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Marco Veronese Passarella

Technical change and the monetary circuit: an input-output stock-flow consistent dynamic model

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Abstract: This paper is organised as follows. Firstly, a simple but complete input-output stock-flow consistent dynamic model of a monetary economy of production is developed, in which credit money is endogenously created by commercial banks, the production sector is split into different industries, and unit prices align with their reproduction values in the long run, while supplies gradually adjust to meet final demands for products. Secondly, after discussing its key features, the model is used to test the impact of technical change on industry-specific financial requirements and profitability.

Keywords: Monetary Circuit, Stock-Flow Consistent Models, Input-Output Analysis

JEL Classification: E16, E17, C67, D57

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1. Introduction

In two recent papers (Veronese Passarella, 2022a, 2022b), I have examined the theoretical legacy of Augusto Graziani's theory of the monetary circuit (hereafter referred to as TMC). This encompasses both the enduring inspiration it provides and the numerous misconceptions it has encountered since its inception. The reality is that there have been numerous endeavours to challenge, rectify, or modernise the TMC since its initial formulation in the late 1970s up to the present day. The basic circuit scheme has been deemed inadequate or insufficient in explaining the role of aggregate demand, technical progress, and the financialisation of (some) early-industrialised countries. Nevertheless, the monetary circuit does not represent a stylised portrayal of a particular historical or geographical configuration of capitalism. Rather, it serves as a method enabling the identification of the logical sequence of essential monetary relationships between opposing social classes in a monetary economy of production.

As Graziani himself observed, the analytical power of the basic TMC scheme emerges precisely from the capacity to discern the sequence of simple (yet pivotal) monetary connections among the principal economic sectors or classes, while minimising individual behavioural assumptions to the greatest extent possible. The monetary circuit is not an exhaustive macroeconomic model, but rather a means to scrutinise capitalist economic relationships, commencing from the crucial role played by money. In this regard, its relevance today exceeds that of four decades ago.

The aim of this paper is twofold. Firstly, a simple but complete input-output stock-flow consistent dynamic model of a monetary economy of production is developed, in which credit money is endogenously created by commercial banks, the production sector is split into different industries, and unit prices align with their reproduction values in the long run, while supplies gradually adjust to meet final demands for products. Secondly, after discussing its key features, the model is used to test the impact of cross-industry interdependencies and technical change on industry-specific financial requirements and profitability.

2. The model

Stock-flow consistent (SFC) models serve as the dynamic counterparts to the TMC single-period scheme (Graziani 2003; Godley 2004; Lavoie 2004, 2021; Godley and Lavoie 2007; Zezza 2012; Veronese Passarella 2014, 2017, 2022a; Sawyer and Veronese Passarella 2017). Specifically, the TMC provides the fundamental monetary-accounting structure upon which SFC models are constructed. Certainly, there exist certain distinctions between these two approaches. These discrepancies primarily arise from the higher level of abstraction found in TMC schemes when compared to SFC models, and thus, from the distinct research questions they endeavour to address. However, both the theoretical presuppositions and the accounting frameworks of these two approaches remain consistent and mutually reinforcing (Veronese Passarella 2022a). While the SFC approach (in contrast to the basic TMC scheme) enables the analysis of the economy's *dynamics over a sequence of periods*, the TMC sheds light on the *sequence of events occurring within each period*, which would otherwise remain a black box. This explains why several prominent SFC economists – notably including Marc Lavoie, Steve Keen, and Gennaro Zezza, among others – still draw upon Graziani's work. A visual representation of the interconnection between the TMC and the SFC approach (and the IO analysis) is provided by Diagram 1.

In this section, the benchmark TMC scheme is reformulated as a simple yet comprehensive macroeconomic SFC dynamic model for a closed market economy, devoid of a government sector. One of the notable limitations inherent in both TMC and SFC models is their lack of explicit inclusion of the production sector's segmentation into distinct industries.[1] In other words, they typically focus on aggregate demand and output. This aspect seemingly renders both the TMC and SFC frameworks inadequate for examining cross-industry interdependencies and the implications of technical progress. To address this concern, a straightforward approach involves integrating a TMC-SFC model with an input-output model (Veronese Passarella 2022c, 2023). This integration is undertaken in the subsequent subsections. To elaborate, the constructed synthetic economy comprises:

- three sectors: households, production firms, and banks;
- two social classes: workers and rentiers;
- three industries: agriculture, manufacturing, and services.[2]

Workers trade their labour power to firms in exchange for a monetary wage. They allocate a portion of their income (wages and interest earnings on deposits and securities) towards consumption and retain the remainder in the form of bank deposits and private corporate securities. Rentiers possess

[1] In this paper I will employ the term 'industry' to refer to distinct branches of production (such as agriculture, manufacturing and services), in contrast to the term 'sector', which will be utilised to delineate divisions within the economy/society (including workers, rentiers, firms, banks, etc.).

[2] The model is quite versatile and can be readily expanded to incorporate additional sectors, industries, or even encompass other social classes and countries. Nevertheless, such extensions would exceed the scope of this paper. For a more intricate model structure, we direct readers to Veronese Passarella (2022c, 2023).

ownership of all private firms and banks. They are the ultimate recipients of distributed profits and a majority of interest payments, which they either expend on consumption or save in the form of deposits and securities. Private production firms utilise bank loans to obtain labour power from workers (and capital goods from other firms). These firms have market power as they can establish a normal mark-up above their costs of production. Lastly, commercial banks extend loans to firms and provide households with deposits. They determine the interest rate on deposits and loans by applying a mark-up over the policy rate announced by the central bank.

A thorough representation of input-output relations is presented in subsections 2.1 and 2.2. Conversely, subsections 2.3 to 2.8 predominantly focus on the accounting TMC-SFC structure of the model and the essential behavio*u*ral equations.

2.1 The input-output structure of the economy

As previously mentioned, the production sector is divided into three distinct industries: agriculture, manufacturing, and services – the reader is referred again to Diagram 1 for a visual rendition of the model's structure. Agriculture typically includes the production of food and beverages. Manufacturing encompasses a wide range of goods, including clothing, electronics, and appliances. Lastly, services include a diverse range of expenses such as healthcare, education, and entertainment. For the sake of simplicity, we assume that each industry produces a single product using a specific production technique. The 3×1 vector of final demands, expressed in real terms, is:

$$\mathbf{d} = \boldsymbol{\beta}_{\mathrm{w}} \cdot c_w + \boldsymbol{\beta}_z \cdot c_z + \boldsymbol{\iota} \cdot i_d \tag{1}$$

where c_w is real consumption of the workers, c_z is real consumption of the rentiers, i_d is real investment undertaken by the firms, $\boldsymbol{\beta}_{\mathrm{w}}$ is the 3×1 vector of workers' shares of consumption of each product, $\boldsymbol{\beta}_{\mathrm{z}}$ is the 3×1 vector of rentiers' shares of consumption, and $\boldsymbol{\iota}$ is the 3×1 vector of shares of investment.[3]

Note that the real volume of workers' consumption is derived by dividing their nominal expenditure by the corresponding price index. In turn, this price index is calculated by multiplying the price vector with the vector representing workers' consumption shares. The real consumption of rentiers and the real investment of production firms are determined using

[3] When considering a multi-period time span, the temporal dimension must also be taken into account for model variables. As a result, each 3×1 vector turns into a $3 \times n$ matrix, where n is the number of periods.

the same methodology (for a formal derivation, please consult sub-section 2.2).

Once the final demands are established, the 3×1 vector representing real gross outputs can be computed through the utilisation of the Leontief inverse function:

$$\mathbf{x} = [\mathbf{I} - \mathbf{A}]^{-1} \cdot \mathbf{d} \quad (2)$$

where $\mathbf{A}$ is the 3×3 matrix of technical coefficients and $\mathbf{I}$ is the corresponding 3×3 identity matrix.

As usual, each element a_{ij} (with $i, j = 1,2,3$) of the $\mathbf{A}$ shows the quantity of product i necessary to produce of unit of product j. As a result, each column j of A is associated with an industry and the related product.

The value added of the economy (in monetary terms) is:

$$Y = \mathbf{p}^T \cdot \mathbf{x} \quad (3)$$

where p is the 3×1 vector of unit prices and superscript T is used for the transpose of the vector.

Table 1. Values of coefficients in the baseline scenario: consumption, investment and production structure

Symbol	Description	Type	Value
$\boldsymbol{\beta}_w$	Real consumption shares of workers	V	0.20, 0.40, 0.40
$\boldsymbol{\beta}_z$	Real consumption shares of capitalists	V	0.10, 0.25, 0.65
$\boldsymbol{\iota}$	Real consumption shares of workers	V	0.25, 0.50, 0.25
$\mathbf{A}$	Technical coefficients	V	0.25, 0.15, 0.10 0.10, 0.30, 0.25 0.05, 0.15, 0.40

Notes: V stands for column vector or square matrix; S stands for scalar.

The coefficient values utilised for model simulations are displayed in Table 1. They have been selected in a manner that ensures the creation of a stable, realistic, and economically meaningful baseline scenario.

2.2 The pricing procedure

One of the major advantages of utilising an input-output structure is that it enables addressing one of the most contentious aspects of the TMC, which is the way in which prices are determined. As Lunghini and Bianchi (2004) argued, the basic TMC scheme can be approached from two distinct angles that should be kept separate. These perspectives involve viewing it either as a single-period bookkeeping scheme or as a reproduction model. The key difference lies in the adopted price theory: the former approach stems from a combination of short-term competitive equilibrium in the consumer goods market and an accounting-based definition of the investment goods market; the alternative view considers unit prices as long-run prices determined by technical production conditions (Sraffa 1960). Both interpretations allow for uniform profit rates or mark-ups across sectors. However, while the former interpretation presents logical and analytical shortcomings, the latter highlights the prerequisite cost conditions necessary for system reproduction.

Unlike Veronese Passarella (2022a), the second approach is explicitly chosen here. Consequently, the 3×1 vector of unit prices is defined in a Sraffian manner:

$$\mathbf{p} = w \cdot \mathbf{l} + \mathbf{p} \cdot \mathbf{A} \odot \boldsymbol{\mu} \odot \boldsymbol{\kappa}_d \tag{4}$$

where w is the uniform wage rate, $\boldsymbol{\mu} = \{1 + \mu_j\}$ is the 3×1 vector of (uniform) mark-ups over the costs of production, and $\boldsymbol{\kappa}_d = \{1 + k_j \cdot \delta\}$ is the 3×1 vector defining the portions of fixed capital that are being amortised in each period.[4]

Unlike Sraffa (1960) and Lunghini and Bianchi (2004), the possibility is explicitly considered of temporary variations in mark-ups. More precisely, each industry-specific mark-up increases beyond (fall below) its medium-run level, $\boldsymbol{\mu}_0$, when current output surpasses (falls below) potential output in that industry:

$$\boldsymbol{\mu} = \boldsymbol{\mu}_0 + \boldsymbol{\mu}_1 \odot (\mathbf{x}_{-1} - \mathbf{x}_{-1}^N) \tag{5}$$

where $\boldsymbol{\mu}_1$ is 3×1 the vector defining the industry-specific sensitivities of mark-ups to output gaps, and the subscript '-1' denotes a time lag.

Potential output is not modelled as an exogenous attractor, as happens in standard neoclassical-like equilibrium models. In contrast, it is presumed to adjust gradually to current output, due to hysteresis (Lavoie 2006):

$$\mathbf{x}^N = \mathbf{x}_{-1}^N - \boldsymbol{\phi} \odot (\mathbf{x}_{-1} - \mathbf{x}_{-1}^N) \tag{6}$$

where $\boldsymbol{\phi}$ is the 3×1 vector of the speeds of adjustment of industry-specific potential outputs to current outputs.

The average price encountered by the workers will depend on the specific bundle of consumer goods and services they purchase from the market:

[4] Note that $\odot$ is the Hadamard multiplication, also called element-wise multiplication matrices.

$$p_w = \mathbf{p}^T \cdot \boldsymbol{\beta}_{\mathrm{w}} \quad (7)$$

Similarly, the average prices paid by the rentiers and production firms are, respectively:

$$p_z = \mathbf{p}^T \cdot \boldsymbol{\beta}_{\mathrm{z}} \quad (8)$$

$$p_{id} = \mathbf{p}^T \cdot \boldsymbol{\iota} \quad (9)$$

Note that employing distinct price indices enables the expression of each component of aggregate demand in real terms, all while avoiding the need for disaggregated consumption and investment functions.

The coefficients utilised for model simulations are displayed in Table 2.

Table 2. Values of coefficients in the baseline scenario: amortization and mark-up coefficients

Symbol	Description	Type	Value
$\boldsymbol{\kappa}_{\mathbf{d}}$	Amortised capital coefficients	V	1.08, 1.15, 1.05
$\boldsymbol{\mu}_0$	Medium-run mark-ups	V	0.25, 0.25, 0.25
$\boldsymbol{\mu}_{\mathbf{1}}$	Sensitivities of mark-ups to output gaps	V	0.001, 0.001, 0.001
$\boldsymbol{\phi}$	Speeds of adjustment of potential output to current output	V	0.25, 0.25, 0.25

2.3 The household sector

The household sector is divided into workers (or lower-class households), who are the primary recipients of labour incomes, and rentiers (or capitalists or upper-class households), who are the primary recipients of capital incomes. Both groups consume according to their anticipated real income and their actual net wealth:[5]

$$c_{w,z} = \alpha_{w,z}^0 + \alpha_{w,z}^1 \cdot \frac{YD_{w,z}}{E(p_{w,z})} + \alpha_{w,z}^2 \cdot \frac{V_{w,z,-1}}{p_{w,z,-1}} \quad (10)$$

where $\alpha_{w,z}^0$, $\alpha_{w,z}^1$ and $\alpha_{w,z}^2$ are positive coefficients, YD stands for disposable income, and $V_{w,z}$ stands for net wealth.

Workers' disposable income comprises the majority of labour incomes along with certain interest earnings:

$$YD_w = WB \cdot (1 - \omega) + INT_w^m + INT_w^b \quad (11)$$

[5] Fully adaptive expectations are assumed in the experiments presented in this paper. Consequently, expected consumer prices are: $E(p_{w,z}) = p_{w,z,-1}$.

where WB is the total wage bill, ω is the share of managerial salaries to total labour incomes, INT_w^m are interest payments received on bank deposits, and INT_w^b are interest payments received on corporate securities.

Similarly, rentiers' disposable income is:

$$YD_z = WB \cdot \omega + \Pi_f + \Pi_b + INT_z^m + INT_z^b \quad (12)$$

where Π_f is firms' distributed profit, Π_b is banks' profit, INT_z^m are interest earnings on bank deposits, and INT_z^b are interest earnings on corporate securities.

Workers and rentiers' stocks of net wealth accumulate as disposable incomes are saved:

$$V_{w,z} = V_{w,z} + YD_{w,z} - p_{w,z} \cdot c_{w,z} \quad (13)$$

For the sake of simplicity, and in accordance with Graziani (2003), the assumption is made that households maintain a constant proportion of their net wealth in the form of interest-bearing securities:

$$B_{w,z} = (1 - \lambda_{w,z}) \cdot V_{w,z} \quad (14)$$

Therefore, bank deposits are the buffer stocks:

$$M_{w,z} = V_{w,z} - B_{w,z} \quad (15)$$

Household coefficients utilised for model simulations are displayed in Table 3.

Table 3. Values of coefficients in the baseline scenario: consumption and portfolio investment coefficients

Symbol	Description	Type	Value
α_w^0	Autonomous consumption of workers	S	0.00
α_z^0	Autonomous consumption of rentiers	S	4.00
α_w^1	Workers' propensity to consume out of income	S	0.70
α_z^1	Rentiers' propensity to consume out of income	S	0.40
α_w^2	Workers' propensity to consume out of wealth	S	0.15
α_z^2	Rentiers' propensity to consume out of wealth	S	0.08
ω	Share of managerial salaries to total labour income	S	0.30
λ_w	Worker's share of deposits to total wealth	S	0.50
λ_z	Rentiers' share of deposits to total wealth	S	0.50

2.4 Production firms

Firms require fixed capital, in addition to circulating inputs, for production. The assumption is that each industry has its specific capital requirement. Hence, the target stock of fixed capital, stated in real terms, is:

$$k^T = \frac{\mathbf{p}_{-1}^T \cdot (\boldsymbol{\kappa}_{-1} \odot \mathbf{x}_{-1})}{p_{id,-1}} \tag{16}$$

where $\boldsymbol{\kappa} = \{\kappa_j\}$ is the 3×1 vector of industry-specific target capital to output ratios.

The real investment function is therefore:

$$i_d = \gamma \cdot (k^T - k_{-1}) + da \tag{17}$$

where γ is the speed of adjustment of the existing capital stock to the target level, and da is fixed capital depreciation expressed in real terms.[6]

It is assumed that the stock of fixed capital depreciates according to a constant ratio:

$$da = \delta \cdot k_{-1} \tag{18}$$

As a result, the current capital stock is:

$$k = k_{-1} + i_d - da \tag{19}$$

Firms retain amortisation funds to fund capital depreciation:

$$AF = p_{id,-1} \cdot da \tag{20}$$

The total profit of the corporate sector is computed as a residual distributional variable. It can be deduced as an accounting identity from the fourth column of Table 8:

$$\Pi_f = Y - WB - INT_l - AF - INT_w^b - INT_z^b \tag{21}$$

where INT_l is the amount of interest payments on bank loans.

In alignment with the initial formulation of the TMC scheme, the ownership of private firms (and banks) lies with the rentiers, with shares being disregarded. Furthermore, for the purpose of simplicity, the quantity of securities issued by the firms perfectly matches the corresponding demand:

$$B_s = B_w + B_z \tag{22}$$

[6] Graziani (2003) simply defines gross real investment as a portion of total production. Nonetheless, the two investment functions yield similar qualitative outcomes (for further reference, see Veronese Passarella 2022a).

Firms' parameters utilised for model simulations are displayed in Table 4.

Table 4. Values of coefficients in the baseline scenario: capital accumulation coefficients

Symbol	Description	Type	Value
$\boldsymbol{\kappa}$	Target capital to output ratios	V	0.80, 1.50, 0.50
γ	Speed of adjustment of current capital to target capital stock	S	0.15
δ	Rate of real depreciation of capital stock	S	0.10

2.5 Initial finance, final funding and the role of the banks

At the outset of each period, private firms are required to cover their production costs. When considering firms as a fully aggregated and consolidated sector, these costs solely encompass wages. On a less abstract level, each individual firm will also account for the acquisition of investment goods. Consequently, the initial finance required by each firm is:

$$FIN_I = WB + [p_{id} \cdot i_d] \tag{23}$$

where the square brackets signify that the purchase of investment goods in an unnecessary or notional component of the initial finance for production firms as a whole (Graziani 2003; Veronese Passarella 2022a, 2022b).

The final funding that the firms receive from the goods and financial markets equals the sum of consumption (and investment) expenditures along with newly issued securities, subtracted by interest and profit payments:

$$FIN_F = p_w \cdot c_w + p_z \cdot c_z + [p_{id} \cdot i_d] + \Delta B_s - \left(INT_l + INT_w^b + INT_z^b + \Pi_f\right) \tag{24}$$

The change in the stock of existing bank loans registered at the end of each period will match the difference between the initial finance and the final funding:

$$L_d = L_{d,-1} + FIN_I - FIN_F = L_{d,-1} + p_{id} \cdot i_d - AF - \Delta B_s \tag{25}$$

It turns out that new loans recorded at the end of each period are equivalent to the portion of investment not funded through internal funds or securities issuance. This aligns with the standard equation used in SFC literature (Godley and Lavoie 2007; Veronese Passarella 2022a, 2022b), which can be derived from the fifth column of Table 8.

In accordance with the horizontalist view of money advocated by the TMC, the supply of loans perfectly adjusts to the demand for loans:

$$L_s = L_{s,-1} + \Delta L_d \tag{26}$$

Given the absence of cash, \$1 of bank deposits is generated concurrently with the issuance of \$1 in bank loans:

$$M_s = M_{s,-1} + \Delta L_s \tag{27}$$

If banks incur no production costs, their profit is simply the gap between interests earned from loans and interest payments on deposits:

$$\Pi_b = INT_l - INT_m \tag{28}$$

Interest rates on deposits, loans, and securities are calculated by employing distinct mark-ups on the policy rate, r^*, established by the central bank:

$$r_m = r^* + \mu_m \tag{29}$$

$$r_l = r^* + \mu_l \tag{30}$$

$$r_b = r^* + \mu_b \tag{31}$$

where it is assumed that $\mu_m \leq \mu_b \leq \mu_l$.

Values of financial parameters and exogenous variables utilised for model simulations are displayed in Table 5.

Table 5. Values of coefficients in the baseline scenario: interest rates' coefficients

Symbol	Description	Type	Value
r^*	Policy rate set by the central bank	S	0.02
μ_m	Risk premium on bank deposits	S	0.00
μ_l	Risk premium on bank loans	S	0.01
μ_b	Risk premium on private securities	S	0.00

2.6 The labour market

A stylised labour market is considered, where wage rates are uniform across industries, and employment fully aligns with firms' demand for labour:

$$WB = w \cdot N \tag{32}$$

$$N = \mathbf{x}^T \cdot \left[\begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \oslash \mathbf{pr} \right] \tag{33}$$

where **pr** is the 3×1 vector of industry-specific labour productivities.[7]

The parameter values for the labour market are displayed in Table 6.

Table 6. Values of coefficients in the baseline scenario: labour market coefficients

Symbol	Description	Type	Value
w	Uniform wage rate	S	0. 20
pr	Products per unit of labour	V	0.80, 0.80, 0.80

2.7 Interest payments

Consistent with the TMC tradition, and in accordance with Veronese Passarella (2022a), the assumption is made that production firms settle interests on total loans secured at the commencement of the period, rather than solely on the net or remaining portion at the circuit's conclusion. Consequently, interest payments must encompass the proportion of loans that firms repay within each period:

$$INT_l = r_{l,-1} \cdot L_{d,-1} + r_{l,-1} \cdot \frac{FIN_{F,-1}}{2} \cdot \frac{M_{w,-1}}{M_{w,-1}+M_{z,-1}} \tag{34}$$

Similarly, if money wages are paid at the beginning of each period, interest payments on deposits held by the workers are:

$$INT_w^m = r_{m,-1} \cdot M_{w,-1} + r_{m,-1} \cdot \frac{FIN_{F,-1}}{2} \cdot \frac{M_{w,-1}}{M_{w,-1}+M_{z,-1}} \tag{35}$$

In contrast, entrepreneurial incomes and other payments occur at the end of each period, that is, once products and services have been sold on the market:

$$INT_z^m = r_{m,-1} \cdot M_{z,-1} \tag{36}$$

The same principle applies to interest payments on securities, which are issued at the conclusion of the monetary circuit:

$$INT_z^b = r_{b,-1} \cdot B_{w,-1} \tag{37}$$

$$INT_z^b = r_{b,-1} \cdot B_{z,-1} \tag{38}$$

Once again, the reader is referred to Veronese Passarella (2022a) for a thorough explanation.

[7] The symbol ⊘ is the Hadamard or element-wise multiplication matrices. To circumvent excessive simultaneity, lagged values for outputs and productivities are employed in the simulations. This approach is equivalent to assuming that employment is contingent on the extent and manner in which firms produced during the prior period.

2.8 Model consistency

The model is now complete. The hidden or redundant equation of the model is the equilibrium condition that matches the supply of bank deposits (defined by equation 27) with the related demand (defined by equation 15):

$$M_s = M_h, \quad \text{with: } M_h = M_w + M_z \tag{39}$$

As usual, this equation is omitted to prevent over-determination of the equation system. If the model maintains complete consistency, condition (39) is invariably fulfilled, regardless of the period or scenario under consideration.

3. Coding and early experiments

Despite its relative simplicity, the model described by the system of equations above cannot be easily solved analytically. Therefore, computer simulations have been employed to determine the (coefficient-dependent) medium-run steady-state values of the variables. The model has been implemented in an *R* environment, which, in contrast to many econometric packages, is well suited for matrix algebra. The considered time span encompasses 80 periods. Simultaneous solutions were obtained by running 100 iterations per period. As mentioned, model coefficients have been chosen using realistic values. The technical coefficients and consumption compositions are loosely based on real input-output data for an early-industrialised economy (e.g. the US).

As in all SFC models, identity equations are derived from two accounting matrices: the balance-sheet matrix (BSM), which illustrates tangible stocks (fixed capital), financial assets, and financial liabilities for each macro-sector; and the corresponding transactions-flow matrix (TFM), which unveils financial flows connected to stocks and sectoral budget constraints. The latter integrates national income equations with sectoral flow-of-funds accounting. However, unlike other SFC (and TMC) models, the model presented in this paper also relies on a standard input-output matrix (IOM), enabling the tracking of interdependencies across distinct industries. Table 7, Table 8, and Table 9 exhibit the BSM, TFM, and IOM for the economy 16 periods after its initiation (in period 5) with an initial autonomous consumption by the rentiers.

Figure 1 and Figure 2 are the visual counterparts of Table 8 and Table 9, respectively. Specifically, Figure 1 provides a snapshot of monetary transactions taking place in the same period. It shows that the model is watertight, as every flow (or change in stock) comes from somewhere and goes to somewhere – refer also to quadrant *a* of Figure 3, which utilises the redundant equation of the model to check its accounting consistency. Figure 2 offers a visual rendition of cross-industry relations. It shows that agriculture produces a smaller amount of output and consumes fewer inputs from the other industries. Manufacturing has a relatively strong demand for inputs from agriculture. It also produces a significant share of output for both internal consumption and other industries. Services, being less resource-intensive, have a comparatively lower demand for inputs from other industries, but contribute significantly to domestic output.

In the upcoming section, we will employ the model to scrutinise the economic dynamics within the baseline scenario, as well as under two distinct alternative experiments. In the initial experiment, we examine the economy's response to an asymmetric surge in market prices, which is aimed at restoring firms' profitability in specific industries. In the second alternative scenario, the restoration of profitability is achieved through the implementation of technical innovations.

4. Findings

4.1 Cross-industry interdependencies in the baseline scenario

As previously mentioned, the economy was initiated through an initial autonomous spending action by the rentiers. Quadrant *b* of Figure 3 depicts the progression in the economy's value added from its commencement to the medium-run steady state. Quadrants *c*, *d*, and *e* illustrate the evolution of real final demand for agricultural, manufacturing, and service products over time, subsequent to the activation of the capitalist production and exchange process by the rentiers' initial consumption. Quadrants *f*, *g*, and *j* depict the respective outputs of each industry, aligned with the final demands for goods they face.

Due to equation (6), potential outputs lag behind (or exceed) current outputs during periods of growth (or decline). This accounts for mark-ups and prices surpassing their standard values along the traverse – that is, while the economy adjusts towards its steady-state position, denoted by quadrants *a* and *b* of Figure 4. Quadrants *c*, *d*, and *e* reveal that the average price paid by each agent or sector reflects on the chosen assortment of goods and services. The process of production also entails the accumulation of fixed capital, as indicated in quadrant *f*. *Ex-post* saving of households consistently match the net investment of firms. Correspondingly, *ex-post* net financial wealth aligns with the value of fixed capital, as displayed in quadrants *f* and *g*.

As detailed in subsection 2.5, firms obtain the initial finance required to initiate the production process from the banking sector. In contrast, they secure the final funding needed to settle their bank debt from the goods and financial markets, as delineated in quadrant h. However, it is important to note that, when considering a range of industries, the equilibrium condition for the overall economy does not inherently translate to positive profits in every industry. This is true even though the total profit remains positive. This can be discerned through the detailed breakdown (per industry) of investment, profit and finance equations. Assuming that loans and securities linked to each industry are proportionate to the corresponding volume of investment made in each period, the resulting equations are:

$$k_j^T = \frac{p_{j,-1}}{p_{id,-1}} \cdot \kappa_{j-1} \cdot x_{j-1} \quad (16B)$$

$$i_{d_j} = \gamma \cdot \left(k_j^T - k_{j,-1}\right) + \delta \cdot k_{j,-1} \quad (17B)$$

$$k_j = k_{j,-1} + i_{d_j} - \delta \cdot k_{j,-1} \quad (19B)$$

$$\Pi_{f_j} = p_j \cdot d_j - WB_j - (INT_l + INT_w^b + INT_z^b + AF) \cdot \frac{i_{d_j}}{i_d} \quad (21B)$$

$$WB_j = w \cdot \frac{x_j}{pr_j} \quad (32B)$$

$$FIN_{I\,j} = WB_j + p_{id} \cdot i_{d\,j}, \quad (23B)$$

$$FIN_{F\,j} = p_j \cdot d_j - \Pi_{f\,j} + [\Delta B_s - (INT_l + INT_w^b + INT_z^b)] \cdot \frac{i_{d_j}}{i_d} \quad (24B)$$

where the subscript 'j' refers to the specific industry considered.

Obviously, the following identities hold in every period:

$$\sum_j FIN_{I\,j} = FIN_I$$

$$\sum_j FIN_{F\,j} = FIN_F$$

Quadrants *e*, *f*, *g* and *h* of Figure 5 illustrate that, in the steady-state condition, certain industries will exhibit positive profits (particularly services), some will experience losses (agriculture), and others will have a combination of outcomes (manufacturing). This result is contingent upon the demand level each industry faces (we refer back to Figure 3*c*, *d*, and *e*), coupled with its market power – that is, the mark-up over its production costs. If uniform mark-ups are sought in the medium term, then profitability directly correlates with demand volume.

Note that, even when firms make positive profits, the final funding acquired by the firms from the market is insufficient to offset entirely the initial finance obtained by the banks along the traverse. However, the latter adjusts to the former in the final steady state, thus stabilising the stock of debt contracted by the firms in the form of bank loans – as seen in quadrants *a*, *b*, *c* and *d* of Figure 5. The same applies to the stock of securities issued by the firms.

4.2 Market power and the monetary circuit(s)

While firms (or industries) can experience losses in the short run, they tend to react by aiming to restore profitability in the medium to long term. The most conventional measures adopted by firms are typically reducing wage rates or adopting labour-saving technologies. However, these possibilities will not be addressed in this paper. Instead, our focus will be on two alternative strategies: firstly, firms operating in loss-making industries might choose to increase their market prices by augmenting their mark-ups; secondly, these same firms could opt to introduce new, more efficient (in terms of non-labour inputs) production techniques. The first option is explored in this subsection, while the second option is elaborated upon in the subsequent section.

Specifically, it is assumed here that firms operating in the agricultural industry opt for a significant increase in their mark-up (doubling from 0.25 to 0.50), while firms in the manufacturing industry choose a moderate increase (from 0.25 to 0.375). Services firms, on the other hand, maintain their mark-up unchanged. Additionally, we consider that due to the presence of substantial barriers to entry in new industries, the heightened mark-ups in the agricultural and manufacturing sectors do not generate relevant capital inflows, leading to a weak tendency for equalising profitability rates. When combined, Figure 7 and Figure 8 reveal that the price rise of agricultural and manufacturing products results in an overall increase in the price level. Unsurprisingly, this depresses the final demand for goods and services, hence total outputs. This, in turn, slows down capital accumulation, leading to a reduction in the demand for bank financing in the medium term, following the initial boost caused by higher nominal sales (in the first period after the shock) and elevated production costs. While total losses are eventually zeroed in the agricultural industry and the manufacturing industry consistently records positive profits in the medium term, total profits diminish in the services industry. Overall, the higher mark-ups have scaled down the economy’s size. Yet they have concurrently restructured profit distribution across industries.

4.3 Technical change and the monetary circuit(s)

Increasing market prices is not always profitable or feasible, given the potential reduction in final demand for products (and the competition between firms, even across different industries). An alternative strategy for firms to enhance profits or, at the very least, mitigate losses, involves adopting a change in the production technique that leads to improved efficiency – specifically, a reduction in (selected) technical coefficients associated with non-labour inputs. In the second experiment discussed here, we assume that the agricultural industry undergoes a significant boost in its production efficiency, resulting in a 20 percent reduction in its requirement for agricultural and manufacturing inputs, as well as a 40 percent reduction in its demand for services inputs. Similarly, the manufacturing industry reduces its demand for manufacturing and agricultural inputs by 10 percent and its requirement for services inputs by 30 percent. Additionally, it is assumed that both agricultural and manufacturing firms keep their prices unchanged, resulting in an implied increase in their mark-ups over production costs. In this scenario, the economy once again experiences a decline due to reduced demand for intermediate products – as depicted in Figure 9. As potential output gradually aligns with current output, the overall price level increases, attributed to the surge in the price of services – as illustrated in Figure 10. Despite this, firms' demand for bank loans diminishes, because of the economic contraction. Once again, both the agricultural and manufacturing industries observe an improvement in profitability, while the total profits realised by the services industry decrease – as outlined in Figure 11.

5. Final remarks

The aim of this paper was twofold. Firstly, a simple but complete input-output stock-flow consistent dynamic model of a monetary economy of production has been developed, in which credit money is endogenously created by commercial banks, the production sector is split into different industries, and unit prices tend to their reproduction values in the long run, while supplies gradually adjust to meet final demands for products. Secondly, after discussing its key features, the model has been used to test the impact of cross-industry interdependencies and technical change on industry-specific financial requirements and profitability. The main findings are as follows. Firms that experience short-term losses tend to restore profitability in the medium to long term. If wage rates and labour coefficients are given, this can be achieved by raising market prices or adopting more efficient production techniques. The former strategy reduces the economy's size but rebalances profit distribution. Alternatively, firms can enhance their profits by improving efficiency through the introduction of non-labour input-saving production techniques. However, unlike one might expect, higher efficiency does not necessarily result in lower prices in the short run. If innovative firms maintain their market price, the contraction in total output due to increased efficiency in some industries can lead to higher costs of production, and subsequently, higher prices in other industries. Without government intervention, technical progress may not lead to generalised reduction in prices and social improvement.

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Additional tables, charts and diagrams

Table 7. Balance-sheet matrix of the economy in period 20 (current prices)

	Households		Firms	Banks	Total
	Workers	Rentiers			
Deposits	3.31	36.04		-39.35	0
Loans			-39.35	39.35	0
Securities	3.31	36.04	-39.35	0	0
Capital stock			78.70	0	78.70
Net wealth	-6.61	-72.08	0	0	-78.70
Total	0	0	0	0	0

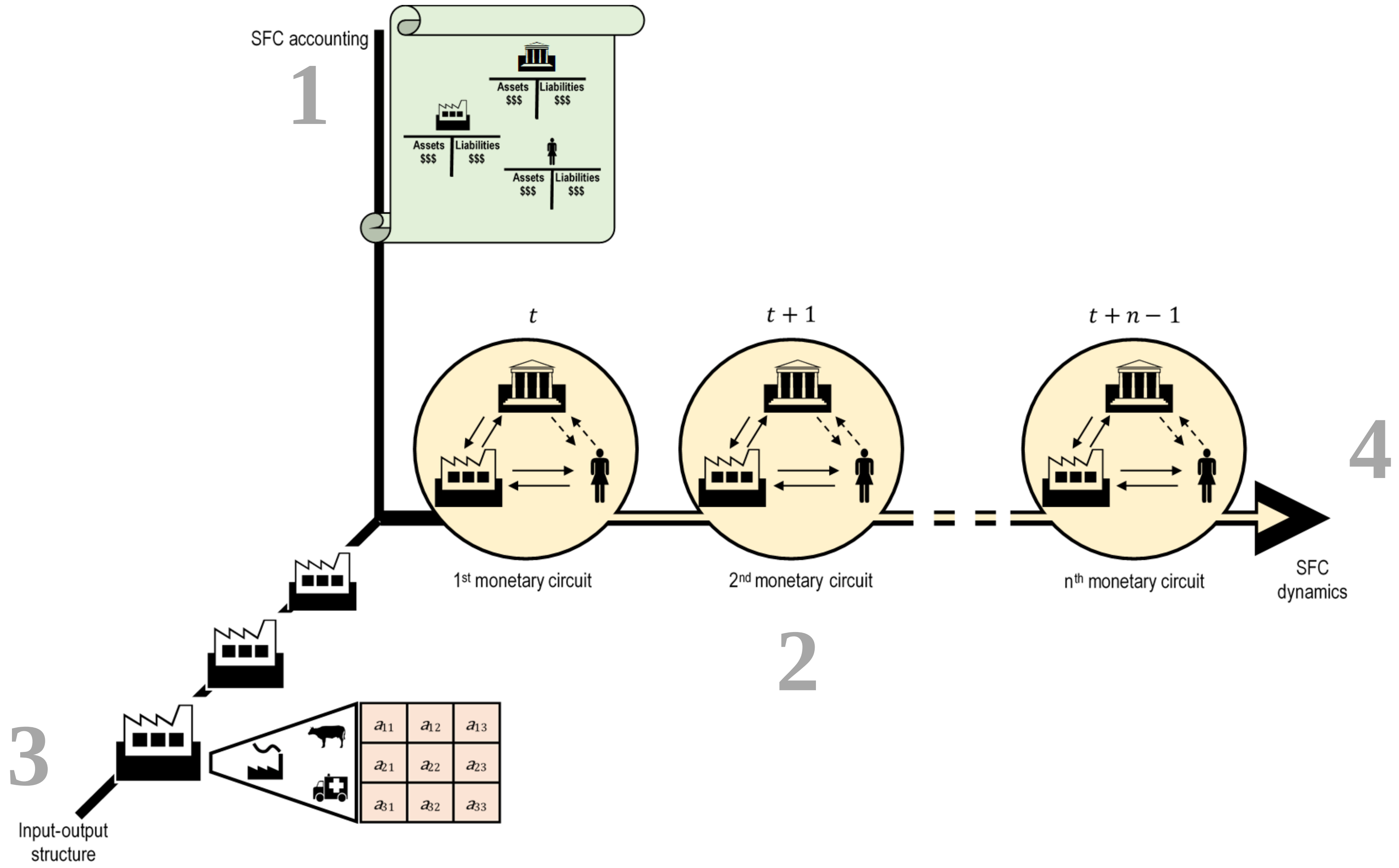
Table 8. Transactions-flow matrix of the economy in period 20 (current prices)

	Households		Firms		Banks	Total
	Workers	Rentiers	Current	Capital		
Consumption	-14.60	-16.22	30.83			0
Investment			10.39	-10.39		0
[Value added]			[41.22]			
Wages	15.21	6.52	-21.73			0
Deprec./Amortiz.			-7.46	7.46		0
Firms profit		10.10	-10.10			0
Banks profit		0.39			-0.39	0
Interests on deposits	0.08	0.70			-0.78	0
Interests on loans			-1.17		1.17	0
Interests on securities	0.06	0.70	-0.76			0
Δ in deposits	-0.37	-1.09			1.47	0
Δ in loans				1.47	-1.47	0
Δ in securities	-0.37	-1.09		-1.47		0
Total	0	0	0	0	0	0

Table 9. Input-output matrix of the economy in period 20 (current prices)

		Demand				
		Agriculture	Manufacturing	Services	Final demand	Tot. output
Production	Agriculture	3.56	3.68	2.60	4.40	14.23
	Manufacturing	2.25	11.61	10.25	14.60	38.70
	Services	1.41	7.30	20.63	22.23	51.57
	Value added	7.02	16.11	18.10	[41.22]	
	▪ Labour incomes	3.09	5.33	5.65		
	▪ Capital incomes	3.92	10.78	12.45		
	Tot. output	14.23	38.70	51.57		104.51

Diagram 1. The ‘3 + 1’ dimensional structure of the model



Note: SFC modelling enables the definition of both the accounting structure of the model through the definition of identity equations (1) and the dynamics of the economic system *over time* through the definition of its laws of motion from one period to the next (4); the TMC facilitates the identification of the exact sequence of capitalist relations between sectors or classes, in the form of monetary transactions, *within each* i^{th} *period* (3); lastly, the IO structure allows for the consideration of interdependencies between different branches or industries within the production sector.

Figure 1. Sankey diagram of transactions and changes in stocks across sectors in period 20 (current prices)

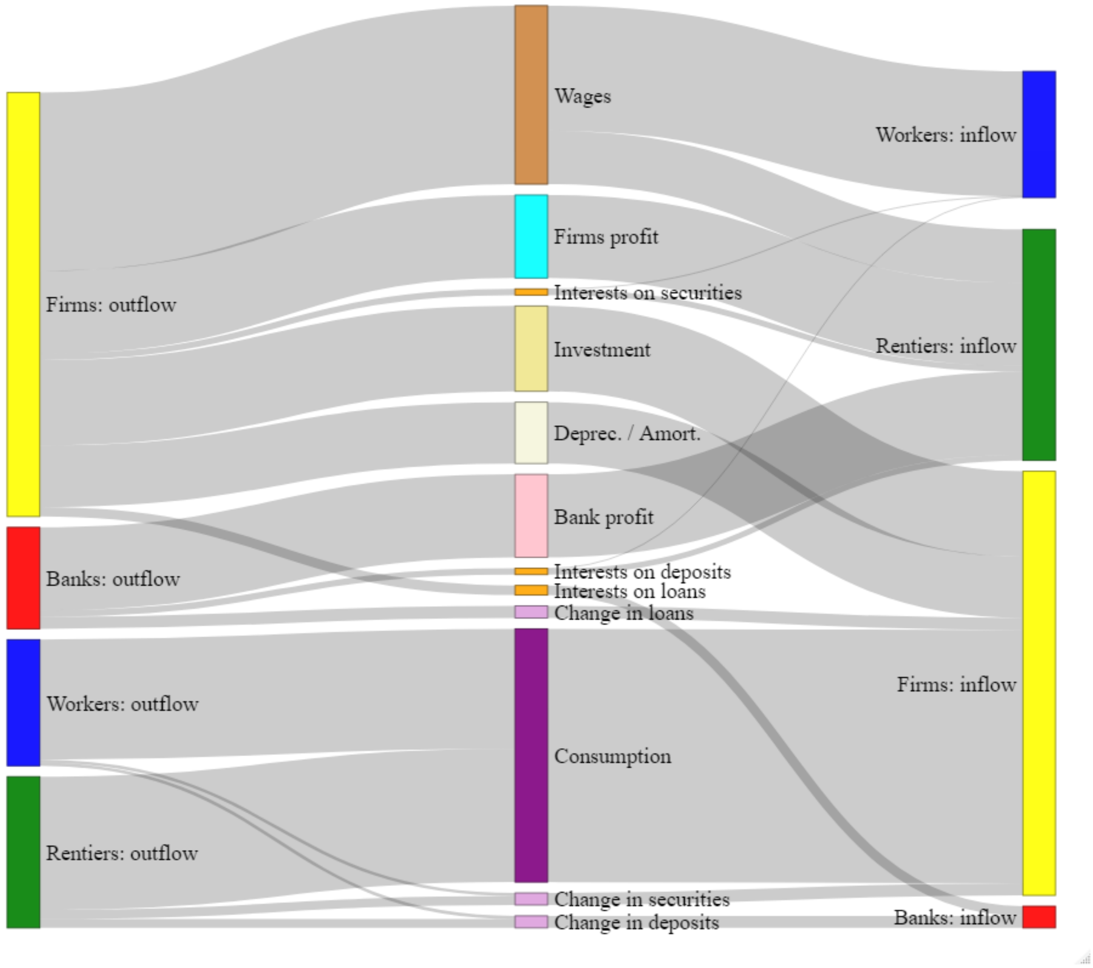


Figure 2. Sankey diagram of input-output interdependencies across industries in period 20 (current prices)

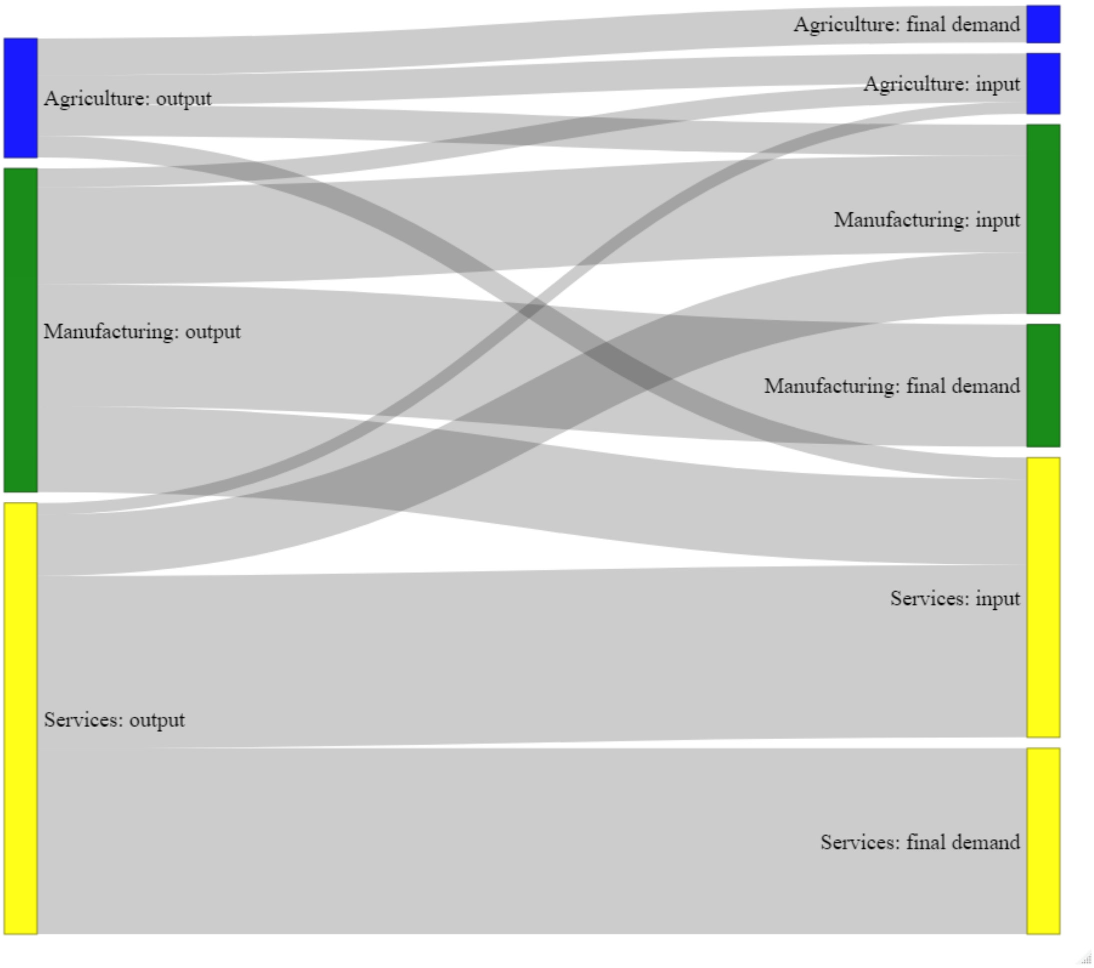


Figure 3. Selected variables under model baseline: adjustment to the medium-run steady state

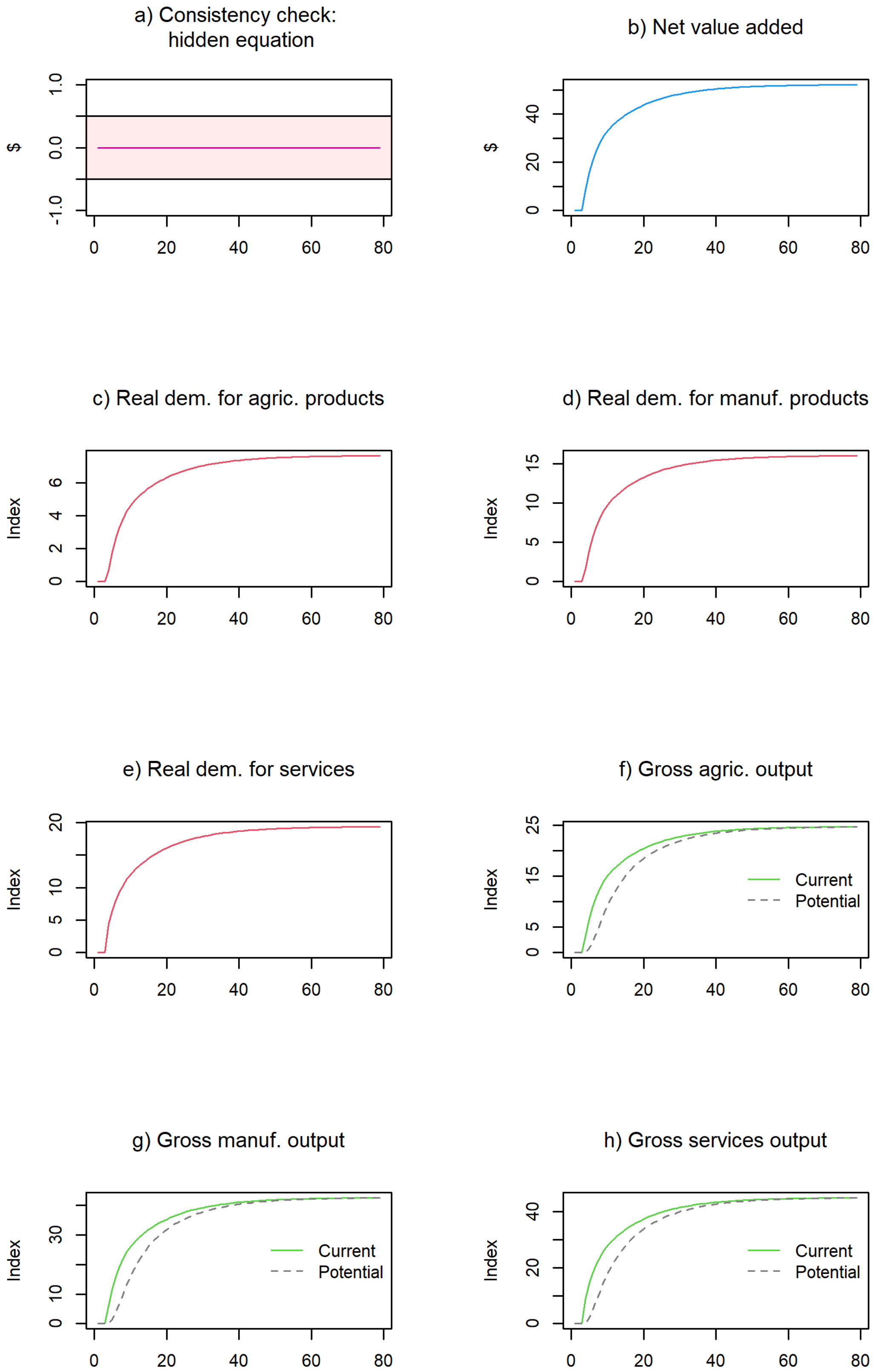


Figure 4. Selected variables under model baseline: adjustment to the medium-run steady state

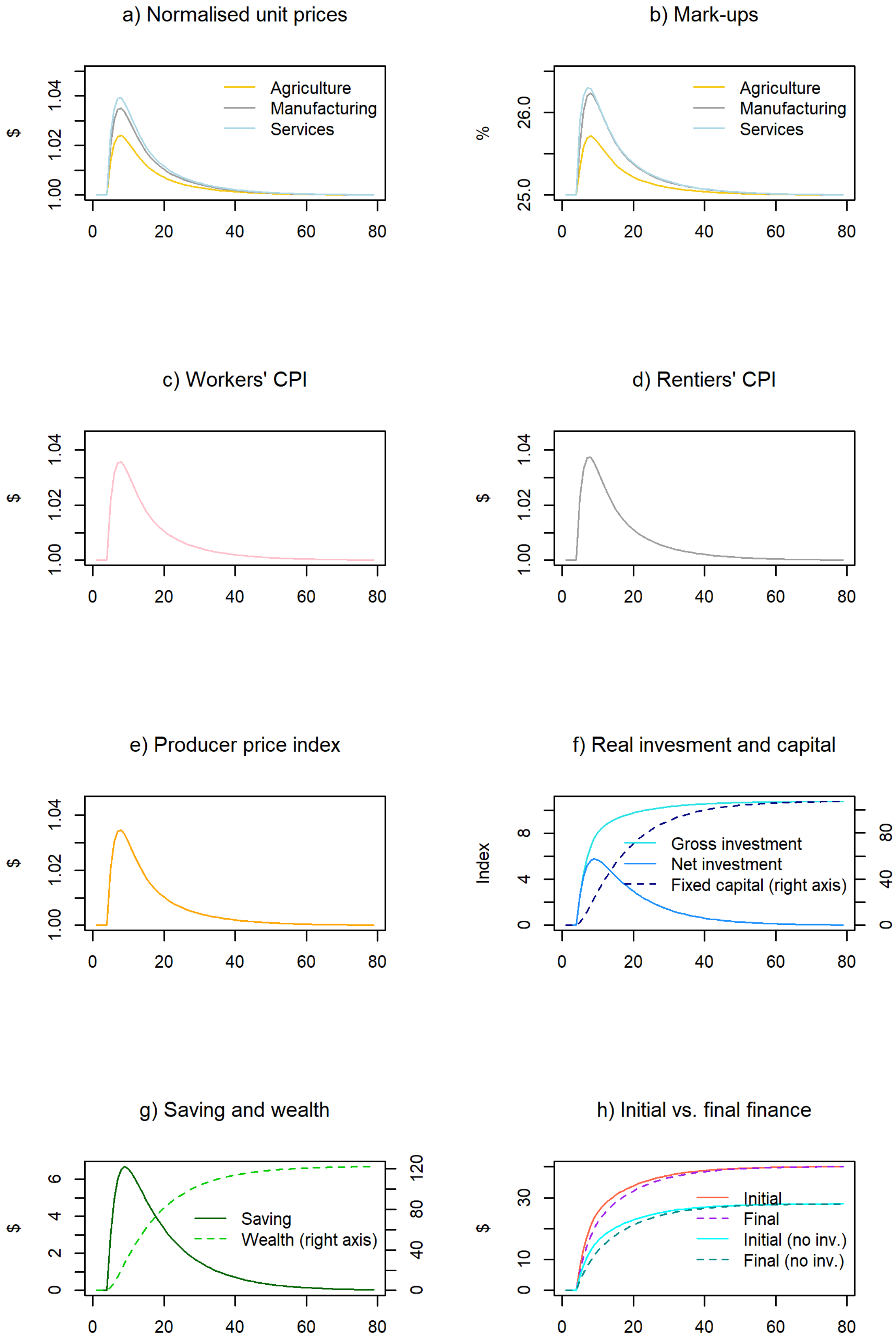


Figure 5. Initial finance, final funding and profits by industry

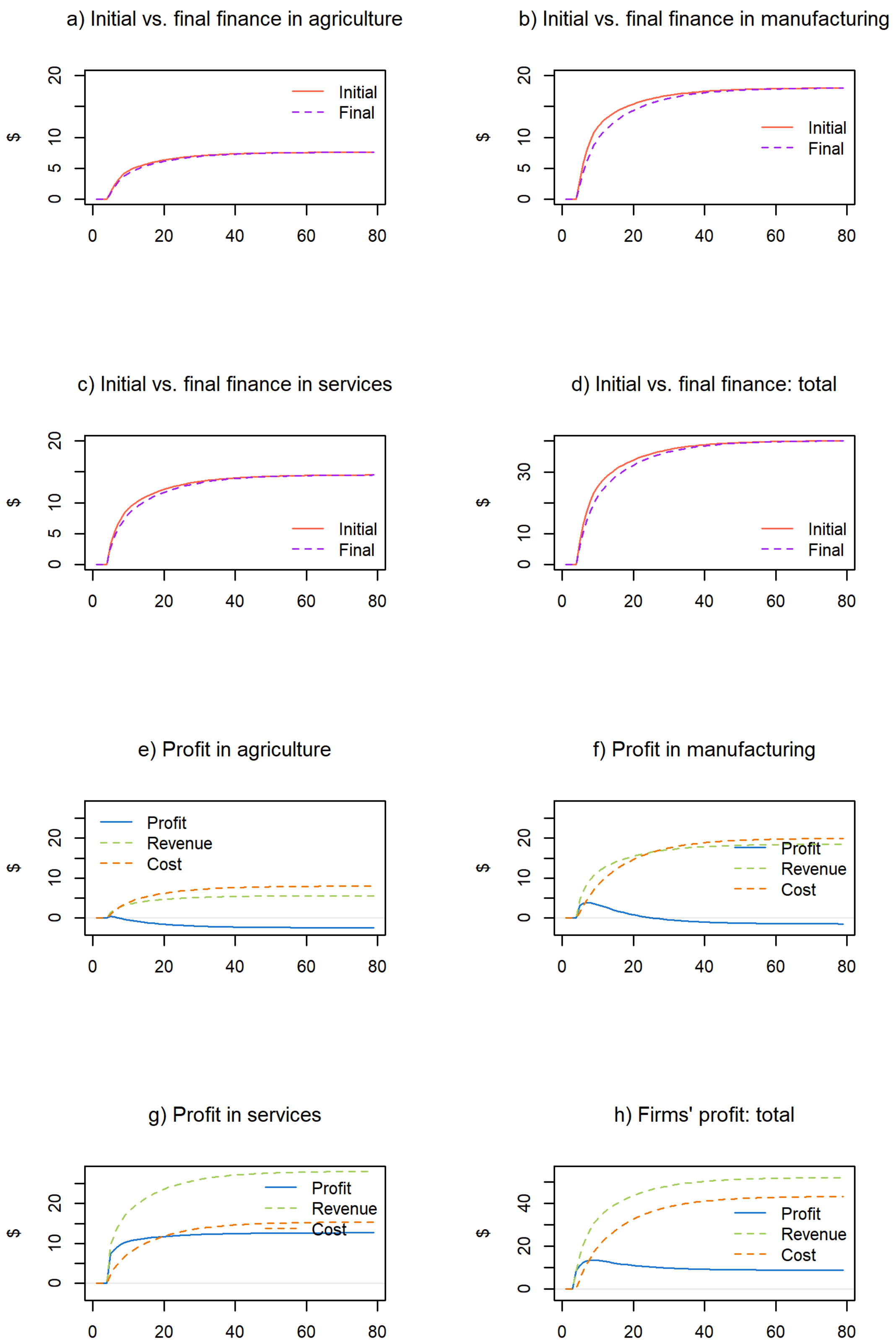


Figure 6. Industry-specific demands and outputs following increase in selected mark-ups

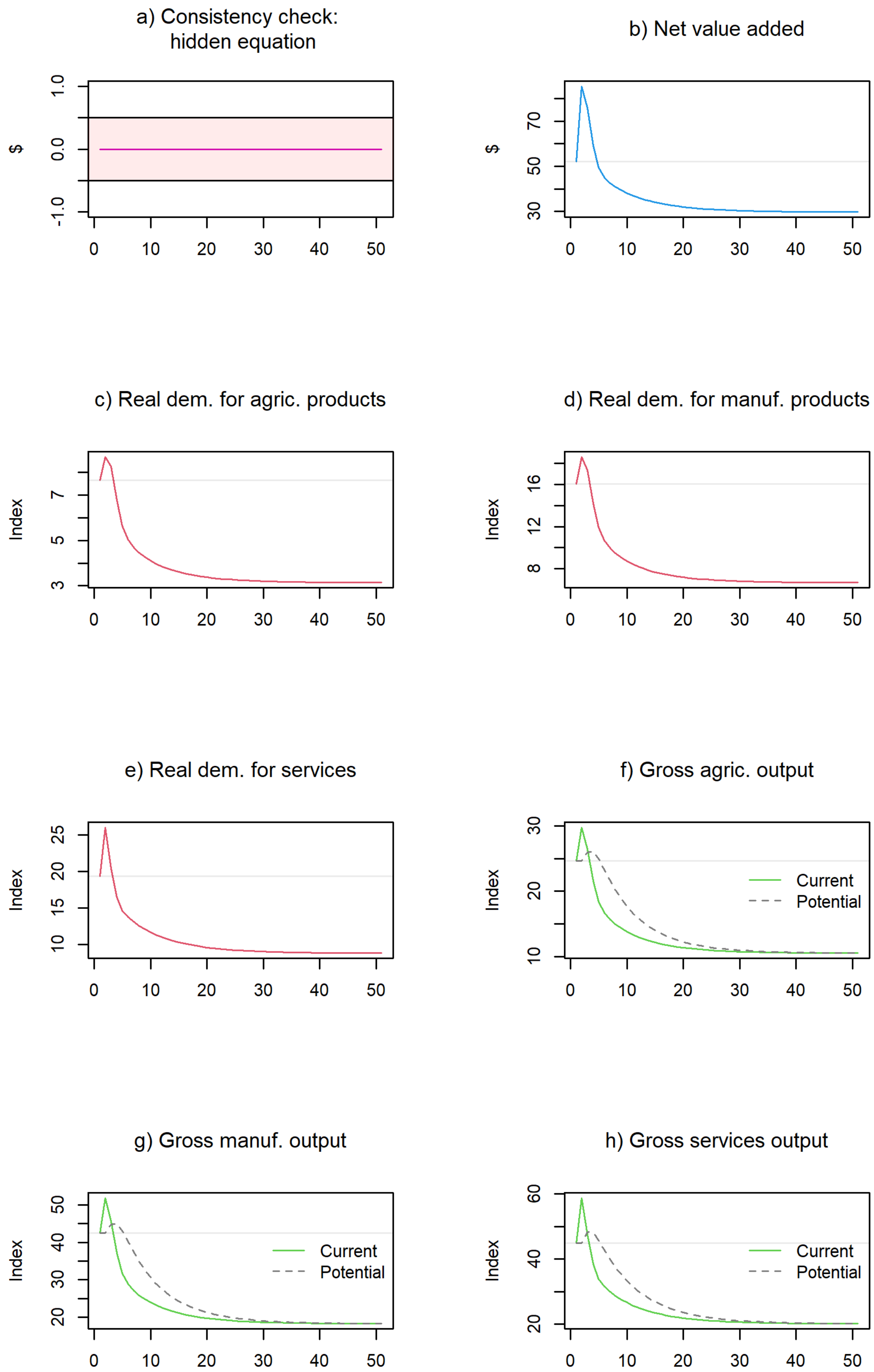


Figure 7. Prices, investment and saving following increase in selected mark-ups

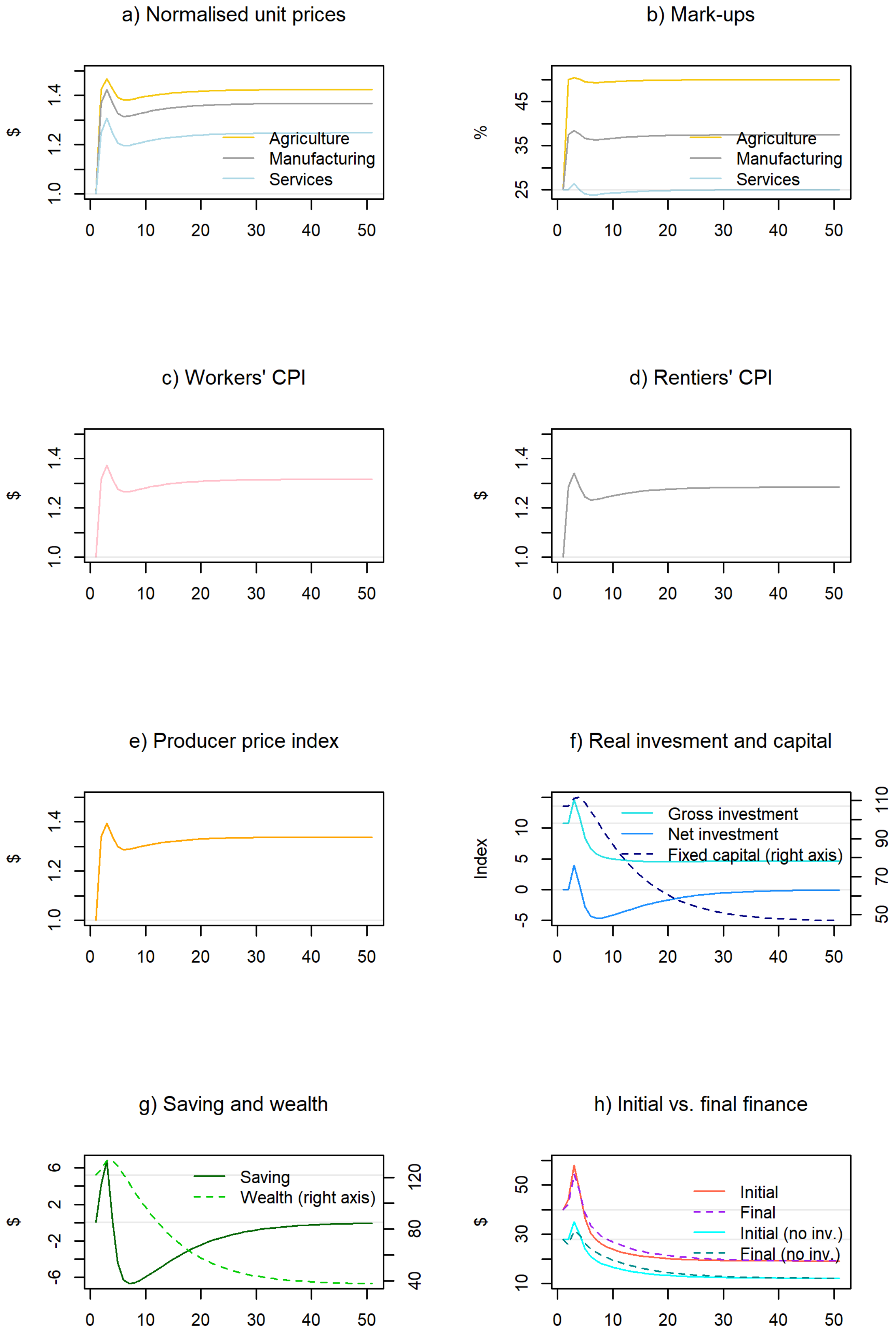


Figure 8. Initial finance, final funding and profits following increase in selected mark-ups

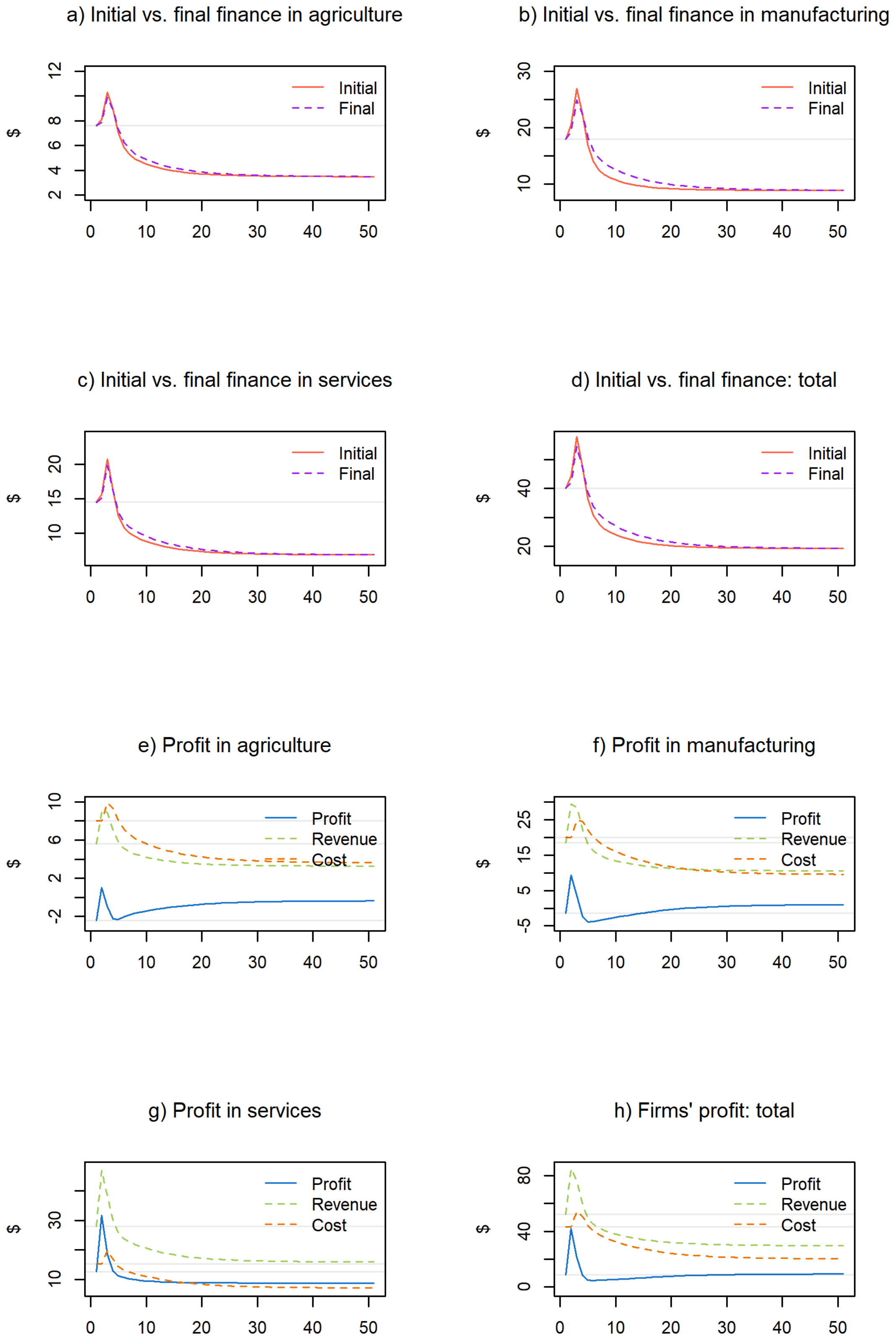


Figure 9. Industry-specific demands and outputs following technical advancement in selected industries

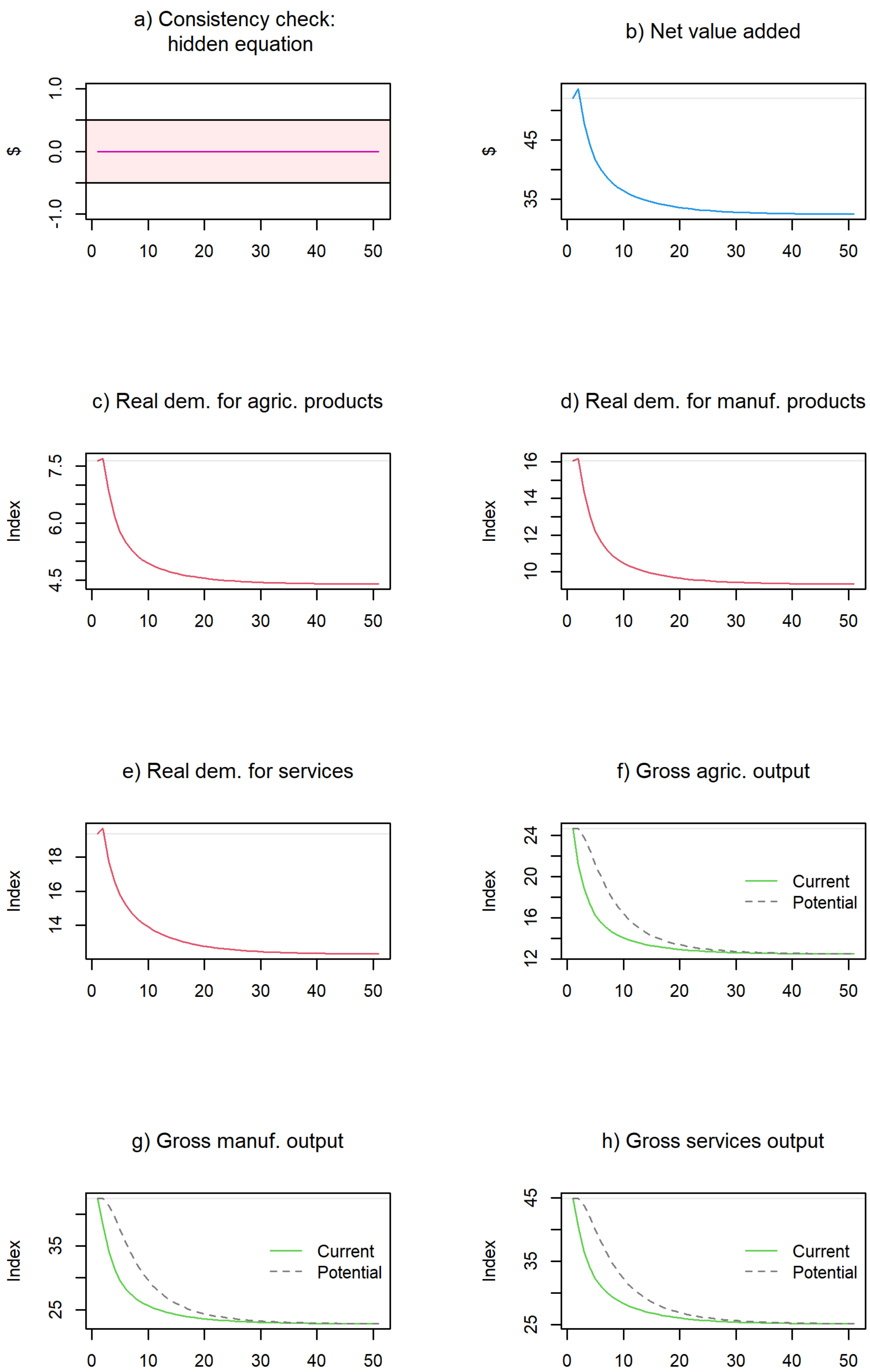


Figure 10. Prices, investment and saving following technical advancement in selected industries

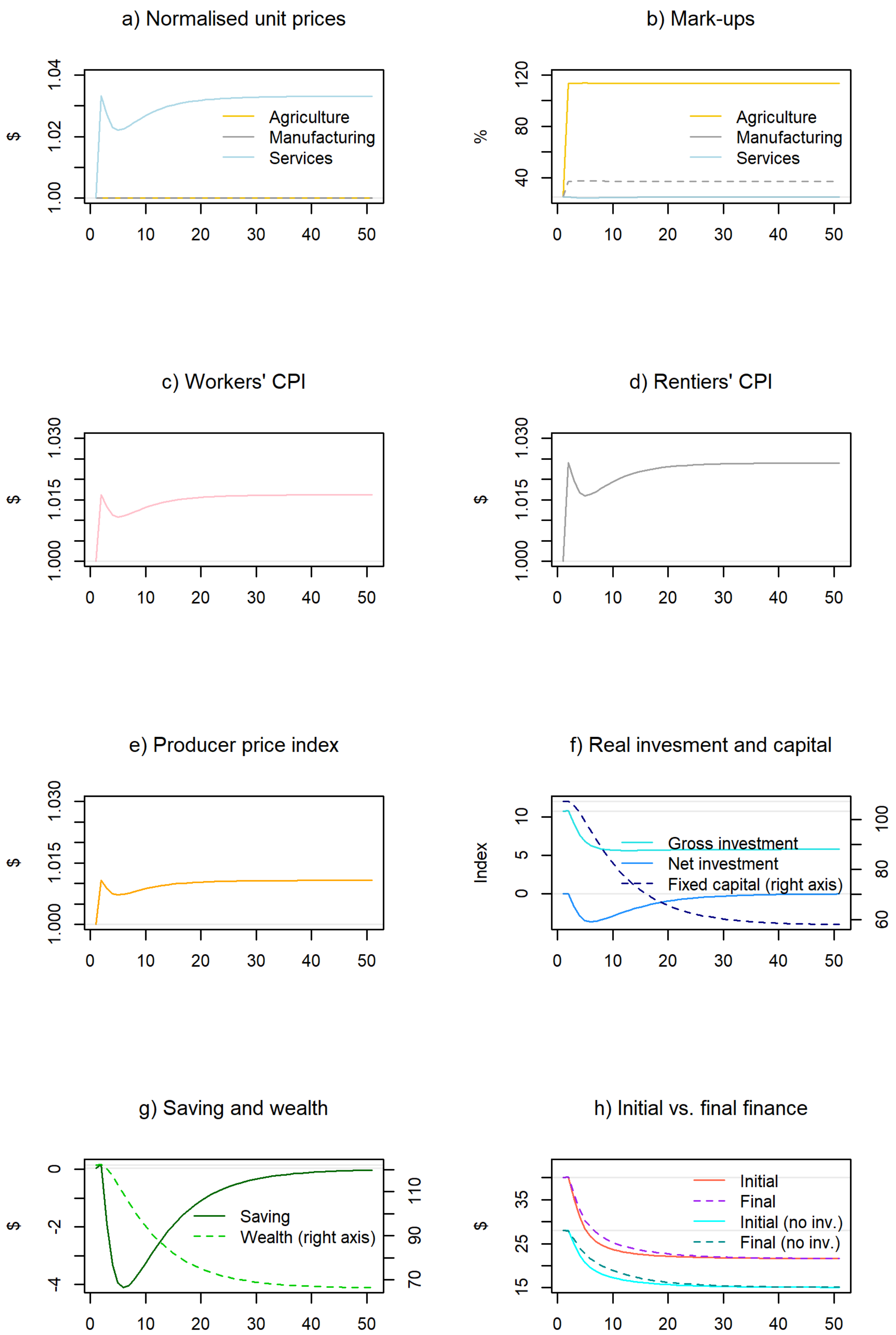


Figure 11. Initial finance, final funding and profits following technical advancement in selected industries