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Abstract

In this paper we develop a theoretical framework to analyze the long-run behavior of an economy characterized by a regime of persistent debt. We introduce a stock-flow consistent dynamic model where the economic system is represented by a network of trading relationships among agents. Debt contracts are one of such relationships. The model is characterized by a unique and stable steady-state, which predicts that (*i*) aggregate income is always limited from the above by the money supply and that (*ii*) debts cause a redistribution of borrowers' wealth and income in favor of lenders. In the aggregate this may also lower nominal income, as empirical evidence suggests.

Keywords : Debt, stock-flow consistency, dynamic systems
JEL classification : C61, D31, E21, E51, G01

1 Introduction

After about three decades of "real" economic theorizing, the 2008-2009 crisis has produced among the economists a renewed interest in the role of debt and financial variables in general. One important research question refers to the long-run consequences of a regime of persistent debt (both public and private).

The existing theoretical literature on debt offers different answers according to the perspective assumed. Microeconomic theories generally agree on a

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positive view of debt, which is seen as an extra resource to finance – otherwise not affordable– productive investments or to implement welfare-enhancing consumption smoothing. More problematic is the position of macroeconomics: while there is an acknowledgment for the short-run benefits of public deficits during recessions, in general macro models tend to predict a negative role for both public and private debts because of their alleged capacity to introduce microeconomic distortions or to destabilize the regular course of business. Without any pretension of completeness we only recall some seminal works. Modigliani (1961) and Diamond (1965) are classical studies relating public debt to a lower pace of capital accumulation because of crowding-out effects and raising taxes. Neoclassical debt-augmented growth models also predict a negative long-run impact of public debt. On the side of private debts, macroeconomists generally focus on the reinforcing feedbacks between real and financial variables produced by firms' balance sheet conditions (leverage). Fisher's Debt-Deflation theory (1933) probably represents the first detailed analysis of the issue, and moreover served as an inspiration to the Financial Instability Hypothesis by Minsky (1982) and to the Financial Accelerator mechanism by Bernanke and Gertler (1989). Both of these theories, the former by stressing the role of expectations and the latter the role of asymmetric information, show how corporate debts can amplify the movements of real sectors and prompt recessions. Along the same lines are Greenwald and Stiglitz (1993) and Kiyotaki and Moore (1997). Another strand of contributions focuses on the adverse impact of external debts in developing Countries, such as Krugman (1988). These results find some confirmation from the empirical literature, as for instance in Checherita and Rother (2010) and Cecchetti *et al.* (2011), which find a negative relationship between growth and high levels of both public and private debt. Even stronger is the empirical evidence confirming the detrimental effects of external debts on developing Countries' growth, as found among the others by Pattillo *et al.* (2002) and by Clements *et al.* (2003).

However, the above models specialize each one on a particular kind of debt and rely upon very different hypotheses: basically, we believe that a general model of the pure functioning of debt and its consequences is still to develop. Thus, our aim is to build a theory of debt that could describe its effects on the economy in isolation, without resorting to auxiliary hypotheses such as capital accumulation, asymmetric information, crowding-out, etc.

The character itself of debt will naturally push us to make specific hypotheses: since debts are intertemporal exchanges of assets between heterogeneous agents, necessarily the model is to be dynamic and not based on a single representative agent setting. The economy will be therefore represented by a network of interconnected agents, where nodes are agents and links are trading relationships. The last main requirement, called for by the dynamical nature of the model, is stock-flow consistency, that is the correct specification of the temporal link between stocks and flows. The relevance of stock-flow consistency as a prerequisite to build realistic and reliable macroeconomic models has been stressed not only by (now) minority schools such as the Post-Keynesian one, according to which “flows come from somewhere and go somewhere” (Godley, 1999; Godley and Lavoie, 2007), but also by prominent orthodox economists (Tobin, 1969; 1982).

Our findings, qualitatively in accordance with the empirical evidence, are straightforward: in the long-run debts determine a redistribution of income and wealth from debtors to creditors. Thus, highly indebted agents will experience a lower capacity to spend. In addition, if debtors, as it is reasonable to believe, have a higher marginal propensity to spend than creditors', then debts will also reduce aggregate spending, opening space to a wide range of policy interventions. These results may not come as a surprise to some Keynesian but we want to claim the added value of our modeling approach: generality and parsimony of assumptions.

The rest of the paper is organized as follows. Section 2 introduces the baseline model without debts, proves the existence of its equilibrium and looks at the aggregate behavior. Section 3 embodies debts into the model deriving the main results. Section 4 concludes.

2 The baseline model

Consider an economy operating in continuous time that is structured as a network of n infinitely lived economic agents. The exact nature of the agents does not need to be specified because in principle our approach can encompass any real economic system. We point out that from a formal viewpoint our model can be also conceived as a neural network or as a deterministic and analytically solvable agent-based model.

Each agent i is characterized by the state variable $W_i(t)$, standing for its current stock of monetary wealth, and by the flow variables $E_i(t)$ and $I_i(t)$ denoting respectively current expenditure and income. Expenditure is treated as money flowing out of one agent and received as income by another agent, what is sufficient to imply the identity between aggregate income and expenditure. Note that here expenditure is to be intended in a broad sense: according to the kind of agents that are exchanging money it can account for any form of spending, such as purchases of goods and services, productive investments, payment of wages, etc. The only transactions that we want to explicitly rule out are those related to debt contracts, which will be included in the next section. As a consequence, the money supply is a constant, so that we can assume $\sum W_i = M$ for each t.

As anticipated, our fundamental assumption is the imposition of consistency between stocks and flows, which requires that flows must originate from stocks and in stocks they must accumulate without leakages or undue additions of money. Formally, two variables $(x(t), y(t))$ are generally said to be stock-flow consistent (Patterson and Stephenson, 1988) if

$$dx(t)/dt = y(t). \tag{1}$$

For example, if y denotes investments then x is the capital stock, or if y is savings then x is the stock of wealth. In our setting the law of motion for the wealth of the generic agent i will be:

$$\dot{W}_i(t) = I_i(t) - E_i(t). \tag{2}$$

However, equation (1) is only a necessary condition for consistency as it simply defines the law of motion for a stock variable, but does not impose any particular restriction on the behavior of the flows. In other words, it says where flows are going but not where they are coming from. Therefore, in order to complete the implementation of stock-flow consistency we need to determine how $E_i(t)$ is financed, while $I_i(t)$ will be automatically obtained by the aggregate identity between income and expenditure. In what follows we explain how.

From a logical point of view a time interval separates the flows of income and expenditure. When an income is earned by an agent, it cannot be simultaneously used to finance expenditure: first it turns into a wealth stock in accordance with equation (2), and then it can be spent. Consequently, current income cannot be a *direct* source of current expenditure. At first glance this statement would seem to clash with the established view according to which income determines expenditure, and in fact it does if we do not consider the proper time interval. If we observe an agent for a long period of time, for example one year, then expenditure $E_i(t)$ relative to this period can hardly be assumed as independent of the contemporaneous income $I_i(t)$. Indeed, almost all expenditure would be financed out of income. Nonetheless, if we consider a period of one quarter, then it is reasonable to think expenditure as largely but not totally financed out of the income earned during the same quarter. Thus, considering shorter and shorter time intervals, we can arrive to conceive a time unit that is small enough in order to be justified in regarding individual expenditure as totally independent, within this period, of individual income. Call this time lapse dt. Of course, real agents are in general characterized by different dt's. For example, a worker receives his income on monthly basis, so in this case dt would correspond to one month, while if we consider an agent making money on daily basis as a seller, then dt would be one day. In order to cope with this heterogeneity it is sufficient to us assuming that the chosen dt corresponds to the smallest among all the agents. To convince the reader, we suggest an analogy with the physical system of a reservoir full of water provided with an outlet for inflows and an outlet for outflows: observed for small time intervals, the water entering in the reservoir is not the water that at the same time is going out.

By now we have argued that for small time periods current income cannot be regarded as the financing source of current expenditure. So, how might agents finance their spending, considering moreover that they cannot resort to debts? The only possible answer is that expenditure is financed by the buffer of wealth available to each agent at the beginning of the period dt. Basically, we are stating that in absence of debts a cash-in-advance constraint must hold. As a consequence, even though from a behavioral point of view expenditure may be any function $f_i(t)$, wealth must always provide an upper bound such that

$$E_i(t) = \min\{f_i(t), W_i(t)\}. \tag{3}$$

Hence, the logical chain backing our definition of stock-flow consistency can be summarized as: $W(t) \to E(t) \to I(t) \to W(t + dt)$.

Finally, to keep the model simple we assume that current expenditure is proportional to wealth:

$$E_i(t) = c_i W_i(t), \tag{4}$$

where c_i is the marginal propensity to spend[1]. Equation (4) satisfies the cash-in-advance constraint (3) and is also an economically reasonable behavioral rule. The condition $c_i \leq 1$ must hold true since we are not considering debts.

[1]However, this is a marginal propensity to spend out of wealth and not out of income.

Hence, agents can spend at most what they posses. Notice that here c_i is treated as a parameter, but in principle nothing prevents it from varying with time, provided it stays within the postulated boundaries.

Since the economy is populated by n agents we may imagine that expenditure E_i is shared among different partners of agent i, so with a slight abuse of notation it can be generalized by a vector representation:

$$E_i = (E_{i1}, E_{i2}, ..., E_{in}) \equiv (c_{i1}, c_{i2}, ..., c_{in})W_i, \tag{5}$$

where the generic element E_{ij} represents a non-negative flow of money from agent i to agent j such that the sum of the elements is equal to E_i and the sum of the $c's$ is equal to c_i. Obviously we have $c_{ii} = 0$. Grouping the agents all together we define the $n \times n$ matrix $E(t)$ of the expenditure flows generated among all the agents during the period dt:

$$E = \begin{pmatrix} E_1 \\ E_2 \\ ... \\ E_n \end{pmatrix} = \begin{pmatrix} 0 & E_{12} & E_{13} & ... & E_{1n} \\ E_{21} & 0 & E_{23} & ... & E_{2n} \\ ... & ... & ... & ... & ... \\ E_{n1} & E_{n2} & E_{n3} & ... & 0 \end{pmatrix} \tag{6}$$

Matrix E defines the network describing the interaction structure among the agents and is based on the $n \times n$ matrix of coefficients C:

$$C = \begin{pmatrix} 0 & c_{12} & c_{13} & ... & c_{1n} \\ c_{21} & 0 & c_{23} & ... & c_{2n} \\ ... & ... & ... & ... & ... \\ c_{n1} & c_{n2} & c_{n3} & ... & 0 \end{pmatrix}$$

We can now obtain the income matrix $I(t)$. Given E, consider for example its element E_{21}. E_{21} is an outflow from agent 2's point of view, but at the same time is an inflow for agent 1. Thus, while each row represents a profile of expenditure by definition, each column represents a profile of income by construction. From this we can deduce the income profile of agent i:

$$I_i(t) = (E_{1i}, E_{2i}, ..., E_{ni}) \equiv (c_{1i}W_1, c_{2i}W_2, ..., c_{ni}W_n). \tag{7}$$

Consequently, the income matrix is straightforwardly defined as $I = E'$.

Equations (5) and (7) allow to define the dynamics of the system as a whole. Denoting the $n \times 1$ vector of ones with $\mathbf{1}$, equation (2) becomes

$$\dot{W}_i = (I_i - E_i)\mathbf{1} = \sum_j c_{ji}W_j - \sum_j c_{ij}W_i.$$

Rearranging the above expression we get

$$\dot{W}_i = c_{1i}W_1 + c_{2i}W_2 + ... - (\sum_j c_{ij})W_i + ... + c_{ni}W_n \equiv \tilde{c}_i W$$

where W is the $n \times 1$ vector of wealth stocks and $\tilde{c}_i = (c_{1i}, c_{2i}, ..., -c_i, ..., c_{ni})$.

If we define the matrix $\tilde{C}$ as

$$\tilde{C} = \begin{pmatrix} \tilde{c}_1 \\ \tilde{c}_2 \\ ... \\ \tilde{c}_n \end{pmatrix} = \begin{pmatrix} -c_1 & c_{21} & c_{31} & \cdots & c_{n1} \\ c_{12} & -c_2 & c_{32} & \cdots & c_{n2} \\ ... & ... & ... & ... & ... \\ c_{1n} & c_{2n} & c_{3n} & \cdots & -c_n \end{pmatrix}$$

our model can be described by the set of n differential equations

$$\dot{W} = \tilde{C}W, \tag{8}$$

with the additional constraint of a constant stock of money, that is

$$\mathbf{1}'W = M.$$

It is sufficient for our purpose to concentrate ourselves on the steady-state solution. Thus, we should find that vector W^* which satisfies the n conditions $\dot{W} = \mathbf{0}$, that is $\tilde{C}W = \mathbf{0}$, and the money constraint $\mathbf{1}'W = M$. Apparently this task seems impossible to accomplish because we have a system of $n+1$ equations with n unknowns. However, our economy is a closed system and aggregate expenditure is always equal to aggregate income. Consequently, when $n-1$ equations are satisfied also the last one is [2]. Thus, the last equation $\dot{W}_n = 0$ can be omitted, and our system reduces to

$$\Gamma W \equiv \begin{pmatrix} \tilde{c}_1 \\ ... \\ \tilde{c}_{n-1} \\ \mathbf{1}' \end{pmatrix} \begin{pmatrix} W_1 \\ ... \\ W_{n-1} \\ W_n \end{pmatrix} = \begin{pmatrix} 0 \\ ... \\ 0 \\ M \end{pmatrix} \equiv \tilde{\mathbf{0}} \tag{9}$$

Since now the $n \times n$ matrix Γ is non-singular, the required unique and stable[3] solution can be immediately found:

$$W^* = \Gamma^{-1}\,\tilde{\mathbf{0}}.$$

[2]Algebraically, matrix $\tilde{C}$ is singular, what can be easily verifiable by summing up its rows.

[3]That it is also stable should be quite evident: wealth velocity is negatively affected by its own level and positively affected by levels of other wealth stocks. Consequently, if for instance $\dot{W}_i$ is positive, W_i increases and the other wealths decrease because of the constancy of total wealth, thus causing $\dot{W}_i$ to decrease and W_i to slow down.

In the simplest case with only two agents we have $W_1 + W_2 = M$ and $\dot{W}_1 = c_{21}W_2 - c_{12}W_1$. The two steady-state solutions are then

$$W_1^* = \frac{c_{21}}{c_{12} + c_{21}} M, \quad W_2^* = \frac{c_{12}}{c_{12} + c_{21}} M.$$

The equilibrium value W^* does not depend on the initial conditions of W but only on the set of marginal propensities to spend and on the total amount of money. Besides, it shows the distributional implications of the model: the wealth amount of one agent is increasing in the propensity to spend of the other agent and decreasing in its own. The 2-agent case can be generalized to any network of agents by the following statement:

Lemma 1. The equilibrium value W_i^* is decreasing in i's spending coefficients and increasing in those of its partners.

Even though we are able to provide a formal proof to Lemma 1 only for special cases, as for instance when the number of agents is small or the network is a regular ring lattice[4], its general validity can be argued by considering that every expenditure from i to j can increase i's income in the next period only less than proportionally since the spending coefficients are all minus than one: given $\partial E_{ij}/\partial c_{ij} = W_i^*$, it follows that $\partial E_{ji}/\partial W_j = c_{ji} dW_j = c_{ji} W_i^* dt$ since wealth W_j is increased by $W_i^* dt$.

Before proceeding with the introduction of debts, which are the main concern of the paper, we conclude this section by giving a look to the aggregate behavior that can be inferred at equilibrium. The steady-state solution W^* implies, in conjunction with equation (4), the existence for each agent of a constant flow of expenditure $E_i^* = c_i W_i^* \leq W_i^*$. As equilibrium wealth stocks are constant, the equality between income and expenditure for any individual agent follows from equation (2): $I_i^* = E_i^*$. Hence, we can define the steady-state aggregate income Y as

$$Y = \sum_i I_i^* = \sum_i E_i^*.$$

Since $\sum_i E_i^* = \sum_i c_i W_i^* \leq \sum_i W_i^* = M$, it follows that the equilibrium aggregate income in a period dt is a fraction of the monetary stock, that is $Y \leq M$. By using a mean-field approximation we can write it as

$$Y = cM, \tag{10}$$

[4]But computer simulations confirmed the result for any kind of network we tried.

where c is a weighted average of the c_i's, with weights depending on the equilibrium wealth stocks W^*. Equation (10) leads to conclude that the steady-state income Y can increase only if $c \to 1$ and/or if the money stock increases. So, in both cases Y is *always* limited by M. However, this conclusion must be interpreted carefully: it does not mean that an increase in the monetary stock M automatically delivers a corresponding increase in income Y, because the true behavioral parameter here is c. Money stock M only determines the upper bound of nominal income.

3 Debt dynamics

In this section we relax the assumption of absence of debts. We limit to consider the case of additional expenditure financed by selling bonds or other securities which do not cause the money stock to increase, such as mortgages, commercial paper or repos, leaving the introduction of bank loans for future research. The results that follow naturally apply to a setting with a Government that finances public expenditure by selling bonds directly to the market, because in this case the stock of money would not grow.

In order to keep things simple, we assume that borrowers and lenders are two disjunct sets of agents such that who borrows does not lend and vice versa. Let $D(t)$ be the $n \times n$ matrix containing the stocks of debt at time t, where the generic entry D_{ij} stands for the outstanding debt that agent i owes to agent j. During the time interval dt debtors have to pay interests and principal to creditors, so we can define

$$F = (i + a)D \tag{11}$$

as the matrix of the financial flows F_{ij} from agent i to agent j, where we make the simplifications of a uniform interest rate i and of a uniform debt repayment coefficient a. The latter coefficient can be interpreted as the reciprocal of the debt contract length: the bigger a, the faster the debt reimbursement. Finally, we define L as the matrix of current credit flows, whose generic entry L_{ij} stands for the new credits supplied by agent i to agent j. In order to fulfill our stock-flow consistency requirements, we make the additional assumption that for every creditor i the condition must hold:

$$\sum_j L_{ij} \leq W_i - E_i \equiv (1 - c_i)W_i. \tag{12}$$

We recall that by construction F_{ij} and L_{ij} are outflows for i and inflows for j. Consequently, the law of motion for the wealth stocks is[5]:

$$\dot{W}(t) = I(t) - E(t) + \sum(F' + L' - F - L). \tag{13}$$

The system is completed by the law of motion for debt stocks, which in matrix form looks as

$$\dot{D} = L' - aD. \tag{14}$$

It remains to define the loan matrix L. In order to satisfy condition (12) we impose that the total flow of credit be proportional to wealth. So, if i is a lender, we have

$$L_i = (L_{i1}, L_{i2}, ..., L_{in}) \equiv (r_{i1}, r_{i2}, ..., r_{in})W_i, \tag{15}$$

such that $\sum_j r_{ij} \leq (1 - c_i)$. The last condition assures that current lending is not greater than the wealth left after expenditure.

Equations (13) and (14) represent a system of coupled differential equations, whose steady state is given by the pair (W^{**}, D^*). Notice, however, that the system is block-recursive since the equations $\dot{W}$ do not directly affect the dynamic of the debts. Hence, we can first resolve the second block of equations (14), and then substitute the steady state values in the first block (13). Doing so, the sub-system (13) reduces to

$$\dot{W}(t) = I(t) - E(t) + \frac{i}{a}\sum(L - L'), \tag{16}$$

where we used the steady-state solution $D^* = L'/a$ together with equation (11). The flows of interest payments are given by iL'/a and enter in equations (16) with negative sign for debtors, while interest gains iL/a enter with positive sign for creditors. Debt repayments aD^* and new loans L offset each other and in the long run do not affect wealth distribution.

In order to find the steady-state solutions W^{**} we have to carry out some trivial matrix manipulation as in section 2. Rearranging the expression $\sum(L - L')$, equations (16) become

$$\dot{W}(t) = \tilde{C}W + \frac{i}{a}HW, \tag{17}$$

[5] By $\sum X$ we mean the $n \times 1$ column vector of the sum of the columns of matrix X.

where $\tilde{C}$ is the same as in section 2. Rows of matrix H are different for lenders and borrowers because we are assuming the two groups of agents to be separate. Supposing that agent l is a lender, then its row in H is

$$H_l = (0, ..., \sum_j r_{lj}, ..., 0),$$

where the non-null entry is in position l. The row corresponding to a borrower b is

$$H_b = (-r_{1b}, -r_{2b}, ..., 0, ..., -r_{nb})$$

where the null entry is in position b. The system is obviously provided with a unique steady-state solution W^{**} since it is affine to system (8) and its coefficients are chosen in order to satisfy the conservation of money[6]. More interesting is to understand how it differs from the solution W^* without debts.

Let's first consider a lender l. The law of motion for its wealth computed in W^* is

$$\dot{W}_l = c_{1l}W_1^* + c_{2l}W_2^* + ... - c_l W_l^* + ... + c_{nl}W_n^* + \frac{i}{a}\sum_j r_{lj}W_l^*.$$

Since W^* is the steady-state solution for system (8), the summation $c_{1l}W_1^* + c_{2l}W_2^* + ... - c_l W_l^* + ... + c_{nl}W_n^*$ is equal to zero. As a consequence, the time derivative of W_l is positive, implying that at W^* the wealth of a lender is increasing. The presence of the last positive term goes to diminish the spending coefficient of the lender towards the other agents. Thus, by Lemma 1 the value of W_l in W^{**} must be higher than in W^*. The same arguments lead to conclude that the opposite is true for a borrower b, whose steady-state wealth will be lower than in W^* because the derivative

$$\dot{W}_b = c_{1b}W_1^* + c_{2b}W_2^* + ... - c_b W_b^* + ... + c_{nb}W_n^* - \frac{i}{a}\sum_j r_{j\,b}W_j^*$$

is negative. The presence of the last negative term goes to diminish the spending coefficients of other agents towards the borrower and, again by Lemma 1, we have $W_b^{**} < W_b^*$.

In principle nothing can be inferred about those who are neither lender nor borrower, because their income depends on the wealth of their partners:

[6]We also need that the ratio i/a is not too high.

if their income relies more on borrowers (lenders), then their wealth should decrease (increase).

These conclusions are simple but meaningful: in the short-run borrowers (lenders) increase (decrease) their spending by using external finance (lending their savings), but in the long-run their wealth and, consequently, their expenditure will be lower (higher). Thus, the ultimate effect of debts financed without affecting the monetary stock is not of increasing expenditure but of causing a redistribution of wealth in favor of lenders. As one could expect, the entity of this redistribution is increasing in the interest rate i and decreasing in the debt contract duration a. Moreover, if borrowers are likely to have a larger marginal propensity to spend than lenders', then in the long run an economy with debts will be characterized by a smaller average marginal propensity to spend. Consequently, debts not only do not increase nominal income and expenditure, but more likely they will reduce them.

Our result bears non trivial policy implications. In fact, if the Government is one of the borrowing agents, then part of the debts D^* are public debt. Therefore, according to above considerations an economy characterized by higher public debt in the long run will dispose in general of a lower income and in particular of less public expenditure. This outcome is consistent at least qualitatively with the ongoing European debt crisis and with debt crises historically experienced by Latin American and African Countries.

4 Conclusive remarks

The scope of this paper was to investigate the long-run consequences of debt on the economy. Our approach was guided by two major concerns. The first one was, differently from most of macroeconomics, to keep the model as simple as possible in order to develop a pure theory of debt where its effects could be analyzed in isolation without resorting to auxiliary hypotheses such as asymmetric information, crowding-out, expectations, etc. The other concern was to introduce a form of dynamic consistency between stocks and flows, able to assure that "flows come from somewhere and go somewhere".

We first started with the outline of a dynamic model without debt and with constant money supply depicted as a system of differential equations, which predicted that the steady-state aggregate income flow is always limited from the above by the amount of money available to the economy.

Finally, we introduced the possibility for agents of going into debts, while retaining the hypotheses of a constant amount of money. The model so augmented predicted that in the long-run debts determine a redistribution of wealth and income from debtors to creditors. As final effect it may also be that debts lower the aggregate marginal propensity to spend and nominal income. We believe that this conclusion is highly consistent with the empirical literature on the topic and with debt crises experienced in the past decades by developing Countries and currently by Europe.

The case with a variable money supply is left for future research.

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