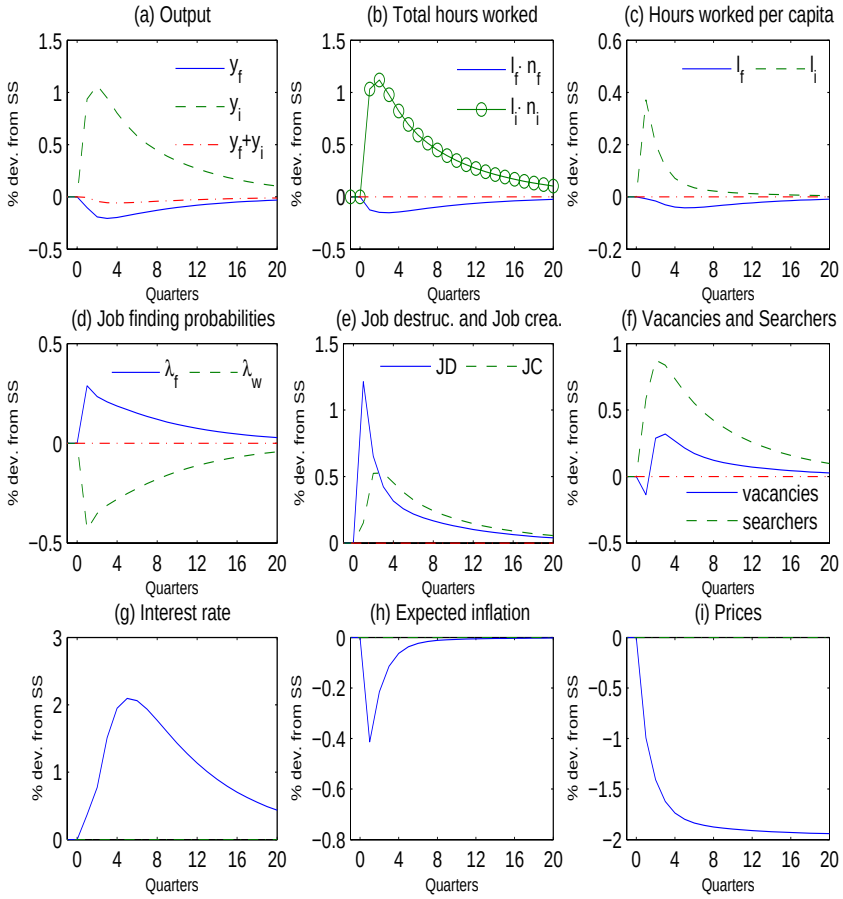

Figure 3: Percentage deviation from the steady-state caused by a contractionary monetary shock.

6 Results

Figure 3 illustrates the impact of a negative monetary shock, a decrease in the growth rate of money g. Since M is constant, a decrease in the growth rate of money increases the nominal amount of the public debt B owned by the banks. An increase in B reduces the liquidity available for transactions in the economy and causes a persistent increase in the nominal interest rate as observed in Figure 3(g). An increase in the nominal interest rate reduces the present value of production and increases the production

cost of formal firms by making loans more costly. These effects generate an increase in the job destruction rate causing a fall in formal employment and hours and, as a consequence, a decline in the output produced by the formal sector.

The increase in the job destruction rate causes an increase in the measure of job searchers and reduces the probability of finding a job in the formal sector thus creating a substitution effect for unemployed workers from searching for a job in the formal sector towards working in the informal sector. This effect induces a rise in the amount of hours per individual allocated to informal activities. Apart from this substitution effect, changes in expected inflation also affect individuals' incentives to work in the informal sector, since expected inflation acts as a tax on informal activities. The reduction in expected inflation increases the present value of informal production and makes more appealing the work in the informal sector. This effect together with the substitution effect explain the increase in hours worked in the informal sector after the first year. Both the increase in the number of hours worked in the informal sector and the increase of informal labor supply caused by the fall in formal employment lead to an increase in the output produced in the informal sector as shown in Figure 3(a).

These results are consistent with the stylized facts of monetary policy mentioned in the introduction that after a negative monetary shock output and employment observed decrease, which in our model corresponds to output and employment of the formal sector. More relevant in our case is that these results are also consistent with the empirical evidence we have presented that output in the informal sector increases after a contractionary monetary shock, which suggests that a contractionary monetary shock induces a switching of activities from the formal towards the informal sector. Since firms in the informal sector use a less productive technology than formal firms, this switching of activities still has a modest negative effect on output, but much smaller than the observed in the formal sector.

Figure 4 shows the response of an economy with a large informal sector, 25% of formal output, to a negative monetary shock. To generate this economy we increase the productivity of informal firms with respect to formal firms from $\delta_p = 0.4665$ to $\delta_p =$

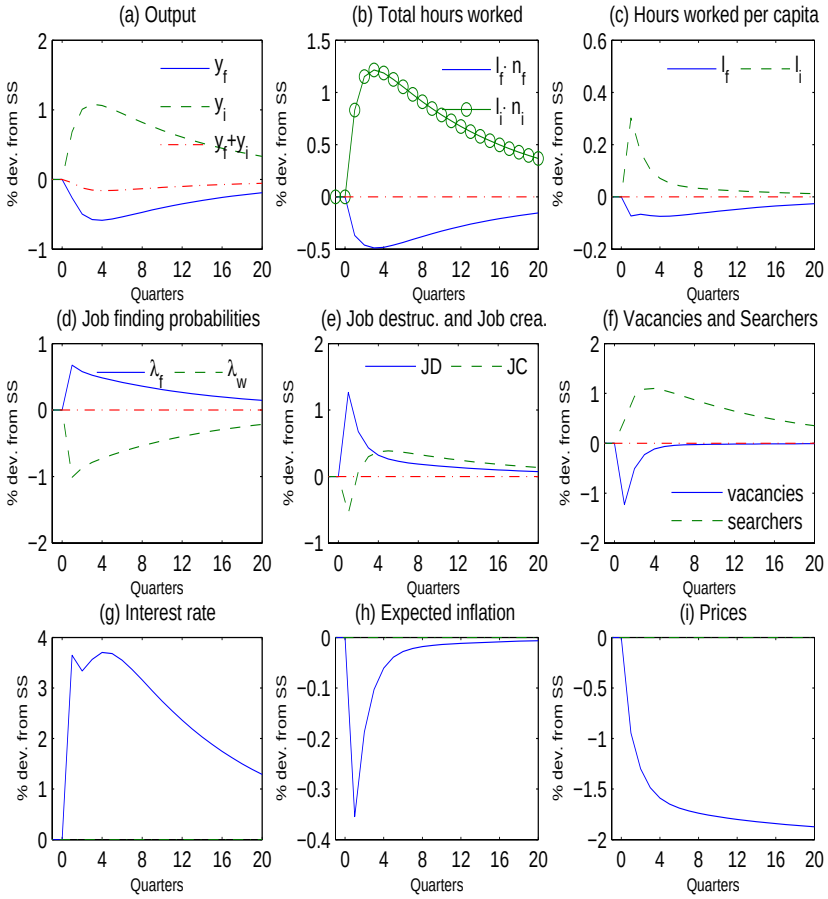

Figure 4: Percentage deviation from the steady-state caused by a contractionary monetary shock. Large informal sector.

0.5131. The response of the economy is qualitatively similar for almost all variables. The main observation is that the responses are larger and more persistent than before. The effect on total output, however, continues to be very small.

7 Conclusions

Many studies have found that informal economic activity is a fact in market economies. Some claim that its share in measured GDP has been increasing in for the last 20 years

to make the informal economic sector a significant phenomenon in many countries. For this reason, it is important that policy makers have a better understanding of both the causes of informal sector activity and its reaction to economic policy measures. While there exist studies on the effects of fiscal policy, social welfare, and institutions' quality on the informal sector we lack understanding of how, if at all, informal sector activity is affected by monetary policy. This paper makes a step towards estimating potential effects of monetary policy on informal sector activity and understanding the mechanism behind these effects. Our first findings are that informal sector activity reacts very different to monetary policy than that in the formal sector. In order to get some insight of this somewhat surprising result we begin by examining the differences between the two sectors. In our opinion, two important differences have the potential to explain this result. First, informal sector activity typically does not have access to external financing and therefore is not directly influenced by liquidity effects. Second, informal sector activity makes its transactions mainly in cash, so that inflation acts as a tax on these transactions. Based on these two observations, we build a two-sector monetary business cycle model that captures quite well what we have found in our estimation. Our next step is to repeat the estimation for various countries with significant informal sector, such as Spain, Italy, and Greece, and to calibrate the model to these economies incorporating aggregate uncertainty. This will allow us to study the business cycle properties and bring us better understanding of how the mechanism works.

As noted earlier, our model accounts for the part of the informal sector that is due to the decisions of the labor force, both official and unofficial. We keep out of our model fiscal causes and the decision of production firms to keep (part of) their activity unreported to fiscal authorities. It is relatively straightforward to incorporate distorting taxes in the model and it is left as future work.

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