THE MEASUREMENT OF UNDERGROUND ECONOMY: A DYNAMIC-SIMULATION BASED APPROACH

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The measurement of underground economy: a dynamic-simulation based approach

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Abstract

This paper presents a theoretical contribution to model and dynamically analyze underground economy.

We build a DSGE model with two sectors and one homogeneous good produced either by the sunlight and the underground firm. The sunlight firm is subject to distortionary taxation, whereas the underground firm evades taxation. The economy is subject to stochastic uncorrelated technology shocks on total factor productivity on private sectors and public labor.

The demand side of the economy is populated by an infinite number of households with preferences defined over legal good consumption, public expenditure and labor services on a period-by-period basis.

The government collects taxation from the sunlight sector and fights tax evasion through audit activity undertaken by public officers. When detected, underground firms are subject to regular taxation and additional fine payments.

We simulate the model under the productivity shocks for Italy, over the sample 1974:01-2011:02.

We find that in Italy underground economy share of GDP is on average about 23%.

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The dynamic behavior of the model shows that: (i) an efficient audit activity has a negative impact on public accounts thus generating a trade-off between the reduction of underground economy and the worsening of public finance; (ii) sunlight production has a greater relative volatility with respect to underground production; (iii) all variables of the underground sector appear to be negatively correlated with the corresponding ones of regular economy. This implies that underground activity is a sort of buffer for the economy, whenever the business cycle is in downturn phases.

Keywords: underground economy; sunlight firms; underground firms; tax evasion; audit activity

JEL classification codes: D58; E26; E32; K42
1 Introduction

Non observed economy is defined as the group of economic activities not directly measured in GDP by official statistics.

According to OECD definition (2002), several types of activities belong to non observed economy: underground economy, criminal economy, informal economy and the deficiencies in data collection programme, that are the so-called statistical underground.

Underground economy is the set of goods and services which, although not violating any criminal law, are deliberately concealed from the tax authorities for one or more of the following reasons: to avoid the payment of taxes and social security contributions; not having to be subject to certain legal requirements such as the minimum wage, quality standards, safety in the workplace and maximum hours of work. There are also activities that can be partially included in the underground sector as they are in part declared to the tax authorities, whereas the remainder part is hidden. An example of this fact could be a firm that under-reports its revenues in order to obtain a tax saving or declaring a number of employed workers less than effective to pay less social security contributions.

Criminal economy, instead, concerns the set of activities carried out in violation of criminal law or legal activities undertaken without any necessary legal requirements (abusive practice of a profession). By definition an illegal (or criminal) activity is also underground, as the violation of criminal laws does not generate any incentive to declare itself to the tax authorities. Even in criminal sector there might exist partially criminal activities in the sense that for a share they are sunlight or underground activities and for the remainder share they are illegal. An example of this may be the phenomenon of usury in which many sunlight firms incur, in the presence of credit rationing or for an underground firm in order to maintain its anonymity.

Informal sector refers, as the underground economy, to the production and sale of completely legal goods and services, but it is characterized by units with a low level of organization, in which there is a low (if not almost absent) distinction between capital and labor. The objective of these activities is to
generate income and employment mainly for persons involved in the activity. An example of this type of activity is the home production. Despite informal economy does not have the primary purpose of tax evasion, it may also be the case of an economic activity carried out on a small scale that not declares itself to the tax authorities for a tax saving and/or because the entrepreneur does not intend to undergo bureaucratic and administrative procedures.

Statistical underground regards to activities that are not recorded for some deficiencies of the statistical system. The causes of this phenomenon are generally due to:

- misclassification, under which a company that should be included in a survey is excluded;
- lack of response in the questionnaires, either because the firm does not answer to one or more questions, or for technical mistakes (e.g. by sending the questionnaire to the wrong address);
- values filled in questionnaires lower than the real ones because the firm under-report them (if the same applies to the tax authorities at the same time there is a statistical and economic underground) or because they are wrongly typed or omitted by the statistician.

Among all these activities belonging to non observed economy, in this work we will focus on underground economy.

According to Shneider et al. (2010) in 2007, the adjusted average incidence of underground economy on GDP for 162 countries of Eastern Europe, Central Asia and high income per capita OECD amounted to more than 1/3.

The estimation techniques adopted by the empirical literature for underground economy are divided into direct methods, indirect methods and MIMIC models.

Direct methods are based on inductive microeconomic approaches that include sample surveys with voluntary response on production, labor, expenditure, income tax audits. Results validity depends crucially on sample quality and on respondents willingness to cooperate, which is not always granted. In any case, direct investigation may provide detailed information about the underground economic structure, which is not recoverable with other methods.

The reluctance of respondents to cooperate is fully overcome by the method of fiscal controls. The discrepancy between income declared for tax purposes and income detected by selective controls provides an estimate of the underground
economy. Notice that these direct methods can only provide point estimates. Thus, there is a lack of knowledge of underground economy growth in time.

Indirect methods are based on macro-economic approaches which use, as a benchmark for the underground economy, the performance of some economic fundamental variables. For instance, an estimate of the underground economy can be obtained measuring the discrepancy between national expenditure and income statistics. Given the fundamental national accounting equality between aggregate income and expenditure, the gap between this latter and the measured income can be used as an indicator of the extension of the underground economy. The reliability of this estimate, however, is strongly affected by all errors and omissions typical of national accounts.

Another approach is based on transaction analysis (Feige and Douglas 1979, Feige, 1990 and 1996). Assuming a constant relationship over time between transactions and official GDP, as summarized by the well-known Fisher’s quantity equation:

\[ M \times V = p \times T \]  

\((M = \text{money supply/demand}, V = \text{velocity of money circulation}, p = \text{absolute level of price} \ T = \text{total transactions}),\) the difference between total transactions and GDP can provide an estimate of the underground economy.

The currency demand approach assumes that underground transactions are carried out only with cash payments (Cagan, 1958 and later Tanzi 1980, 1983). This implies that an increase in underground economy volume would necessarily yield an increase in currency demand. Econometric estimation of this excess in money demand provides the basis to estimate underground economy. This approach had great success in the past, applied in many OECD countries, although it has been subjected to harsh criticism, because of the risk of overestimate the phenomenon: in fact also criminal economy transactions make use of money.

The physical input method (Kaufmann and Kaliberda, 1996) is based on electricity consumption, which is considered a reliable estimate of overall economic activity within a country, given the well known universal correspondence between economic activity and electric power consumption. Thus, subtracting from this latter quantity the official GDP estimates we can obtain an estimate of the underground economy.

As example of these methods, consider estimates shown in 1 (using physical input method for Poland and Hungary, and the money demand method for all other countries). Notice a clear overestimation of the phenomenon, due to
weaknesses underlying these approaches. Indeed, an increase in cash demand or an increase in electricity use is not necessarily due to an increase in underground economy.

It is by now clear that direct and indirect approaches are somewhat partial and thus unsatisfactory, because of the failure to jointly consider all the effects of the underground economy, which occur simultaneously on production, labor market and money markets. The MIMIC model approach (Giles, 1999) attempts to overcome this difficulty, taking into account the stochastic nature of unobserved variables. In particular, the MIMIC (multiple indicators–multiple causes) model assumes that underground economy is a latent variable, explainable by determinants (indicators and causes) such as burden of taxation and regulation, citizen propensity to join the irregular sector, monetary transactions, labor market participation and production level in the regular sector. Structural equations typically define relationships between observed and non-observed variables providing a more realistic picture of the underground economy. However, there remain concerns about reliability of these variables and computation difficulties.

This paper aims to provide an alternative technique, but complementary to the existing methodologies. Following the seminal works of Ingram et al. (1997) on house-production, Argentiero et al. (2008) and Bagella et al. (2009)
on money laundering, we construct a dynamic stochastic general equilibrium model (DSGE) in which there are two sectors:

1. a sunlight firm, which produces a legal good and pays taxes and social security contributions;

2. an underground firm which, although producing the same legal good as the sunlight firm, if it is undetected (with an endogenous certain probability) it won’t pay any form of tax and therefore has a higher profit than the sunlight firm; if, instead, it is discovered evading, it will pay taxes and social security contributions as the sunlight firm together with a fine.

The economy is subject to stochastic uncorrelated technology shocks on total factor productivity on both these sectors and public labor employed in the audit activity.

The demand side of the economy is populated by an infinite number of households with preferences defined over legal good consumption, public expenditure and labor services on a period-by-period basis.

The Government not only collects taxation and fines from the two sectors, but has also a driving role in the fight against tax evasion through audit activity.

In particular, the higher is the auditor effort, the lower will be the probability of success in belonging to underground economy.

Then, under an appropriate parameterization, we simulate the model with productivity shocks; we perform this analysis for Italy over the sample 1974:01-2011:02.

The choice of Italy is related to the dimension of the underground economy in this country, much higher than other developed countries.

We find that in Italy underground economy has an average weight on total GDP of 23%, a value about 6% higher than Italian National Statistical Office (ISTAT) last estimations (2010). Notice, however, that ISTAT estimations are mainly based on labor input and do not directly take into account capital stock and some other important aspects such as the role of the Government in the prevention and repression activities of the underground economy.

The model dynamics shows that sunlight production has a greater relative volatility with respect to regular production: this result is driven by sunlight capital stock, that is much more volatile than underground capital stock; sunlight labor input, instead, has a volatility equal to the half of that of underground labor input.
In fact capital stock has a lower degree of mobility than labor; furthermore, in the presence of better live conditions in the sunlight sector (positive phases of the business cycle), the workers prefer to have the protection provided by a social security insurance system rather than the risks (accidents, the lack of any form of social protection) related to an underground activity.

Moreover, all variables of the underground sector appear to be negatively correlated with the ones of regular economy, showing that they constitute a sort of buffer for the economy, whenever the business cycle is in downturn phases.

The paper is organized as follows.

In the next section we briefly revise the two major theoretical contributes on the underground economy. The model structure, its properties and its optimality conditions derived from the Decentralized Economy Problem are set out in the next section 3. In Section 4, we describe the calibration of the parameters. In Section 5, we discuss the dynamic properties of the model resulting from the impulse response function analysis and the simulated time series. In section 6 we conclude.

2 The Underground Economy in the literature

The underground economy is a field of research where there is certainly continuous advancement.

Schneider (2005) attributes the formation of the underground economy mainly to structural reasons: high burden of taxation and labor market regulation would push entrepreneurs to operate in the shadows. Social solidarity measures (such as unemployment benefits) may have a perverse effect when they are excessive. Too severe worker protection legislation could push employers to hire illegal workers or an overly generous welfare system might induce beneficiaries to work in the black economy. A study by Baja and Schneider (2009) on the interaction between underground economy and official labor market confirms precisely this point: there is a definite positive correlation between the high level of social security system and the extent of the underground economy.

Other causes of underground economy are (Zizza, 2002) the industrial structure, as small firms are more easily hidden to the authorities, the increasing volatility of the economy as new technologies may help to conceal production activities, the increase of personal services, tourism and recreational activities, as self-employed activities are more easily concealable.
We deem that underground effects are absolutely harmful to the official economy. In fact, despite the neoclassical view on its desirable effects enhancing competition, it remains true that it depresses the official economy, primarily subtracting resources to public finance.

A fundamental contribution analyzing underground economy effects is the model proposed by Busato and Chiarini (2004), which considers explicitly real business cycle implications of the underground economy.

Given the contribution of non-registered production to national income, it is difficult to understand the cyclical fluctuations without knowing the underground economy effects. Real Business Cycle (RBC) standard models do not take account this important aspect. The model includes explicit definition of the underground economy as an alternative productive sector. Agents are able to shift production resources between the official and underground sectors.

In this way it is possible to appreciate the cyclical properties of the underground economy. The irregular sector, in fact, helps economic agents to cope with downturn phases experienced by the official economy, allowing agents to decide consumption smoothing through optimal allocation of labor between the two sectors.

Another key contribution in research of the effects of the underground economy on the economic system is offered by Orsi et al. (2012). They construct and estimate, using a Bayesian approach, a DSGE model that explicitly takes into account the hidden transactions. They provide estimation of the irregular economy size, study the trend of the phenomenon and test the effects of alternative fiscal policies in an economic environment characterized by tax evasion. They use a structural econometric approach, which has solid theoretical foundation and allows to derive estimates of the variables that are not observed from the equilibrium conditions of a theoretical model.

They estimate the model using quarterly data for Italy in the time interval 1982-2006.

The results of the Bayesian estimates show that the underground size in Italy amounts on average to 23% of GDP, the same value of our simulations, that, instead, take into account the role of public sector in raising the probability of detection of an underground firm.

The dynamic properties of the model show a negative correlation between the cyclical component of the shadow economy and official output. Policy implication is that Italy could improve its fiscal position by reducing taxes or alternatively strengthening enforcement. The optimal solution, however, would
be a mix of the two policies resulting in both welfare improvement and permanent increase tax revenues.

3 The model structure

3.1 The firms

The supply-side of the economy is populated by two kinds of firms, the sunlight firm and the underground firm that produce the same homogeneous good, i.e. a legal good $Y^l$.

There are no barriers to entry, hence there exists a perfect competition market regime.

The firms are owned by households who earn profits in the form of dividends,$^1$ as we will show in the next section.

Total production $Y$ is allocated to these two sectors according to a percentage $\alpha$ for sunlight production and $\beta$ for underground production, so that the sum of the firms’ shares is equal to unity:

$$Y_t^l = (\alpha + \beta) Y_t^l$$
$$\alpha + \beta = 1$$

The production functions have constant returns to scale and use as inputs labor, $n$, and capital, $k$ i.e.:

$$\alpha Y_t = Y_t^s = \lambda_t^s (k_t^s)^\gamma (n_t^l)^{1-\gamma}$$
$$\beta Y_t = Y_t^u = \lambda_t^u (k_t^u)^\delta (n_t^l)^{1-\delta}$$

The superscripts $s$ and $u$ stand for sunlight and underground whereas $\lambda_t^s$ and $\lambda_t^u$ represent total factor productivities (TFP) in these two private sectors. The law of motion of the TFPs is described as follows:

$$\Lambda_{t+1} = \Sigma \ast \Lambda_t + v_t,$$

where $\Lambda_t = [\lambda_t^s, \lambda_t^u, \lambda_t^u]$ is a stochastic disturbance vector including TFP, $\lambda_t^u$ is

$^1$Because in each sector there is a perfect competition among the firms, in the long term there are zero dividends as a consequence of the equality between prices and average costs.
the TFP in the public sector, that carries the activity of underground economy
detection, and \( \nu_t \) is a vector of the shocks’ innovations; the autocorrelation
coefficient matrix \( \Sigma \) and the covariance matrix \( \Xi \) are defined as follows:

\[
\Sigma = \begin{bmatrix}
\varphi_{\Lambda^*} & 0 & 0 \\
0 & \varphi_{\Lambda^*} & 0 \\
0 & 0 & \varphi_{\Lambda^{\omega}}
\end{bmatrix}
\quad \text{and} \quad
\Xi = \begin{bmatrix}
\xi_{\Lambda^*} & 0 & 0 \\
0 & \xi_{\Lambda^*} & 0 \\
0 & 0 & \xi_{\Lambda^{\omega}}
\end{bmatrix}
\]

Notice that in our model firms differ in productive structure and in expected
profit level. Profit crucially depends on the probabilities of being detected when
a firm belongs to the unobserved sector. In this respect, our model differs from
the one of Prado (2011), who assumes that both formal and informal sector
(i.e. underground sector) operate in a monopolistic competition scheme. In this
model it follows that lower productivity firms endogenously choose to operate
in the informal sector.

Define a price vector for this economy as \( [p_t^I, w_t^u, w_t^g, r_t^u, r_t^g, u_t^g] \) where \( p_t^I \) is the final output price, \( w_t^u \) and \( w_t^g \) are sunlight and underground wages, \( u_t^g \) is the wage paid to fiscal authorities to detect underground firms, \( r_t^u \) and \( r_t^g \) are the prices of sunlight and underground capital.

Normalizing next price \( p_t^I \) to unity, the normalized price vector supporting
the equilibrium equals \( [1, w_t^{ue}, w_t^{ge}, w_t^{ug*}, r_t^{ue}, r_t^{ge}] \) where \( w_t^{ue} \), \( w_t^{ge} \), \( w_t^{ug*} \), \( r_t^{ue} \), \( r_t^{ge} \) denote equilibrium prices (see below).

The sunlight firm is subject to distortionary taxation on sales, \( \tau_s \), on labor
wages \( w_t^u \) in the form of social security contributions \( s \), that are a percentage of
the wages payed.

The sunlight firm’s net profit structure is:

\[
\pi_t^u = [\alpha (1 - \tau_s) Y_t - (1 + s) w_t^u n_t^u - r_t^u k_t^u]
\]

where \( n_t^u \) is the labor offered in the sunlight sector and \( k_t^u \) is the capital
invested in the sunlight firm.

The underground firm evades any form of taxation, and hence profits are
higher than those of the sunlight firm, but only if it is not detected evading,
that happens with probability \( d_t \); if, instead, the underground firm is detected
evading, with probability \( 1 - d_t \), it is fined with the same amount of taxation as
the sunlight firm plus a penalty factor, \( \vartheta^u k_t^u \) with \( 0 < \vartheta^u < 1 \), that is a fraction
of the capital invested in the underground firm. The underlying idea is that tax
evasion is relatively more costly for society if it is undertaken by a big-size firm. Thus, the sanction should be greater in this case than for the small-size firm.

The underground firm’s expected profit structure is:

\[
E(\pi^n_u) = d_t(\beta Y_t - w^n_t n^n_t - r^n_t k^n_t) \pi^n_u + (1 - d_t) [\beta (1 - \tau_s) Y_t - (1 + s) w^n_t n^n_t - k^n_t (r^n_t + \vartheta^n)]
\]

Notice that the first part of the sum identifies underground firm profits in the case of not detection (\(\pi^n_{u,n} \)), whereas the second part represents profits whenever the underground firm is detected evading (\(\pi^n_{u,d} \)).

### 3.2 The households

The demand-side of the economy is populated by an infinite number of infinitely-lived households with preferences defined over private consumption \(C^t\), with share \(\eta^t\), public consumption \(G_t\), with share \(1 - \eta^t\), and labor services \(N_t\). These latter are allocated to regular production (\(N^s_t\)), underground production (\(N^u_t\)) and audit activity (\(N^{gu}_t\)) on a period-by-period basis.

Public expenditure is entirely allocated to the audit activity, which is financed by taxation and considered exogenous by consumers.

Each agent aims to maximize the expected value of an intertemporal utility function, i.e.:

\[
E_0 \sum_{t=0}^{\infty} \rho^t U_t (C^*_t, N^s_t, N^u_t, N^{gu}_t, G_t)
\]  

with \(\rho^t\) corresponding to the subjective discount factor.

We assume that there is an idiosyncratic cost in supplying labor in the underground sector, \(B^u > 1\) (similarly to Busato and Chiarini, 2004, and Argentiero et al., 2008). We rationalize these costs as the lack of social protection for those workers who decide to work in the underground economy.

Let the period utility function assume the following form:

\[
U_t = \eta^t \left( \frac{c^n_t}{1 - q_1} \right)^{1 - q_1} + (1 - \eta^t) g_t - \frac{(n^n_t)^{1 + \psi}}{1 + \psi} - B^u \frac{(n^u_t)^{1 + \omega}}{1 + \omega} - \frac{(n^{gu}_t)^{1 + \kappa}}{1 + \kappa}
\]

There are three resource constraints in our model; the first two regard the
allocation of labor and capital services (sunlight and underground), i.e.:

\[
\begin{align*}
    n_t &= n_t^s + n_t^u \\
    k_t &= k_t^s + k_t^u
\end{align*}
\]

The third one is typically an intertemporal budget constraint, stating that the total flow of consumptions and investements, indicated with \( x_t^s \) and \( x_t^u \), cannot exceed disposable income, net of taxes\(^2\):

\[
c_t^s + x_t^s + x_t^u \leq \left(1 - \tau^s\right) w_t^s n_t^s + \left(1 - \tau^k\right) r_t^s k_t^s + \left(1 - \tau^u\right) w_t^u n_t^u + \left(1 - \tau^l\right) k_t^u + \left(1 - d_t\right) \left[ \left(1 - \tau^s\right) w_t^u n_t^u + \left(1 - \tau^k\right) r_t^u k_t^u \right] + \pi_t^s + \pi_t^u + \pi_t^l
\]

(3)

where \( \pi_t^l \) is a measure of public sector profits equal to the difference between tax revenues and audit activity expenditure. If public sector profits turn negative, a lump-sum taxation has to be paid by households, so that the Government budget is balanced in each period.

Capital accumulation constraints are:

\[
\begin{align*}
    x_t^s &= k_{t+1}^s - (1 - \Omega)^s k_t^s \\
    x_t^u &= k_{t+1}^u - (1 - \Omega)^u k_t^u
\end{align*}
\]

where \( \Omega \) indicates the rate of capital depreciation.

### 3.3 The Government

In this framework the Government aims to maximize an expected profit function given by the difference between the expected fiscal revenues and the audit costs paid to detect underground firms:

\[
[C(A)]_t = n_t^{su} w_t^{su} (1 + s)
\]

\(^2\)For the sake of simplicity, we do not consider the share of social security contributions payed by the workers, that in general is much lower than the one payed by the firm.
These costs are represented by gross wages paid to public officers involved in the audit activity. The output of this activity is given by the probability of being detected in the underground sector according to the following production function

\[ 1 - d_t = \frac{n_t^{gu}}{\mu_t^u + n_t^{gu}} \]

This function is concave with the variable \( \mu_t^u = \frac{1}{\gamma^u} \) indicating the degree of concavity, that here represents a degree of efficiency in audit activity. In fact, given a (positive) level of \( n_t^{gu} \) and \( \mu_t^u \), if \( \mu_t^u \to 0 \) then \( 1 - d_t \to 1 \), hence there is maximum efficiency, i.e. any audit activity is able to completely annihilate underground economy. If, instead, \( \mu_t^u \to \infty \) then \( 1 - d_t \to 0 \), that is the case of complete inefficiency, i.e. any audit activity is totally unsuccessful.

Let us analyze what happens when audit costs increase or decrease, for each level of \( \mu_t^u \).

Given a (positive) level of \( \mu_t^u \), it is easy to show that if \( n_t^{gu} \to 0 \) then \( 1 - d_t \to 0 \) and if \( n_t^{gu} \to \infty \) then \( 1 - d_t \to 1 \).

Therefore, from these considerations the following proposition holds:

**Proposition 1** Underground sector can be completely eliminated either with a maximum efficiency in the audit activity or by spending an unlimited resource amount for a given a level of efficiency.

The expected fiscal revenues, \( E(R) \), given by the sum of fiscal revenues levied on sunlight firms and households’ income taxation, \( R^s \), and expected fiscal revenues levied on underground firms and households’ income taxation, \( E(R^u) \), is:

\[
E(R_t) = R_t^s + E(R_t^u) = \tau_s Y_t + sw^s n_t^s + \tau^n w^u n_t^u + \tau^k r^u k_t^u + sw^u n_t^{gu} + \tau^n w^u n_t^{gu} + \tau^k r^u k_t^{gu} + \phi^u k_t^{gu} + (1 - d_t) \left[ \tau_u Y_t^u + sw^u n_t^u + \tau^n w^u n_t^u + \tau^k r^u k_t^u + \phi^u k_t^u \right] \]

The Government, for a given level of tax rates and fines, aims to choose an optimal level of audit activity \( (n_t^{gu} > 0) \) which is able to detect tax evaders:

\[
\max_{n_t^{gu}} [E(n_t^{gu})] = E(R_t^u) - [C(A)]_t
\]
The optimal levels of tax auditors generate the efficient level of the probability of being detected, $1 - d_t$.

### 3.4 Equilibrium Characterization

In this section, we derive optimal conditions characterizing firms, households and the Government, given a set of parameters whose value will be discussed in the next section.

Each firm faces the following profit maximization problem:

$$\max_{k_t, n_t} [E(\pi_t)]$$

First order conditions are summarized in the next two groups of relationships

$$w_t^{**} = \frac{(1 - \tau_s) \lambda^s (k_t^*)^\gamma (1 - \gamma) (n_t^*)^{1 - \gamma}}{1 + s} = \frac{\partial Y_t^*}{\partial n^s} (1 - \tau_s)$$

$$r_t^{**} = (1 - \tau_s) \lambda^s (k_t^*)^{\gamma - 1} \gamma (n_t^*)^{1 - \gamma}$$

(sunlight firm)

$$r_t^{**} = \frac{\partial Y_t^*}{\partial k_t^s} (1 - \tau_s)$$

From these preliminary results, we are able to make some considerations:

- For the sunlight firm, real wages and interest rates are equal to their marginal productivities reduced by the tax levy on sales, $\tau_s$, and, only for the real wages, also by the tax wedge, here represented by the social security contributions;

- For the underground firm the level of real wages and interest rates, given the tax rates and social security contributions, depends crucially on the probability of not being detected: in fact the higher is $d_t$ the higher will be real wages and interest rates. It’s easy to show that in the polar case
of $d_t = 1$ (zero probability of being detected by the fiscal authorities):

$$r_t^{u*} = \frac{\partial Y_t^u}{\partial k_t^u}$$

$$w_t^{u*} = \frac{\partial Y_t^u}{\partial n_t^u}$$

that represent standard first order conditions for a firm using labor and capital as inputs in the absence of any form of taxation.

In the other polar case of $d_t = 0$ (maximum probability of being detected by the fiscal authorities), real wages and interest rates first order conditions collapse to:

$$r_t^{u*} = \frac{\partial Y_t^u}{\partial k_t^u} (1 - \tau_s) - \vartheta^u$$

$$w_t^{u*} = \frac{\partial Y_t^u}{\partial n_t^u} (1 - \tau_s) + \frac{1}{1 + s}$$

that, for real wages are equal to the sunlight firm first order conditions, while for real interest rates are lower than the sunlight firm first order conditions due to the weight of the fine, $\vartheta^u$.

Let us now analyze the representative household’s behavior.

Each consumer aims to maximize the discounted sum of his expected utility (2) subject to the intertemporal resource constraint (3). Moreover we assume that the initial capital stock is positive, $K_0 > 0$ and given, and that the following inequality constraints hold $C_t^z > 0$, $N_t^z > 0$, $N_t^v > 0$, $N_t^m > 0$, i.e.:
and the following transversal condition holds:

\[
\lim_{t \to \infty} \rho^t \phi_t K_t = 0
\]  
(4)

4 Calibration

Before describing the equilibrium behavior of the our economy under the framework illustrated above, we need to parameterize the model.

Our calibration is based on quarterly data of Italian economy (1974:01-2011:02).

The system of equations we use to compute the dynamic equilibria of the model depends on the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varphi_{\Lambda^s}$</td>
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</tr>
<tr>
<td>$\varphi_{\Lambda^n}$</td>
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</tr>
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<td>$\tau^k$</td>
<td>0.3</td>
</tr>
<tr>
<td>$s$</td>
<td>0.33</td>
</tr>
<tr>
<td>$\vartheta^u$</td>
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</tr>
<tr>
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<td>0.8</td>
</tr>
<tr>
<td>$B^u$</td>
<td>2</td>
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<tr>
<td>$q_1$</td>
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<tr>
<td>$\varepsilon$</td>
<td>3.0</td>
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Parameter $q_1$ is set to 0.5, a value able to match a marginal propensity to consume equal to 0.8, that is the correspondent value for the Italian economy (source: ISTAT) we use to calibrate the preference for private consumption in the utility function, $\eta^l$. 

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The sunlight capital share \( \gamma \) is set to match the share of total output belonging to capital, whereas for underground sector this value, \( \delta \), is supposed slightly lower under the hypothesis that these firms are less capital intensive than the sunlight one, due to the fine proportional to capital held that they have to pay in the case of detection. The parameter \( B^u \) represents the disutility of supplying labor specifically to underground activities. This is intended to be typically risky, both in terms of lack of social insurance and sanctions received in the case of detection; hence the disutility for consumers is high. Technically, this can be seen as a free parameter and is calibrated to 2, that is consistent with a Frisch labor supply elasticity for underground sector \( \left( \frac{1}{0.5} \right) \) equal to 0.5, a much higher value than in the sunlight sector, 0.16\(^3\), to stress that the absence of any form of regulation in the underground labor market make this productive input more flexible than in the sunlight economy. Moreover, the Italian Frisch labor supply elasticity is in general lower than the standard value calibrated for the US economy (i.e. Kydland and Prescott (1982), Cooley and Prescott (1995) and Prescott (2004)).

The values of tax rates are consistent with the same implicit tax rates in Italy: tax rate on capital \( \tau^k \) is set to 0.3, tax rate on labor \( \tau^n \) is set to 0.4 and tax rate on sales equals to 0.2.

The rate for social security contributions \( s \) is set to 0.33, that is the Italian average legal rate for social security contributions paid by the firms.

Following the real business cycle literature (King and Rebelo (1999)), we suppose high values for the persistence coefficients of total factor productivity \( \varphi_{\Lambda^s} = \varphi_{\Lambda^u} = \varphi_{\Lambda^{sc}} = 0.9 \) and for the subjective discount factor \( \phi \) (0.99).

The capital depreciation rates \( \Omega \) are set equal to the ratio between capital depreciation and gross capital stock for the regular economy, i.e. 0.05.

Finally, following Busato and Chiarini (2004), we set the penalty factor \( \phi^u \) to 0.3, that is the surcharge on the standard tax rate that a firm must pay when detected employing workers in underground sector, according to the Italian Tax Law (Legislative Decree 471/97, Section 13, paragraph 1).

Because the model does not provide a description of the trends in the series, we focus on the cyclical component by using the Hodrick and Prescott filter\(^4\).

---

\(^3\) Source: our calculations on ISTAT data.

\(^4\) The model generates time series at a quarterly frequency; after log linear transformation of the series, the trend is computed setting the smoothing parameter to 1600, as the standard value in literature. The cyclical component is obtained as the difference between the actual (raw) series and the computed trend component.
5 The model results and policy analysis

5.1 The impulse response function analysis

The steady state values of the model consistent with the parameterization discussed above indicate for Italy a dimension of underground economy equal to 23% of total GDP; the Italian official estimates\(^5\) underground economy share in GDP are 17%. However despite this latter value corresponds to an upper part of a confidence interval, and hence could overestimate the phenomenon, it does not consider the role of capital in underground economy and the audit activity of the government as we do in our model. In particular, we find a steady state value equal to 0.30 for the probability of being detected as a firm belonging to underground economy, \(1 - d_f\). This value is very similar to the average probability of being audited by the Italian fiscal authorities for the firms and self-employed\(^6\).

We analyze the impulse response functions of model variables in the presence of the technology shocks on both the productive sectors and on the fiscal auditors’ productivity.

When a unitary positive technology shock hits regular sector, sunlight GDP increases two percentage points above its steady state value, whereas the reallocation of labor and capital stock from underground to sunlight sector determines a underground GDP reduction. Increase in regular TFP yields sunlight real wages and capital rents rise with a consequent increase in input demand and supply. Nevertheless there is also a slight increase in the underground rental rate; this is due to the positive effect on private consumption generated by the technology shock. In fact the increase in private consumption leads to a reduction in its marginal utility that generates a capital rental rate rise, through the Lucas asset price equation. Sunlight fiscal revenues increase, whereas underground revenues decrease, but the overall government revenues increase. Labor reallocation towards sunlight sector affects also government; in fact the decrease in public officers’ labor supply generates a slight increase in the probability of success in tax evasion. However, social profits increase due to the prevalent effect of tax revenues.

\(^{5}\)Source: ISTAT.
\(^{6}\)Source: Our calculations on Relazione Annuale della Corte dei Conti 2010 and ISTAT data.
When a unitary positive technology shock hits underground sector, effects on underground inputs and their prices are similar to those for sunlight variables, although smaller in size.

Notably, underground GDP increases but response value is less than one. This happens because there is a probability of being discovered in undertaking an underground activity and because supplying labor in this sector is risky for the worker in (lack of any form of social security insurance). Sunlight indicators decrease with the exception of capital rental that increases in order to balance Lucas asset price equation\(^7\). Total fiscal revenues increase as a consequence of underground revenues increase (although smaller than sunlight revenues increase). Public workers and their real wages decrease with a consequent fall in the probability of detection, \(d_t\).

FIGURES 5-6-7 ABOUT HERE

When, instead, a positive productivity shock hits public workers involved in audit activity, public employment increases and likewise the correspondent real wages. This produces a decrease in the probability of success in tax evasion. Moreover, this audit activity leads to an increase in sunlight labor and capital and in their respective prices, but it generates reduction of underground activity with a decrease in its labor and capital and in their respective prices. This "decline" of underground sector drags down private consumption; the overall effect on total GDP is negative. In this case, even if private consumption decrease should produce a fall in underground capital rent, this variable increases because of the prevalent growth effect of the probability of detection in the Lucas asset price equation. Finally, the growth in audit activity has a negative impact on public accounts: in fact, to reduce the probability of success in tax evasion and hence underground activities size, the government spends more than fiscal revenues recovered with audit. Thus, to restore the previous equilibrium the Government needs to raise taxation. However, the increase in tax burden represents one of the reasons that in Italy pushes the firms into the underground sector.

FIGURES 8-9-10 ABOUT HERE

\(^7\) Also in this case, private consumption raises but less than in the case of sunlight technology shock.
5.2 The numerical simulations

The model is simulated for Italy by generating time series of length 150 quarters, over the sample 1974:01-2011:02.

In the following figure we compare the simulated time series with the HP-filtered values for underground GDP with the actual ones.\textsuperscript{8}

FIGURE 11 ABOUT HERE

The comparison between our simulated time series of the underground economy and the one of ISTAT shows a correlation of 0.32; note that while our series is quarterly and defined over a large period, ISTAT series is annual and publicly available only for eight years (2000-2008).

In the following table (1), instead we summarize the volatilities of sunlight and underground series: in the first column we indicate the volatility of sunlight series, in the second column we put the standard deviation of underground series, whereas the third column measures the relative volatility of underground series with respect to the corresponding sunlight ones:

TABLE 1 ABOUT HERE

The analysis of the second moments of the simulated series indicates a relative lower volatility of the underground GDP with respect to sunlight one: this result is in line with the literature (Busato and Chiarini, 2004 and Orsi et al., 2012).

A possible explanation of this fact can be found in the high tax burden\textsuperscript{9} level present in Italy, that has made possible the formation of a stable parallel economic structure, i.e. the underground economy. Hence, the survival of this sector over time has to be understood as a reaction to difficulty of some firms in paying taxes and social security contributions. Nevertheless, a strong presence of underground economy reduces the possibility for a Government of decreasing taxation.

On the other hand, underground labor input shows an higher relative volatility compared with sunlight labor, because whenever the business cycle moves from a downturn phase to an expansion there is a quick reallocation of labor input towards sunlight sector. The better living conditions insured by the regular economy (social security contributions and insurance against accidents at work) make it convenient for workers to supply labor in a sunlight firm.

\textsuperscript{8}To compare the series with different frequency we empirically covert low frequencies into high frequencies.

\textsuperscript{9}For 2012 in Italy this value is almost 44%.
Capital stock, instead, is much more volatile in the sunlight sector than in the underground one.

Moreover, our simulations show that the hidden feature of the underground economy generates less variations in its productivity than the regular economy.

Finally, from the correlation matrix of our simulated time series (2) it emerges a weak negative correlation between the sunlight GDP and the underground GDP: this result is similar the one found by Busato and Chiarini (2004), Orsi et al. (2012) and Argentiero et al. (2008) for money laundering. We think that a relatively larger GDP could mean greater opportunities, better living conditions and hence a deterrent in being a member of the underground sector. In this respect, unobserved activities would be seen as a "buffer" that economic agents use whenever the business cycle is in downturn phases. Therefore, the increase of regular GDP could weaken the origin of unobserved economy.

We find negative correlation between sunlight and underground labor and capital, although for capital the negative correlation is higher due to the sanction in the case of detection that drives capital stock outside the underground sector when the sunlight sector grows up.

The probability of success in tax evasion, $d_t$, shows a negative correlation with: i) public labor, due to the enforcement role of audit activity against the underground economy; ii) with sunlight capital, because a reallocation of capital stock from irregular sector to regular economy weakens underground firms; iii) with private consumption, because the increase in $d_t$ is linked to a decrease in public labor supply and/or demand that causes an increase of leisure and a reduction of consumption.

These results are quite robust to a sensitivity analysis on the parameters varying them in a neighborhood of ±5%.

6 Conclusions

This paper has derived an alternative methodology, but complementary to existing ones, to build and analyze time series of underground economy.

This technique is based on a DSGE model considered consistent, both in its structure and in the parameter calibration, with the dynamics of the variables involved in the analysis.

The advantage of this scheme is to generate high frequency data for non
observable quantities and to study their relationships on the economic system.

The method used can be considered as a sort of indirect method based on "top-down" estimate which, although not starting from empirical aggregate data it is based on a theoretical macroeconomic model able to generate data qualitatively consistent with the stylized facts.

To the best of our knowledge, this is the first paper that endogenizes the probability of success in tax evasion through the study of a dynamic interaction between fiscal authority and underground firms.

Moreover, our model avoids the confusion between underground and criminal economy; in fact, although also a criminal firm, by definition, evades taxation, in the case of detection it does not emerges with the payment of a fine, but it is forced to close and the workers are arrested.

In a forthcoming paper we aim to analyze the interaction between underground sector, criminal sector and regular sector.

The simulations are carried out for Italy, but they can be repeated for any other country.

The steady state values of our theoretical model show a dimension of the underground economy on total GDP of 23%, which in absolute value means more than 300 billions of Euros. Such data are in line with similar models (Orsi et al., 2012) and slightly higher than the official estimates that, however, do not consider the role of capital stock and the enforcement activity undertaken by fiscal authorities.

This high presence of underground economy in Italy can be explained by an high level of tax burden that pushes some firms in the underground sector, thus generating a decrease in sunlight fiscal revenues (Laffer effect).

The dynamic properties of the model state a negative correlation between underground economy and regular one due to the reallocation of inputs towards the more productive sector. This means that in downturn phases of the business cycle fiscal policy should create the right conditions to not give incentives to firms to join the underground economy together with a strong fight to fiscal evasion.

Moreover, the Government has to pay a price to lower the probability of success in tax evasion, that is the decrease in its profits, resulting from an increase in auditors and/or their real wages.

The proposed analysis is not intended to be a substitute for econometric modeling, but to complete it and integrate it in some aspects as well as borrowing from econometrics some results, as the calibration values of the parameters.
References


7 Appendix

7.1 Tables

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<th>$\sigma_{\text{underground}}$</th>
<th>$\sigma^*$</th>
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<td>$x^s = 2.92$</td>
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Table 1: Volatilities and relative volaties of the simulated series

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<th>$y^u$</th>
<th>$n^s$</th>
<th>$n^u$</th>
<th>$k^s$</th>
<th>$k^u$</th>
<th>$n^{su}$</th>
<th>$d$</th>
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<td>0.99</td>
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<td>0</td>
<td>0</td>
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<td>-0.12</td>
<td>0.99</td>
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<td>0.95</td>
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<td>0.36</td>
</tr>
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<td>0.5</td>
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<td>-0.33</td>
<td>0.6</td>
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Table 2: Correlation Matrix
IMPULSE RESPONSE FUNCTIONS FOR AN ORTHOGONALIZED SHOCK TO SUNLIGHT TFP

FIGURE 2

FIGURE 3

FIGURE 4
IMPULSE RESPONSE FUNCTIONS FOR AN ORTHOGONALIZED SHOCK TO UNDERGROUND TFP

FIGURE 5

FIGURE 6

FIGURE 7
IMPULSE RESPONSE FUNCTIONS FOR AN ORTHOGONALIZED SHOCK TO PUBLIC PRODUCTIVITY

FIGURE 8

FIGURE 9

FIGURE 10
ACTUAL AND SIMULATED HP-FILTERED TIME SERIES FOR ITALIAN UNDERGROUND ECONOMY

FIGURE 11

UNDEGROUND GDP (HP FILTERED SERIES)

UNDEGROUND GDP (LEFT SCALE)  SIMULATED UNDEGROUND GDP (RIGHT SCALE)
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