Structural liquidity: the money-industry nexus

ABSTRACT

This paper addresses the relationship between liquidity and production activity. It argues that this relationship becomes fully evident only if one considers intermediate levels of aggregation, and in particular stages of production within each industrial sector and their interdependence across sectors. To illustrate this, the paper introduces the concept of *structural liquidity*, which denotes material funds that are endogenously formed within the productive system before one considers the provision of liquidity by means of money. Structural liquidity is analyzed by combining (i) the representation of the productive system as arrangement of fabrication stages sequentially related in time; and (ii) the representation of the productive system as a set of interdependent industrial sectors. The analysis identifies the structural liquidity problem as the need to satisfy *both* a viability condition (deriving from sectoral interdependencies) and a full employment condition (deriving from the sequencing of fabrication stages). The analysis highlights a previously unexplored trade-off, which has wide-ranging implications for monetary and liquidity policy.

1. Introduction

The close relationship between production and financial arrangements has been a distinctive feature of modern economic systems at least since the First Industrial Revolution (Deane, 1965; Hicks, 1969; Crouzet, 1972; Kindleberger, 1984; Neal, 1990). The analysis of this relationship, however, often involves accounts that are only of the microeconomic or macroeconomic type. We will argue that the nexus between money and industry becomes fully evident only if one considers intermediate levels of aggregation, and in particular interdependent industrial sectors and stages of production within each sector.

To illustrate this, we introduce the concept of *structural liquidity*, by which we mean material funds that are endogenously formed within the productive system before one considers the provision of liquidity by means of money or the financial system. We show that structural liquidity is generated by interdependencies between productive processes of different lengths. Analysis of interdependencies thus allows us to appreciate the different liquidity needs of different sectors, and different reactions to liquidity provision from the monetary and financial systems.

Our analysis draws on two economic traditions. One is the representation of the productive system as a set of processes extended through time and consisting of arrangements of fabrication stages sequentially related with one another, in the tradition initiated by Adam Smith (1776) and subsequently taken up by Böhm-Bawerk (1890), Strigl (1934), Hicks (1973) and Lowe (1976). The other is the representation of the productive system as a set of interdependent industrial sectors, first formulated by François Quesnay (1759) and systematized by Wassily Leontief (1928, 1941) and Piero Sraffa (1960). The above representations shed light on different but equally important aspects of the production system. Yet they have very rarely been integrated with each other, much less have the implications of such integration been explored. We show that it is by doing so that structural liquidity becomes apparent. In fact, the need to coordinate interdependent processes of different lengths requires the creation flows of liquidity that compensate for different timings in the delivery of outputs.

The paper provides contributions along three main lines of inquiry. First, it combines the above analytical representations, thus bringing to the fore interdependencies between processes of different lengths, and the resulting interdependencies of material and financial flows[1]. Second, it identifies as structural liquidity the type of liquidity that is endogenously formed and required within the productive system. Third, it identifies the structural liquidity problem as the need to satisfy *both* a viability condition (deriving from industrial interdependencies) and a full employment condition (deriving from the sequencing of fabrication stages). The analysis of structural liquidity highlights a previously unexplored trade-off, which has wide-ranging implications for monetary and liquidity policy.

The paper is organized as follows. Section 2 outlines the conceptual premises of a structural theory

[1] This paper considers a productive system in which processes consisting of sequentially arranged stages of fabrication deliver essential intermediate inputs to each other. The issue arises of which time arrangements are compatible with: (i) the full utilization of productive capacities and full employment of labour; (ii) the viability of any given system of specialized processes (processes) delivering essential inputs to each other. Here processes delivering final products are kept distinct from the processes delivering the corresponding intermediate inputs, and there is no vertical integration across fabrication stages, either upstream from final products to intermediate and primary inputs, or downstream from primary and intermediate inputs to final products. This representation of productive activity highlights the relationship between utilization issues and viability issues once time-coordination prerequisites are considered. It is therefore distinct from the representation of production processes as activities vertically integrated along the time dimension (Hicks, 1973; Zamagni, 1984) as it does not explicitly consider bottlenecks arising from the time required to build the capacity needed to deliver final output. This approach is also distinct from the representation of productive activity as a set of vertically integrated subsystems derived from the interdependencies between processes delivering intermediate inputs to each other (as in Sraffa, 1960, Appendix A 'On Subsystems'; Harcourt and Massaro, 1964; Pasinetti, 1973, 1981, 1988; Quadrio Curzio, 1967, 1975, 1986, 1990). The emphasis of this paper is on the time-coordination constraints arising from the integration of specialized processes *of different lengths* in a system of interdependent activities. Its principal research question does not concern the timing of traverse from one fully settled position to another under the influence of horizontal and vertical bottlenecks (Baldone, 1996: Belloc, 1990, 1996). Rather, this paper is concerned with the coordination requirements arising from the interdependence of processes characterized by different lengths, and with the liquidity arrangements needed in order to meet those requirements.

of liquidity. Section 3 introduces the analytical building blocks of our theoretical framework by integrating John Hicks's analysis of the sequential dependence between different stages of a given process of production with Wassily Leontief's analysis of the interdependencies between productive sectors. Section 4 is the conceptual core of the paper. In this section we introduce a scale condition and a proportionality condition as the two separate prerequisites that liquidity provision should meet so as to allow full employment in a productive system of interdependent processes of different lengths. The section argues that there generally is a tradeoff between the two conditions and that in most cases liquidity provision may target one or the other condition but not both. Section 5 discusses the implications of structural liquidity conditions for macroeconomic policy in different institutional set-ups. This section highlights the need of grounding macroeconomic policy in the internal structure of production systems, and of identifying policy objectives and policy trade-offs on that basis.

2. Structural liquidity: a framework

Liquidity is a fundamental structural prerequisite of any economic system that has attained a developed division of labour and specialization of production processes. For division of labour presupposes the technical and organisational coordination of specialized processes of different time durations[2]. In a 'primitive' phase, division of labour may take the form of a set of vertically integrated processes specialized in the production of final consumer goods; in an 'advanced' phase, division of labour may take the form of a circular system of interdependent processes of different time-lengths delivering intermediate inputs to one another (see Ames and Rosenberg, 1965). The coordination of processes of different lengths, which is required in the latter case, can only be

[2] The classical treatments of division of labour in an integrated system of economic activities are provided by Smith, 1976 (1776) and Young, 1928 (see also Robinson, 1931; Ames and Rosenberg, 1965; Rosenberg, 1965; Bianchi, 1983: Kerr, 1993: Scazzieri, 1993; Yang, and Ng, 1993; Yang, 2003; Scazzieri, 2014).

achieved if ‘short’ and ‘long’ processes are connected with one another through *buffers* by means of which: (i) short processes can wait until the productive inputs delivered to them by the long processes are ready; and (ii) long processes can advance their products to short processes that have not yet started and that need them as intermediate (produced) inputs[3]. This condition derives from the internal structure of production and makes visible the structural need for borrowing and lending that leads to the emergence of 'material' debt-credit relationships. The material funds generated by these relationships, which logically precede the introduction of money and the emergence of the financial sphere in the ordinary sense, are what we call *structural liquidity*. The following example may clarify the concept.

Let us consider a simple economy consisting of one process delivering looms and one process delivering cloth. Let us also assume that the two processes are interdependent in the sense that cloth cannot be produced without looms, and that looms cannot be produced without cloth (this would be the cloth needed for the maintenance of workers needed for the making of looms). The distinction between cloth making and loom making, and the different time lengths of the two processes, introduce a lack of synchronization between the flows of products from one process to the other. Let loom making require 20 days from iron smelting to assembling, and cloth making 10 days from spinning to weaving and tailoring. This situation entails that loom makers would be required to deliver a given number of looms at definite times in the cloth manufacturing cycle. Similarly, cloth makers would be required to deliver batches of cloth at definite times in the loom manufacturing cycle. Given the different durations of loom making and cloth making, there would be the need of cloth advances from cloth makers to loom makers, which would allow loom makers to be provided

3 Following Hicks's *Capital and Time* (Hicks, 1973), we may associate short and long processes respectively with labour-intensive and machinery-intensive production activities (see also Böhm-Bawerk, 1890; Strigl, 1934; Magnan de Bornier, 1980, 1990; Zamagni, 1984). Liquidity as a problem associated with material synchronization between short and long processes is identified in Menger (1892), Clark (1899), Strigl (1934), and Lachmann (1956); see also Hicks, (1969) (Chapter ix on 'The Industrial Revolution) and Amendola (1991).

with cloth while waiting for the actual delivery of looms to cloth makers. Correspondingly, the cloth makers would need to be able to produce cloth in sufficient amount so as to allow the accumulation of a 'cloth fund' available outside the cloth-making sector. The need for liquidity is generated by the time asymmetry between cloth making and loom making. The cloth fund would be needed for two different purposes: (i) cloth provision to cloth makers from the spinning stage to the weaving and tailoring stages; (ii) cloth provision to loom makers from one loom-making cycle to the other. In either case, the cloth fund is provided by the excess availability of cloth over what is immediately needed after weaving and tailoring. This entails the formation of a physical *net product* (surplus) of cloth, which in turn explains the greater flexibility acquired by the economic system. For the availability of net produce allows a specific kind of structural 'waiting': loom makers can wait from the start of one cloth-making cycle to the start of another cloth-making cycle thanks to material advances from cloth makers, while cloth makers can wait until the end of each cloth-making cycle thanks to cloth stocks accumulated in the past. In either case, the economic system makes use of the material liquidity generated within the production sphere by the existence of a net product. The cloth net product makes waiting physically possible (provided storage is technically feasible), thus freeing the economic system from the need to produce for immediate consumption.

The possibility of purchase through advance payment (in this case, payment in advance of the material need for looms) highlights the emergence of a material debt-credit relationship. Such a relationship originates from the time asymmetries between different productions processes within an integrated production system, and presupposes the availability of a *material* loanable fund (in our case the cloth fund resulting from the different durations of production processes). Material debt-credit relationships are of fundamental importance, as they emphasize that, in a productive system characterized by division of labour, liquidity may be generated independently of financial debt-credit relationships.

3. Sequential dependence and interdependent processes

As we have seen, time asymmetries between interdependent processes are central to the emergence of liquidity needs within the production system. They are also conducive to the endogenous formation of liquidity stocks at the juncture between processes of different time profiles. This intertwining of linkages between successive stages of production and linkages between processes carried out side by side is at the core of the formation and allocation of structural liquidity. This requires addressing two distinct coordination problems: coordination over time and coordination across specialized and technologically interdependent processes (see also Strassman, 1959; Landesmann, 1986; Leijonhufvud, 1986; Landesmann and Scazzieri, 1990). It is useful to start by examining coordination problems within any given process taken in isolation. We shall then consider the input and output time profiles of a machinery-intensive and a labor-intensive process, and will finally turn to analyse coordination problems when interdependencies between such processes are taken into account.

Within a given process taken in isolation, the issue arises of how many processes of any given type should be active at a given time in order to have continuous utilization of capacity and full employment of labour. Let t_i be the time length of specialized process i ($i= 1... k$) (say, the length of plough making, or that of corn production). Division of labour entails that, in principle, specialized production processes (henceforth *processes*) may be carried out continuously throughout the relevant accounting period (be it the day, the week, or the year). A necessary condition for this is that the number of processes carried out in each period be such as to make each process active throughout the whole period. If each process delivers its output in a fraction n_i/p_i of any given period of duration T (where p_i is the number such that T is divided into a certain number of identical time-intervals), the continuity of operation of all processes is achieved provided each process is performed m_i times in immediate succession, where $m_i = (p_i/n_i)$ [4]. This condition expresses the fact that each process cannot repeat its operations more than m_i times in each period (say, in each working day). When this condition is satisfied, the machinery and labour required in each process are continuously employed throughout the relevant period. The condition makes continuous utilization possible provided the scale of production is m_i or an integer multiple of it[5]. This type of coordination requirement highlights a structural condition for full employment and full capacity utilization within each production process, independently of the relationships between processes of different types.

When moving from a single process taken in isolation to multiple processes, we need to consider the different time profiles of different processes. Figure 1 represents the input and output time profiles of a production process requiring significant capital equipment for its operation (see Hicks, 1973, p. 14). This production profile entails an initial period (*construction phase)* in which there are 'large inputs but no final output' (Hicks, 1973, p. 15), followed by a longer period (*utilization phase*) 'in which output rises from zero to a normal level, while input falls to its normal level' (Hicks, 1973, p. 15). Figure 2 represents a different production process, in which labour only, virtually unaided by tools and machinery, is required as an input. The output and input profiles are different from those in Figure 1. For the output curve starts rising from a point much closer to the beginning of the process, while the input curve, after reaching a much lower peak, falls pretty soon down to its normal level.

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4 See Georgescu-Roegen (1970) and Scazzieri, (1993, pp. 118-20; 2014, pp. 76-79), for a discussion of this condition.

5 If continuous utilization is achieved at scale m_i , any scale increase above m_i would entail a degree of time idleness for the additional processes introduced until scale attains an integer multiple of m_i.

Insert Figure 1 here

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Insert Figure 2 here

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The next step is to consider that in most economic systems with an advanced division of labour specialized processes of different lengths are *interdependent*, in the sense that the output of any given process is required as intermediate input for other processes. As we have seen in section 2, stock formation is a necessary condition for the viability of any given system of interdependent processes in so far as these stocks make available intermediate inputs that could not be produced within each single period. Stock formation in a system of interdependent processes entails a number of important consequences that we explore in what follows: (i) at the beginning of each single period, new processes may start thanks to advances from processes completed in previous periods; (ii) material advances from one period to another make division of labour compatible with the given system of technological interdependencies; (iii) advances from one period to another make transfer of material funds a necessary condition for the viability of any given system of interdependent processes; and (iv) transfer of material funds consistent with viability presupposes a proportionality condition between processs within any given period.

The conditions under which the formation of stocks is compatible with the viability of the system of interdependent processes may be investigated through the matrix below, which represents a system of technologically interdependent stock-flow relationships in a simple two-period set-up:

$$A(t, t+1) = \begin{bmatrix} a_{11}(t, t+1) & a_{12}(t, t+1) \\ a_{21}(t, t+1) & a_{22}(t, t+1) \end{bmatrix}$$

In matrix ***A*** ***(t, t+1)***, each element a_{ij} *(t, t+1*) denotes the quantity of commodity *i* that has to be absorbed in process *j* in order to enable this process to *transfer* one unit of commodity *j* from time *t* to time *t+1* (that is, to enable a unitary increment of the stock of commodity j transferred from *t* to *t+1*). Matrix ***A (t, t+1)*** describes the technological interrelatedness of the processes of stock formation in an integrated production system. It also allows identification of the structural conditions for stock formation once the interdependence of processes within the given system is taken into account. Informally, matrix ***A (t, t+1)*** calls attention to the fact that, in a system of fully interdependent processes, it is impossible to increase the stock of, say, commodity *1* in processes *1* and *2* without a corresponding increase in the quantity of commodity 2 available in process *1* (as commodity 2 is an intermediate input for the production of commodity 1). Similarly, it is impossible to increase the stock of commodity 2 in processes 1 and 2 without a corresponding increase in the quantity of commodity 1 available in process 2 (as commodity 1 is an intermediate input for the production of commodity 2).

The Hawkins-Simon conditions for the viability of a system of interdependent commodity flows (input-output flows) may be applied to matrix ***A (t, t+1)***, where they would specify the feasibility requirements for the intertemporal transfer of commodity stocks.[6] These requirements are

6 If the matrix *A* of technical coefficients is both non-negative and indecomposable, the Hawkins-Simon conditions make sure that any non-negative final demand vector would be associated with a vector of non-negative industrial

proportionality conditions for the formation and absorption of material liquidity that derive from the technological interrelatedness of the different processes and constrain the intertemporal coordination of intermediate product flows between processes. In a system of interdependent processes of different time lengths, the operation of processes presupposes the availability of stocks of goods that can be moved between processes of different types according to their mutual requirements for intermediate inputs. This is because the different lengths of different types of processes make it impossible to meet the intermediate input requirements through transfer of goods produced within each accounting period. Each accounting period can no longer be self-contained and physical goods need be moved *across* different accounting periods.

The foregoing discussion suggests that any given system of interdependent processes presupposes two different conditions concerning the time coordination of processes in that system. First, the *proportionality condition* requires that sufficient stocks of produced goods be available as intermediate inputs at the start of each period. In order for this condition to be met, the completion of each batch of output needs to coincide with the start of production of another batch of output in each process. Second, the *scale condition* requires the continuous operation of processes in each period. This condition is met if each process is performed m_i times in immediate succession, where

outputs (Hawkins and Simon, 1949; Nikaido, 2014; see also Duchin and Steenge, 2007; Steenge, 2011 for an economic interpretation of the conditions). In other words, 'the state of technology expressed by [the technology matrix] is such as to allow a net production, that is an excess production of goods produced relative to goods used as means of production' (Quadrio Curzio, 1967, pp. 56-57). The Hawkins-Simon conditions have an interesting economic interpretation for the case of an economic system of the type considered in this paper, in which a developed division of labour is reflected in a system of interdependent processes of different time lengths. Here, full connectivity (such that each good is directly or indirectly required for the production of any other good) may or may not be accomplished depending on the length of the time horizon under consideration. For example, there could be a time horizon such that the 'short' processes deliver inputs to the 'long' processes without in turn receiving inputs from them. Provision of liquidity through debt-credit relationships ensures full connectivity, and thus the possibility to produce each good in excess of the quantity needed as an input in the productive system as a whole. Thus liquidity becomes a necessary condition for viability once division of labour through interdependent processes is introduced. We may conjecture that this liquidity condition gets increasingly relevant as the economic system moves from a simple division of labour (such as one achieved through simultaneous activation of a set of vertically integrated processes) to an advanced division of labour (such as one achieved though activation of a 'circular' system of fully interdependent processes). Liquidity provision makes processes of different time lengths to be fully interdependent and thus allows the economic system to fulfil the viability requirements.

$m_i = (p_i/n_i)$, as discussed above. The proportionality condition may be satisfied even if the production system operates at a scale lower than the scale compatible with the continuous operation of processes, whereas the scale condition presupposes the endogenous formation and transfer of material funds unless external sources of liquidity are available to the system of interdependent processes. In principle, the scale condition and the proportionality conditions may be jointly satisfied. However, this is unlikely to be the case in practice, as it requires that: (i) the precedence patterns of different processes are such that stocks of produced goods can be transferred from one process to another according to their respective needs for intermediate inputs; (ii) sufficient stocks of intermediate goods are available to allow the start of any new batch of processes; and (iii) there are a sufficient number of processes *of each type* to allow the matching of scale and proportionality requirements.

This situation may be illustrated as follows. Let P_1 (a short process) and P_2 (a long process) be imperfectly synchronized processes of different lengths. P_2 is 'ready to absorb' inputs from P_1 before it is able to exchange its own outputs for P_1's outputs. On the other hand, P_1 needs inputs from P_2 before P_2 is completed. This situation points to a coordination problem, which may in principle be solved by introducing the in-line arrangement of multiple processes of the P_1 and P_2 types. If the in-line arrangement is introduced, we could have one or more processes of type P_2 started one or more time periods before the start of one or more processes of type P_1 (say, at time $t-1$) so as to allow the start of processes P_1 at time t. However, P_2 processes cannot start unless outputs from P_1 processes are available. This means that starting processes of type P_2 presupposes the availability of a stock of goods produced by processes of type P_1. In turn this stock may be completely or partially transferred to processes of type P_2 by introducing a kind of material lending from P_1 -processes to P_2 -processes. In short, time asymmetries between interdependent processes may be at the origin of 'material' debt-credit relationships. For these relationships to be feasible, processes need to be arranged according to appropriate sequences, so that there will be sufficient stocks of goods delivered by long processes *whenever* need for such goods arises within the production system. This arrangement presupposes a 'perfect' fine tuning of start times within the integrated system of processes and is a limit case in which both the scale condition and the proportionality condition would be satisfied. In general, however, the two conditions would not be met at the same time and a trade-off arises between scale requirements and proportionality requirements.

4. Scale, proportionality, and structural liquidity: trade-off and paradoxes

The distinction between scale condition and proportionality condition for time coordination in a system of interdependent processes has far reaching consequences for what concerns liquidity needs and liquidity provision. As we have seen, the two conditions may be jointly satisfied only in a limit case. In general, a viable system of integrated processes may require proportions between material stocks that are only compatible with certain scales and not others, while for any given pattern of specialization full capacity utilization and full employment may be incompatible with the intertemporal viability of the system. The production side of the economy is entangled in a seemingly inescapable tension between the conditions for intertemporal coordination and those for the avoidance of idleness. And what is even more significant, the problem is likely to become more and more serious with increasing division of labour and specialization of processes. The increasing returns advantages traditionally associated with division of labour would manifest themselves side by side with increasing difficulties for full utilization of capacity and full employment.

Take a simple economy in which the cloth and loom processes deliver essential intermediate inputs to each other and no further subdivision of either process is considered. Assume that each cloth-making process delivers its output in a fraction n_c/p_c of each time period, and that each loom-making process delivers its output in a fraction n_l/p_l of the same period. The scale condition discussed above entails full capacity utilization and full employment in both productive sectors provided cloth-making and loom-making are performed, respectively, $m_c = (p_c/n_c)$ times and $m_l = (p_l/n_{wl})$ times within the corresponding sectors. The viability of this cloth-loom economy would require meeting the proportionality condition for what concerns the proportion of cloth production to loom production, and there is no guarantee that the proportion compatible with viability would also meet the scale condition for full capacity utilization and full employment. For there is no guarantee that the m_c/m_l ratio would be the one required by the proportionality condition for viability. In a two-process economy (that is, in an economy with a 'simple' division of labour) it might be relatively easy to get close to the required proportions while also approximating full capacity utilization and full employment in both sectors. On the other hand, in a production system with a more developed division of labour (i.e. a more complex pattern of specialization) cloth-making and loom-making would be split into a number of distinct processes associated with specific scale conditions for full capacity utilization and full employment. Rather than having the two scale conditions $m_c = (p_c/n_c)$ and $m_l = (p_l/n_l)$, we may have a much higher number r of scale conditions $m_i = (p_i/n_i)$, $r = 1,...,q$. As the number of process types r rises, it is increasingly unlikely that full capacity utilization and full employment will approximate the proportionality condition for viability, and vice versa. This property points to what may be called the *Keynes-Smith paradox*. Technical progress and increasing returns through division of labour and process specialization may make it more difficult to simultaneously approximate the scale conditions for full capacity utilization and full employment, *and* the proportionality condition for viability.[7] This riddle highlights the structural constraints to be considered when trying to combine 'Keynesian' and 'Smithian' policy objectives.

[7] This trade-off could prove particularly relevant in the transition from rigid to flexible mass production. We thank an anonymous reviewer for calling our attention to this point.

At this point, it becomes interesting to ask whether the consideration of monetary and financial institutions may provide an escape route to the difficulties that originate at the material level of interdependence, thereby enhancing the overall effectiveness of an advanced system of processes. The introduction of money makes intertemporal coordination independent of the material proportionality requirements expressed by the structural liquidity condition, and allows the system to operate at a scale that would not be compatible with intertemporal coordination at the material level. This is due to the nature of money, which makes debt-credit relationships feasible independently of the double coincidence of needs (Menger, 1892; Ostroy and Starr, 1974)[8]. Under monetary conditions, a mismatch between stocks of goods produced by long processes and stocks of goods produced by short processes can be overcome provided that sufficient stocks of money are available at specific times and at specific interfaces between processes of different durations. For example, we may assume that, in a system of interdependent processes, a number of short processes would need a sufficient number of goods produced by long processes as intermediate inputs. If material stocks of goods produced by long processes are not available, or are not available in sufficient amounts, the integrated system of processes may still be able to work provided that sufficient monetary stocks are available that would allow the short processes to acquire the required stocks of intermediate goods from outside the system of interdependent processes.

This point of view entails that monetary liquidity is central to the working of a sufficiently complex arrangement of processes, because money is essential to overcome lack of synchronisation in a system of interdependent processes. However, for the liquidity function of money to be effective,

[8] The property of money that makes joint satisfaction of scale and proportionality conditions easier in a monetary production economy than in a non-monetary production economy is due to the greater degree of 'saleableness' of money relative to the other commodities (Menger, 1892, pp. 242-3). The fact that money is '*the universal commodity* […] that is universally received in exchange for any other commodity' (Verri, 1998 [1771], p. 21; author's emphasis) has far reaching consequences for the time coordination of processes in an integrated production economy. For monetary stocks may buffer time asymmetries even when material stocks are not useful to that purpose.

money should be available at appropriate times and interfaces within the production system. In short, in a monetary production economy a purely macroeconomic monetary provision does not guarantee coordination. In fact, the material liquidity condition may or may not be satisfied in the system of processes, and when it is not, a monetary liquidity condition must be satisfied. The latter does not assume the coincidence of material stock provision and material stock utilization at specific times within the system of interdependent processes. However, in order for monetary provision to be effective in coordinating processes of different durations, specific timing and availability conditions must be satisfied[9]. If monetary liquidity is not available at the right times and interfaces in the production system, the outcome is likely to be a failure in the coordinating function of money. Structural prerequisites determine the way in which liquidity provision may work as a coordinating device. In a *non-monetary production economy* liquidity can only be of a material kind and fulfilment of the structural liquidity condition presupposes a system of coordinated material stock delivery and use. In a *monetary production economy*, intertemporal coordination may be achieved even in the absence of material stock coordination. A necessary condition for this is that monetary liquidity be available to the different processes according to the same proportions specified by the structural liquidity condition for a non-monetary production economy. In short, money allows overcoming structural bottlenecks if and only if the internal structure of monetary liquidity is consistent with the intertemporal coordination requirements of the production system[10]. This can be seen as follows.

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[9] This condition is inherently structural in so far as it reflects the 'material credit' configuration of the productive system (see above). It is thus distinct from the stock-flow requirements considered in the macroeconomic analysis of investment (Aoki and Leijonhufvud, 1988).

[10] The above framework suggests that money is *not* neutral in the sense that monetary provision may significantly modify the coordination set-up of the economy relative to non-monetary conditions. Structural liquidity would highlight features of monetary policy that are generally overlooked in the Wicksellian or post-Wicksellian discussions of money, interest, prices and crises (see Wicksell, 2001 [ms. 1902-1905]; Hagemann, 2001; Boyanovsky and Trautwein, 2001).

Let the structural liquidity conditions require a distribution of liquidity between processes such that process p_i , whose start needs a material stock delivered by process p_j, has in its place a corresponding monetary stock. If this monetary stock has to be an effective replacement for the required material stock, it must be available to p_i at the right time and in a sufficient amount. However, this is seldom the case, as monetary stocks accumulate within the different sectors of the economy at a pace that could be independent of the viability and full utilization prerequisites expressed through the structural liquidity condition[11]. Under these circumstances, financial institutions may play a critical role in providing external sources of liquidity and thus in making the intertemporal coordination of processes possible. This very possibility, however, is constrained by the same proportionality requirements at work behind the material liquidity condition and the monetary liquidity condition. Financial intermediation can successfully meet the viability requirements of a system of interdependent processes as long as the debt-credit relationships that financial intermediation makes possible are consistent with the need to provide adequate liquidity for intertemporal processes coordination at a given scale of the production system. Here we meet one important condition for effective financial intermediation in a system of interdependent processes: liquidity provision by means of finance presupposes financial institutions capable of delivering the required liquidity *at appropriate times for specific stages of production*[12]. The trade-off between proportionality conditions and scale conditions makes it possible to distinguish

11 The possibility of monetary stock formation independently of the viability conditions for a production economy highlights the difficulties associated with money as a means to achieve the intertemporal coordination of production processes. In fact, 'money concentrates in some groups instead of others' (Tusset, 2014, p.57) quite independently of the scale and proportionality conditions, and this could make intertemporal coordination difficult to achieve. This is one important reason for the differentiated dynamics followed by the accumulation and/or depletion of monetary reserves across different firms or sectors in the different phases of the business cycle (Hunter, 1978, 1982). Monetary regimes may be an important influence on accumulation or depletion of monetary reserves (Hunter, 1982). Alternative monetary regimes may thus entail different conditions for effectiveness of monetary policy (Leijonhufvud, 1995).

12 The relationship between the effectiveness of financial intermediation and the structure of production processes is examined in Gottschalk (2010, 2012); Arena, Cartapanis, Dutraive (2011); Sen (2011).

between different channels through which financial provision may impact upon the system of interdependent processes. Two principal cases can be distinguished. In one case, liquidity provision through financial intermediation meets the liquidity needs for the full operation of the given system of interdependent processes but the liquidity needs for viability are not satisfied. In the other case, liquidity provision through finance meets the liquidity needs for system viability but not the liquidity needs for the full utilization of the existing system of processes. We may conjecture that only by chance, or deliberate and successful ‘fine tuning’, would financial intermediation simultaneously meet the condition for system viability and the condition for full capacity utilization and full employment. However, it is important to realize that this coordination failure is due not to financial intermediation by itself but to a *structural trade-off* internal to the system of interdependent processes. In short, the provision of financial liquidity may be seen as a means to overcome liquidity bottlenecks that make it impossible to satisfy either the viability condition or the full utilization condition. However, financial provision by itself cannot always overcome the structural trade-off between viability and full utilization. This coordination failure has far reaching consequences for the effectiveness of liquidity policy in a macroeconomic setting. For it calls attention to the fact that, in general, a policy targeting the viability of material debt-credit relationships will be different from a policy targeting macroeconomic goals such full capacity utilization and full employment. Ultimately, meeting macroeconomic objectives such as full capacity utilization and full employment may be associated with structural disequilibrium and crises, while structural coherence (viability of material debt-credit relationships) may be associated with underutilized capacity and unemployment[13].

13 The dichotomy between macroeconomic sustainability and the structural sustainability of debt-credit relationships is emphasized in Masera (2008; see also Masera, 1972). Structural economic dynamics makes the two objectives even more difficult to achieve and highlights the need of '[d]ifferent kinds of external interventions' (Amendola and Gaffard, 2008, p. 404; see also Amendola and Gaffard,1998). Specific policy instruments addressing a differentiated range of liquidity requirements are needed for time-coordination in a complex production economy.

5. Concluding remarks

This paper has introduced a new conceptual framework for analyzing the money-industry nexus. This has been done by outlining a theory of production in which liquidity plays a central role. Production in a modern economic system presupposes a complex division of labour, and the latter requires a degree of coordination between production activities characterized by different time profiles of input use and output delivery. The money-industry nexus involves interdependence between production activities both at any given time as well as across different time periods. The theory of production of this paper combines *both* types of interdependence and calls attention to the structural opportunities and constraints associated with liquidity arrangements in a system of interdependent production activities. This approach leads to a ‘monetary theory of production’ in which the structure of production and its dynamics take central stage[14]. Important but generally neglected features of the money-industry nexus may be elucidated on its basis. First, a trade-off is identified between, on the one hand, the *scale condition* for a system of specialized and interdependent production processes to work at full capacity utilization and full employment and,

14 Luigi Pasinetti has called attention to Keynes’s emphasis on the monetary theory of production as a fundamental component of his attempt to move away from the conceptual framework of *A Treatise on Money* (Pasinetti, 2007, p. 220). According to Pasinetti, this feature of Keynes's argument points to the central role of liquidity in industrial economies, ‘with their tendency towards change and an evolving structure, as against the more static conditions of pre-industrial societies’ (Pasinetti, 2007, p. 220). Keynes had argued that in a monetary production economy money is *more* than 'a mere link between cloth and wheat,or between the day's labour spent on building the canoe and the day's labour spent on harvesting the crop' (Keynes, 1973 [1933], p. 408). In other words, a monetary production economy is one in which 'money plays a part of its own and affects motives and decisions and is, in short, one of the operative factors in the situation, so that the course of events cannot be predicted, either in the long period or in the short, without a knowledge of the behaviour of money between the first state and the last' (Keynes, 1973 [1933], pp. 408-409). In his turn, Pasinetti highlights the need to look at money from the point of view of a production economy of an industrial type, in which division of labour and structural dynamics are characterizing features. In his view, money should be assessed by primarily considering the role of money in the production sphere, rather than in the exchange sphere, and by introducing a distinction between the fundamental (structural) features and the contingent features of a monetary production economy (Pasinetti, 2015). The analysis in this paper provides a conceptual framework for investigating the way in which 'operative factors' of the monetary and financial type may impact upon the scale and proportionality conditions for time-coordination in a production economy.

on the other hand, the *proportionality condition* for that system to generate viable stock-flow relationships across different periods. The two conditions are distinct and may be jointly satisfied only in a limit case.

The aforementioned distinction has far reaching consequences for liquidity provision in the production system. For liquidity arrangements compatible with the proportionality condition may be incompatible with the scale condition, and thus be incompatible with full capacity utilization and full employment. On the other hand, liquidity arrangements allowing full capacity utilization and full employment may be incompatible with the proportionality condition and make coordination between different specialized processes impossible. The scale-proportionality trade-off highlights a *tension* within systems of specialized and interdependent processes of production. Systems of this type need a degree of liquidity provision to be viable, but the condition for viability only exceptionally coincides with the condition for full capacity utilization and full employment. This tension between structural coordination and full capacity utilization (full employment) points to an important and so far neglected feature of a monetary production economy. The consistency condition determining which combinations of consumption coefficients and production coefficients are compatible with full employment in a Pasinetti-type pure labour economy (Pasinetti, 1993, p. 18) should be complemented with the proportionality condition ensuring consistency (viability) in a system of specialized and interdependent processes of production. In this connection, liquidity policy may perform a pivotal role in steering the economic system towards full employment *or* structural viability *or* a satisficing approximation to both. However, the scale-proportionality trade off makes clear that there would generally be opportunity costs associated with one or another policy option. In particular, this trade off calls attention to a *systemic* constraint on liquidity policy that is consistent with the 'non-monetary' rigidities and effects often mentioned when discussing asymmetric effects of policy decisions (Bernanke, 1983; Christiano and Eichenbaum, 1995; Kiyotaki and Moore, 2012). A single-minded pursuit of structural viability might lead to significant structural unemployment, whilst a single-minded pursuit of full capacity utilization and full employment might lead to significant disproportionalities between production processes and eventually to structural disruptions and crises[15].

Liquidity policy may also have a pivotal role in a dynamic monetary production economy under conditions of structural change. For example, central bank policy and financial intermediation may alternatively make structural changes more likely or more difficult depending on whether they afford liquidity to processes of new type or, alternatively, strengthen the existing pattern of interdependencies. In this case as well, the trade-off between scale and proportionality is of central importance. For liquidity supply compatible with the scale condition in a full employment trajectory may be incompatible with the proportionality condition corresponding to the existing technology in use, but may facilitate the introduction of a different technology. On the other hand, liquidity supply compatible with the proportionality requirements for the existing technology but not with the scale requirements for the same technology may *at the same time* bring about structural unemployment and structural stagnation by holding up liquidity that might be used for innovation and structural change.

[15] Inflation targeting is another example of the way in which the pursuit of a macroeconomic objective regardless of proportionality requirements may be incompatible with the overall coherence of the economic system. In fact, inflation targeting implies that the central bank responds to inflationary pressure on the general price index by triggering liquidity contraction in the macroeconomy independently of the movements of the individual prices that make up the aggregate price index. It follows that, when different sectors follow different dynamic paths (say, certain sectors are expanding while other sectors are contracting), liquidity contraction triggered by the aim of containing macroeconomic inflationary pressure may take place even if a number of sectors have already been shrinking both in absolute and in relative terms. In this case, central banking policy targeting the aggregate price index may lead to further contraction of the latter sectors. This would further increase the cleavage between expanding and contracting activities independently of the proportionality between production processes that may be required by the viability of any integrated system of processes under given technological conditions (see Aftalion, 1929, for an early criticism of inflation targeting; see also, in this connection, Cardinale, Coffman, Scazzieri, 2017a,b).

In short, the trade-off between coordination requirements and full employment requirements highlights that different liquidity instruments may be required for different purposes. Disentangling the money-industry nexus calls attention to the need of grounding macroeconomic policy in the internal structure of production systems, and of identifying policy objectives and policy trade-offs on that basis.

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