

Hic Rhodus, Hic Salta! Profit in a dynamic model of the Monetary Circuit

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Graziani's simple but profound insight that "A true monetary economy *must therefore be using a token money*" (Graziani 1989: 3) was undoubtedly a major advance in the development of the monetary theory of production. But attempts to go beyond it have raised a new dilemma that in many ways parallels the paradox of surplus value solved by Marx one and a half centuries ago. It is the paradox of monetary profit: how can capitalists borrow money, repay it with interest, and still make a profit?

Graziani provided a static equilibrium formula for profits (Graziani 1989: 14), but this was effectively derived from Kaleckian identities, and not integrated with the model of the circuit itself. Subsequent attempts to solve the paradox within the context of the circuit have concluded that profit is a "zero sum gain": profit earned by one capitalist *must* be at the expense of someone else—be it worker, other capitalist, or banker. Rochon (2005) provided a thoughtful survey of the literature, starting from the proposition that

The existence of monetary profits at the macroeconomic level has always been a conundrum for theoreticians of the monetary circuit... not only are firms unable to create profits, they also cannot raise sufficient funds to cover the payment of interest. In other words, how can M become M' ? (125).

In concluding that all extant attempts to answer this question were unsatisfactory, Rochon also, in our opinion, took the first step towards a solution. Though he commenced with the proposition that "simplification requires us to deal with a single circuit" (127), ultimately he concluded that

while firms need to reimburse their working capital at the end of a given period of production, they typically reimburse the investment over several periods of production. Indeed, firms often take years to pay back an initial investment. We can claim, therefore, that the investment circuit is multi-period... Hence, profits are formed because incomes equaling the value of working and fixed capital are created, while only a portion of the fixed capital needs to be reimbursed in any period. (135)

Rochon's insight is that solving the paradox of profit requires breaking free of the distinction between "single period analysis" and "continuation analysis", which has been one of the major axes of dispute between endogenous money theorists. As Fontana puts it, "horizontalists" have relied upon single period analysis, while "structuralists" have emphasized "a continuation theory of endogenous money" (Fontana 2004: 378).

The trap of segmented time

The concept of dividing time into periods during which expectations remain constant, linked to other single periods with different (but also constant) expectations, has an obvious familiarity to economists who, though they are non-neoclassical themselves,

were trained in the Marshallian concepts of the short and long run. It also has an appeal of apparent simplicity, as Fontana put it:

"A single-period theory of money is to be used as a simple device to separate out the effect of constant expectations from the effects of disappointment and changes in the state of expectations." (Fontana 2004: 83)

However, there is a trap in this beguiling simplicity, as Fontana acknowledged. If "horizontalists" treat each single period as being in equilibrium, all disequilibrium change has to occur between periods—and effectively, out of time. With equilibrium analysis explaining the situation during each period, it appears that successive periods can only be linked via comparative statics.

On the other hand, "continuation analysis" seems to beset "structuralists" with overwhelming complexity, since expectations—and everything else—are changing continuously. Often this has resulted, as Fontana observed, in "the practical need for structuralists to often rely on comparative statics exercises rather than full-blown dynamic experiments" (Fontana 2004: 381). Whichever way Circuitists turn, comparative statics seems inescapable.

The solution, we argue, is to abandon the distinction itself, and instead to seek to combine in one analysis the horizontalist desire for analytic rigor, and the structuralist emphasis on processes of change. We achieve the latter by modeling the Circuit in continuous time using differential equations, and the former by starting with the simplest possible level of analysis, deliberately omitting consideration of behavioral issues, expectations (fulfilled or dashed), uncertainty, etc.

We anticipate criticism that, by omitting these issues, our analysis is non-Keynesian. We concur that a full-blown Circuitist model must include expectations and uncertainty. However, until such time as Circuitists can explain the existence of profits in a capitalist economy, Circuitist analysis is not merely non-Keynesian, it is not even an analysis of capitalism itself. Once the basic analysis explains what we perceive in the real world—the long-term perpetuation of monetary production—then we can move on to the signature issues of Post Keynesian analysis.

Modeling the Circuit in continuous time

We consider a pure credit economy with capitalists, bankers and workers, but no central bank.¹ The circuit begins with bankers extending loans to capitalists that enable them to hire workers, buy intermediate goods, produce and sell output.²

Loans necessarily include the obligations to pay interest and repay principal. While loan contracts can take many forms, we model an intermediate form that is also the aggregate outcome of many different loan contracts of different terms in a multi-agent economy. Given an initial loan level of $K_D(0)$, by the time T capitalists will attempt to

¹ However, the framework we construct can serve as a basis for introducing fiat money at a later stage.

² We use plurals throughout because our model aggregates the outcome of multiple agents, without at this stage considering dynamics between agents of the same type.

reduce the debt outstanding to the proportion X of its original level, where $X < 1$. This gives us the basic relation:

$$K_D(T) = K_D(0) X \quad (1)$$

We take the rate of interest on debt r_d *p.a.* as fixed, and likewise the rate of interest on positive account balances of r_c , where $r_c < r_d$.

We assume that capitalists attempt to meet their principal and interest repayment obligations by paying a fixed proportion R *p.a.* of the outstanding debt. Part of R reflects repayment of the principal only;³ we label this R_p . Part reflects repayment of the interest on the debt, and is identical to the amount added to debt by banks under the loan contract. We spell these out here for the sake of clarity, even though the two terms cancel each other out. Recording debt as a positive number, so that interest accruals add to it and repayments subtract from it, the complete equation for the debt account is thus:

$$\frac{d}{dt} K_D = r_d K_D - (r_d + R_p) K_D \quad (2)$$

A second account is also needed: a “credit” (more correctly, working capital) account K_C , into which the endogenously created money is paid by the banks. When this account has a positive balance, the banks are obliged to pay interest at the rate r_c . This second account is the source from which capitalists meet, as best they can, their loan repayment obligations. Its equation of motion is thus:

$$\frac{d}{dt} K_C = r_c K_C - (r_d + R_p) K_D \quad (3)$$

As with the debt account, interest receipts accrue to K_C and principal and interest repayments subtract from it—and are instantly also deducted from the debt account.⁴

Finally, accounts are needed to record the banks’ transactions. Here we note an important observation from Graziani: in order to prevent seigniorage, banks cannot spend the money they endogenously create, but only the profit on the spread between loans and deposits. We therefore also provide two accounts for banks: a principal account B_P , into which principal repayments flow, and an income account B_Y for banks’ lending activities. Thus $R_p K_D$ flows into the principal account:

$$\frac{d}{dt} B_P = R_p K_D \quad (4)$$

and the net difference between $r_d \cdot K_D$ and $r_c \cdot K_C$ flows into the income account:

³ Solving for R , we get $R = r_d - \frac{\ln X}{T}$ where $X < 1$. The r_d component represents the repayment of interest on debt; the $-\frac{\ln X}{T}$ component is the repayment of principal (this is positive because $X < 1$)

⁴ This is the one sense in which “simultaneity” is allowed in this model: when, like a couple kissing, one act is the mirror image of the other.

$$\frac{d}{dt} B_Y = r_d \cdot K_D - r_c \cdot K_C \quad (5)$$

Equations (2) to (5) complete the model at this stage, and encapsulate the dilemma on which all previous attempts to explain profit in the monetary circuit have foundered: it is obvious that, at the putative end of this cycle, capitalists will make a loss. Figure 1 illustrates this with an initial loan D_0 of \$1 million, a repayment target X of 10%, a target time T of 5 years, debit interest rate r_d of 5% and a credit rate r_c of 3%. The graphic shows the execution of this model in the mathematical simulation program Mathcad.⁵

⁵ This model could be implemented in any of several other packages—including Mathematica, Maple, Matlab, Scientific Workplace—but we find Mathcad to have by far the most intuitive interface.

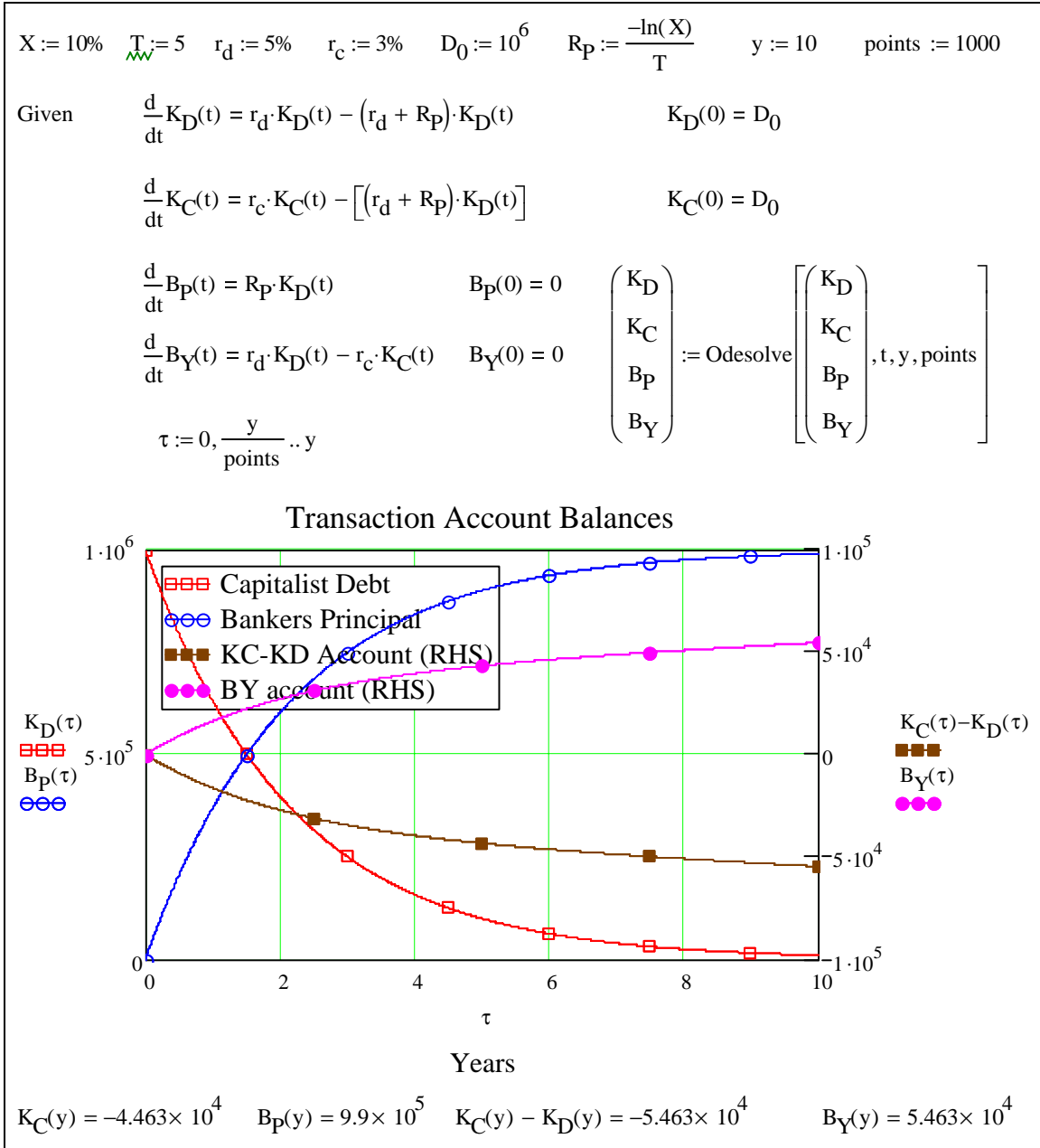


Figure 1: Mathcad implementation of basic circuit without production or exchange

Even at this simple level, our model enables us to reject an accepted Circuitist proposition, that endogenously created credit money is destroyed when debt is repaid. In his seminal paper Graziani's states that "As soon as firms repay their debt to the banks, the money initially created is destroyed" (Graziani 1989: 5). This belief is echoed in many subsequent Circuitist works, as Rochon documented (Rochon 2005: 126, 127, 128). It is implicit in the "Kaldor-Trevithick reflux principle" (Lavoie 1999—though it is possible to re-interpret this concept in a manner consistent with our results), and accepted widely in Post Keynesian analysis (see for example Lavoie 1992, p. 130, cited in Rochon 2005 p. 130).

Money is *not* destroyed when debt is repaid, even when no income is generated from the borrowed money. Instead, the debt is paid down to (almost) zero, while the money that was simultaneously created with it flows into the bankers' principal account as an unencumbered asset. Only the failure to repay debt fully can destroy money, because then the flow back to B_p is less than the principal repayment required by the debt contract.

The total amount of money is conserved in this simple instance of a single injection of endogenous money, and equals (at this stage) $K_C + B_p$.⁶ In a more complex model, with new credit creation, this amount would rise over time—and fall during a crisis, when insolvency and bankruptcy destroyed more money than was newly created.

Nonetheless, ten years after accepting our hypothetical \$1 million loan, the capitalists in our model are still \$5,463 in the red, and bankers are an equivalent amount ahead. The advantages of being a banker are obvious: but why would anyone want to be a capitalist?

Because capitalists use the working capital K_C to finance production, sell commodities, make a profit, and repay their debts. Production is therefore, not amazingly, an essential aspect of the monetary theory of production. It is this real insight of Marx's that has become obscured in the initial attempts to come to grips with Graziani's monetary vision. Without a surplus generated in production, there can be no profit.

A prelude: time lags

To finance production, an outflow must occur from the capitalist working capital account. Here we introduce the systems engineering concept of a *time lag*, which is a measure of the rate at which a substance flows out of a vessel—in this case, money out of the working capital account K_C . The faster this flow is, the more rapidly money finances production, which in turn generates income for capitalists and workers.

While this concept is deliberately mechanistic in this simple model, a time lag can also be interpreted as the aggregate outcome of many different agents with many differing time responses (Andresen, 1998, 1999). In a more complex model, the lags would be a function of behavioral variables—expectations of profit, propensities to consume, etc. At this point, we use constant time lags, since the only question afoot is whether it is feasible for capitalists in the aggregate to make a profit. Whether they do so in practice at a given time, or in a more complete dynamic model, is another matter altogether.

A time-lag differs from the discrete *time-delay* that has been a mainstay of economic reasoning, in which a variable $Y(t)$ is argued to be a function of other variables at times $t-1$, $t-2$, etc. While most economic activities *are* discrete—wages are paid once a fortnight, cars come off the production line one at a time, consumers buy units of commodities at discrete times, etc.—the aggregate of many such discrete events at

⁶ The Kaldor-Trevithick reflux principle can be made consistent with this by treating the balance in B_p as money “not in circulation”, even though it is clearly not destroyed.

uncorrelated times is better approximated by a continuous time function with a time lag than a discrete time function with a time delay.

For technical reasons, the time lag is expressed as a fraction of the time unit of the model—in this case, years—and shown as an inverse in the system equations. We label the time lag for the outflow τ_{KC} , so that the outflow from the account is $\frac{1}{\tau_{KC}}K_C$.⁷

The essence of the circuit: financing production & profit

The outflow hires workers and buys intermediate goods from other capitalists to enable the production of commodities, which are then sold to capitalists, workers and bankers. In this simple one-commodity model, all intermediate goods purchases resolve themselves into wages and profits for workers and capitalists. Thus, given production and the sale of output, the outflow $\frac{1}{\tau_{KC}}K_C$ generates income flows that resolve exclusively into either profits or wages. The ratio of one to the other is, in Marx's notation, the ratio of s to v , or the rate of surplus value.⁸

The source of profit within the monetary circuit is thus the generation of a surplus during production, the same as it was within Marx's abstraction of a real circuit. Given that these represent fractions of a flow that sum to 1 in our model, we express this ratio as $\frac{s}{v} = \frac{s}{1-s}$, so that $s = \frac{rsv}{1+rsv}$ where rsv is Marx's rate of surplus value. $\frac{1-s}{\tau_{KC}}K_C$ is the flow of wages. $\frac{s}{\tau_{KC}}K_C$ is, however, *not quite* the flow of profits.

It is instead the outflow of financial capital needed to generate the flow of profits back. Purchase of inputs, production, and sale, must all first occur, and all these processes take time. We introduce the system state F (for "factory") to represent this process, and use τ_F for the related time lag between expenditure on production and income from sale.

We treat production implicitly in this simple model. Our explicit model—which we are currently extending—has the inflow $\frac{s}{\tau_{KC}}K_C$ purchasing inputs Q at price P , the production process generating output $Q' = (1+\theta)Q$ with a production time lag τ_F , which is then added to stocks Θ , from which sales occur at a rate determined by the transaction time lags τ_F , τ_W and τ_B . This, however, raises issues about the time

⁷ This is a first order time lag. We eschew more complex ones in this simple model, however higher order lags result from the interplay between the related first order differential equations.

⁸ Given the invalidity of the labor theory of value (Keen 2003a, 2003b, 2001), in a multi-sectoral setting, the Marxian concept of the rate of surplus value has no meaning. However in this one commodity model, it is a valid abstraction relating capitalist to worker income from production.

dynamics of P , the consideration of which we wish to leave for a later paper.⁹ Our new implicit-production equation is thus:

$$\frac{d}{dt}F = \frac{s}{\tau_{KC}}K_C - \frac{1}{\tau_F}F \quad (6)$$

We also add the terms $-\frac{1}{\tau_{KC}}K_C$ and $\frac{1}{\tau_F}F$ to the working capital account to represent, respectively, the outflows of money to finance production, and the returning lagged inflow of monetary profits.

We introduce an account for workers wages W_Y with an inflow term of $\frac{1-s}{\tau_{KC}}K_C$, and include the fact that workers accounts accrue interest $r_c W_Y$; this in turn requires a matching outflow from the bankers' income account B_Y .

To complete the modeling of financial transactions,¹⁰ we must introduce expenditure by bankers and workers with time lags that reflect how rapidly each class must draw on its transaction account balances to fund consumption. Bankers' and workers' consumption spending is thus proportional to their account balances, with the ratios τ_B and τ_W respectively. There is thus an outflow from workers' account of $\frac{1}{\tau_W}W_Y$ and bankers' account of $\frac{1}{\tau_B}B_Y$, with matching inflows into the capitalists' account.

The complete model is (with the new inflows and outflows highlighted in matching brackets):

⁹ Since the model currently lacks an explicit concept of capital, Sraffa prices cannot be used. A simple Kaleckian markup price would be feasible, but this overrules the income distribution dynamics. We have experimented successfully with an inventory-stock pricing equation, but generally feel these issues are best left for a longer, specialized paper.

¹⁰ We emphasize that transactions and income are different concepts. The flow of the amount $\frac{1}{\tau_{BY}}B_Y$ from bankers' accounts to capitalists' is a transactional flow; the portion of that which exceeds the cost of production is a flow of income to capitalists. All capitalist income flows are incorporated in $\frac{1}{\tau_F}F$.

$$\begin{aligned}
\frac{d}{dt} K_D &= -R_P K_D \\
\frac{d}{dt} K_C &= r_C K_C - (r_d + R_P) K_D - \left\{ \frac{1}{\tau_{KC}} K_C \right\} + \left\langle \frac{1}{\tau_F} F \right\rangle + \left[\frac{1}{\tau_W} W_Y \right] + \left[\frac{1}{\tau_B} B_Y \right] \\
\frac{d}{dt} F &= \left\{ \frac{s}{\tau_{KC}} K_C \right\} - \left\langle \frac{1}{\tau_F} F \right\rangle \\
\frac{d}{dt} W_Y &= \left\{ \frac{1-s}{\tau_{KC}} K_C \right\} + [r_C W_Y] - \left[\frac{1}{\tau_W} W_Y \right] \\
\frac{d}{dt} B_P &= R_P K_D \\
\frac{d}{dt} B_Y &= r_d \cdot K_D - r_c \cdot K_C + [r_C W_Y] - \left[\frac{1}{\tau_B} B_Y \right]
\end{aligned} \tag{7}$$

Figure 2 shows the results of a simulation of this model over a 20 year time period, with the additional parameter values of $\tau_{KC} = \tau_F = \frac{1}{4}$, $\tau_B = 2$, $\tau_W = \frac{1}{26}$ and $rsv = 200\%$ (corresponding to an s value of 0.667). The top graph shows the account dynamics over the full twenty years; the bottom graph highlights the second and third order dynamics that occur in the first three years of the simulation. In contrast to the previous incomplete model, capitalist indebtedness tapers to zero—as do all income accounts. Capitalists have been able to borrow money, produce output, sell it, repay debt, and make a profit.

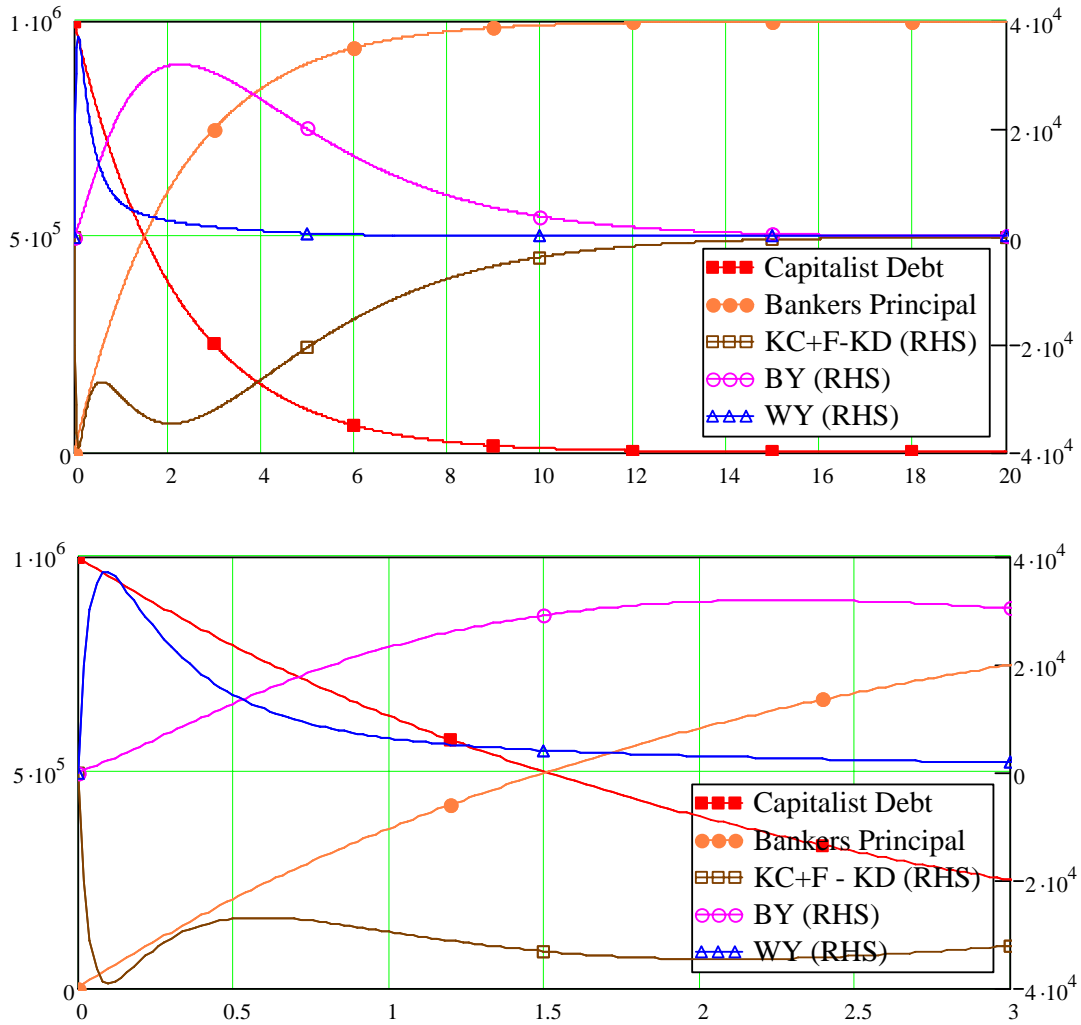


Figure 2: Transaction account dynamics without relending

Figure 3 shows the associated income flows, and the aggregate income levels generated by the model. These are, respectively:

$$\text{Net Profits: } \int_0^y \left(\frac{1}{\tau_F} F - r_d \cdot K_D \right) \cdot dt$$

$$\text{Wages: } \int_0^y \frac{1-s}{\tau_{KC}} K_C \cdot dt \quad (8)$$

$$\text{Bank Income: } \int_0^y (r_d \cdot K_D - r_c \cdot K_C - r_c W_Y) \cdot dt$$

The first two are the Circuitist versions of Kalecki's classic statement that "capitalists get what they spend, workers spend what they get".¹¹ The third adds the component that neither Keynes nor Kalecki properly incorporated, bank profits from finance—"bankers interest what they lend". In this debt-finance only model, $\int \frac{1}{\tau_F} F - r_d \cdot K_D$ is the $M+$ of Marx's monetary circuit; the M is solely the servicing costs of their debt because, in the absence of equity finance, capitalists advance no money of their own.

In the incomplete model, bankers were the clear winners and capitalists the losers. In this complete model, however, "everybody wins", though capitalists more so than workers (given the assumed rate of surplus value), and bankers least of all.

¹¹ Workers' and capitalists' incomes include interest on their credit balances, so that aggregate income sums to wages plus profits plus interest on outstanding debt. The term y in the integration limit is the number of years in the simulation—in this case, 20.

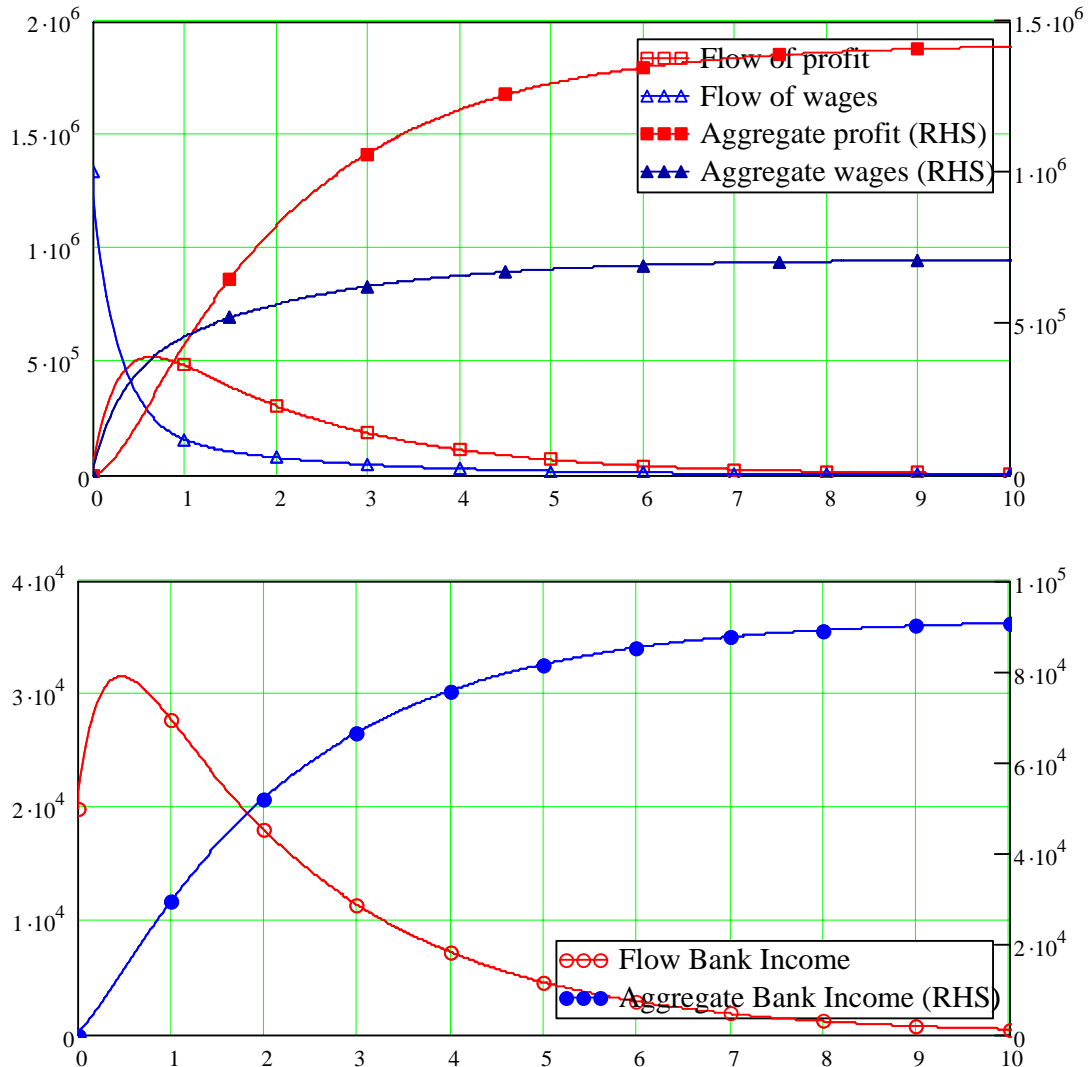


Figure 3: Income dynamics without relending

The magnitude and dynamics of profit and income distribution

This model indicates other determinants of profit considered by Marx, but neglected until now in Circuitist thinking: the rate of turnover of financial capital, and the speed of the process of production. τ_{KC} determines how quickly capitalists employ their financial capital; τ_F determines how quickly production and sale turns inputs into outputs and then profits. The faster both these processes are, the more income that is generated in production per unit of time—and the more quickly capitalists repay their debts to bankers. A fall in either of these time lags thus increases capitalist and worker incomes and reduces bankers’, as shown in Figure 4. For a sufficiently small time lag—under $1/6^{\text{th}}$ of a year in these simulations—the profits earned in this model can exceed the size of the original loan. In general, profits far exceed the interest payments necessitated by the loan, even with a production lag of one year. Clearly, as Minsky once observed in another context, “it pays to lever”.

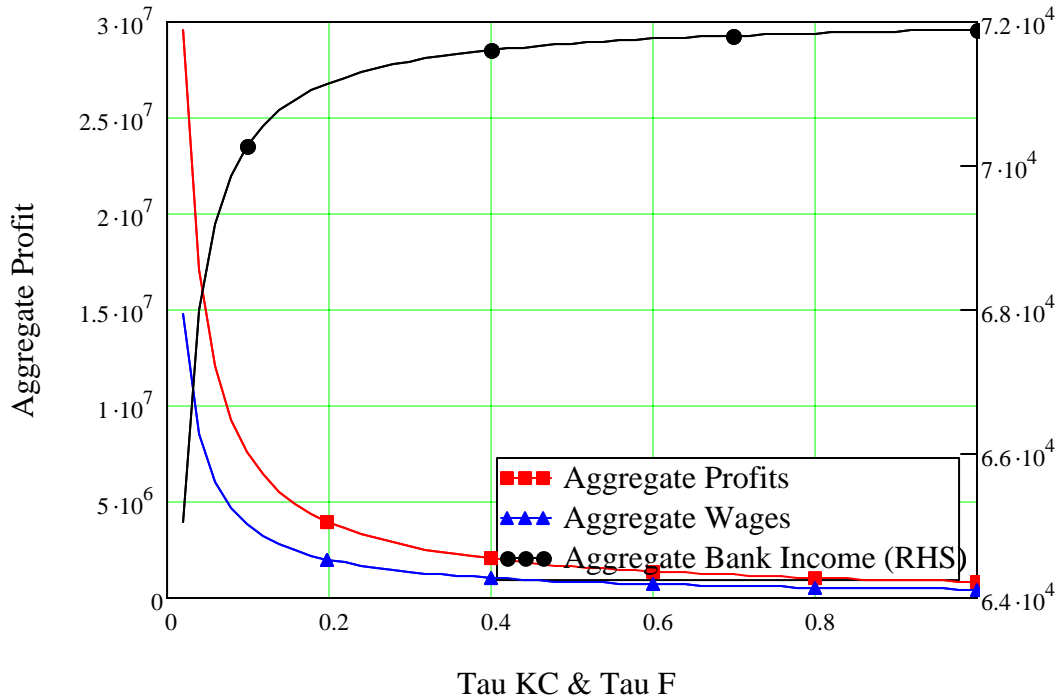


Figure 4: Income distribution vs time lags in production

The time pattern of relative income flows also bears noting. As Figure 5 shows, given our base simulation with $\tau_{KC} = \tau_F = \frac{1}{4}$, capitalist income starts well below both worker and banker income. However, by the end of the simulation, aggregate profits are precisely twice aggregate wages (equivalent to the rate of surplus value of 200%), while aggregate profits exceed aggregate bank income by a factor of more than 15.

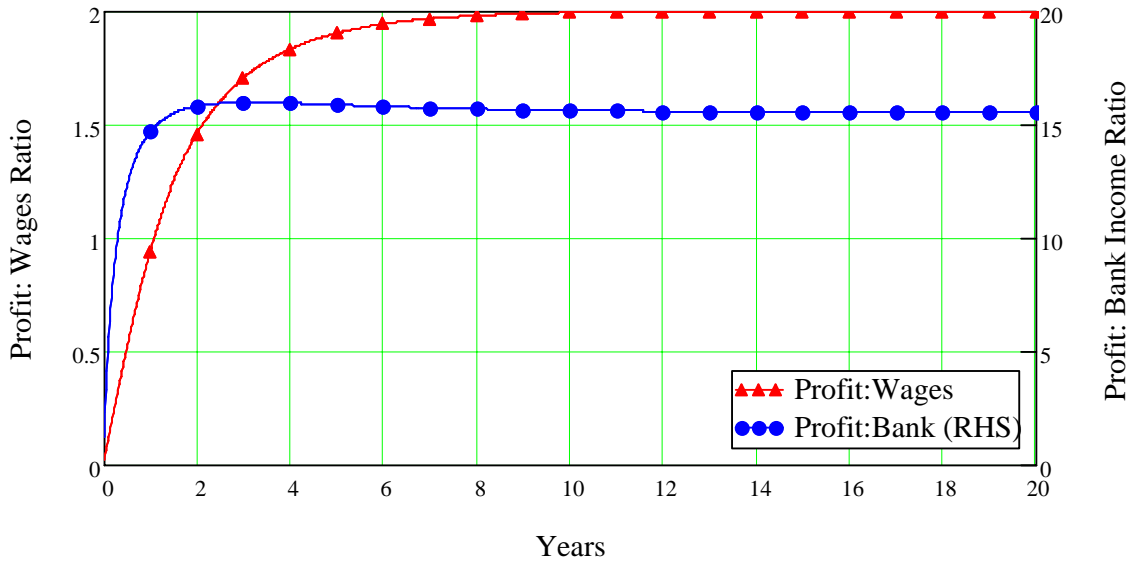


Figure 5: Ratio of aggregate income levels over time

The non-destruction of money

One final point deserves emphasis here: the conservation of money in this simple model without re-lending, and, in capitalism in general, the non-destruction of money except via bankruptcy. The top graph in Figure 6 plots the sum of all income accounts plus bankers' principal: this is identically equal to the original injection of endogenous money.

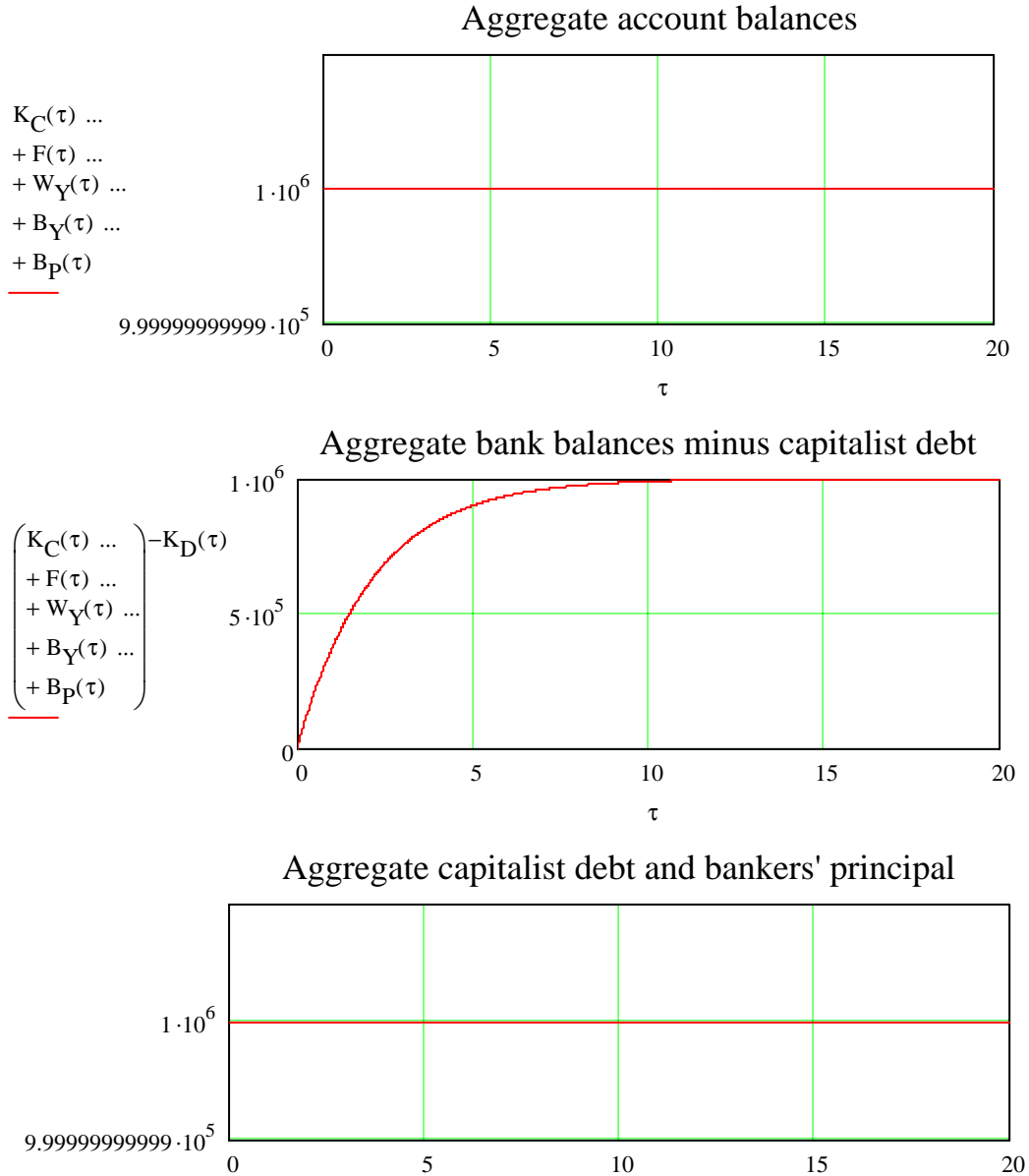


Figure 6: the non-destruction of money

The middle graph shows that what is destroyed by debt repayment is simply debt. As the impulse from the original injection of endogenous money dies out, all the endogenous money accumulates in the bankers' principal account, while capitalist debt is paid down to zero.

The final graph establishes another identity: the sum of bankers' principal and capitalist debt represents the net assets of bankers, which is identical to the initial creation of endogenous money.

Perpetuating the circuit: re-lending of bankers' principal

The model as specified above decides two issues that have remained in contention amongst Circuitists for some time: money is not destroyed by debt repayment; and a profit can be earned on borrowed money. However, it cannot yet address a third area of debate: whether economic activity can be sustained without new injections of money.

Contrary to Fontana (2000), Andresen (2006) answers this question in the affirmative. We consider this issue by allowing for re-lending of bankers' principal B_P . Again, we model this with a simple time lag τ_{BP} , where in this simulation $\tau_{BP} = 4$. This is added as new debt to the capitalists' debit account, and new working capital to the credit account. Our complete model of financial flows is thus (with the new elements highlighted by matching brackets):

$$\begin{aligned}
 \frac{d}{dt} K_D &= -R_P K_D + \left\{ \frac{1}{\tau_{BP}} B_P \right\} \\
 \frac{d}{dt} K_C &= r_C K_C - (r_d + R_P) K_D - \frac{1}{\tau_{KC}} K_C + \frac{1}{\tau_F} F + \frac{1}{\tau_W} W_Y + \frac{1}{\tau_B} B_Y + \left\{ \frac{1}{\tau_{BP}} B_P \right\} \\
 \frac{d}{dt} F &= \frac{s}{\tau_{KC}} K_C - \frac{1}{\tau_F} F \\
 \frac{d}{dt} W_Y &= \frac{1-s}{\tau_{KC}} K_C + r_C W_Y - \frac{1}{\tau_W} W_Y \\
 \frac{d}{dt} B_P &= R_P K_D - \left\{ \frac{1}{\tau_{BP}} B_P \right\} \\
 \frac{d}{dt} B_Y &= r_d \cdot K_D - r_c \cdot K_C + r_c W_Y - \frac{1}{\tau_B} B_Y
 \end{aligned} \tag{9}$$

As Figures 6 and 7 show, our modeling concurs with Andresen's: this model economy can function at a sustained level with only a single injection of endogenous money. Economic activity continues because, rather than all the money accumulating in the bankers' principal account, a proportion of it continues to be lent, renewing the supply of circulating money, and hence production and the generation of income.

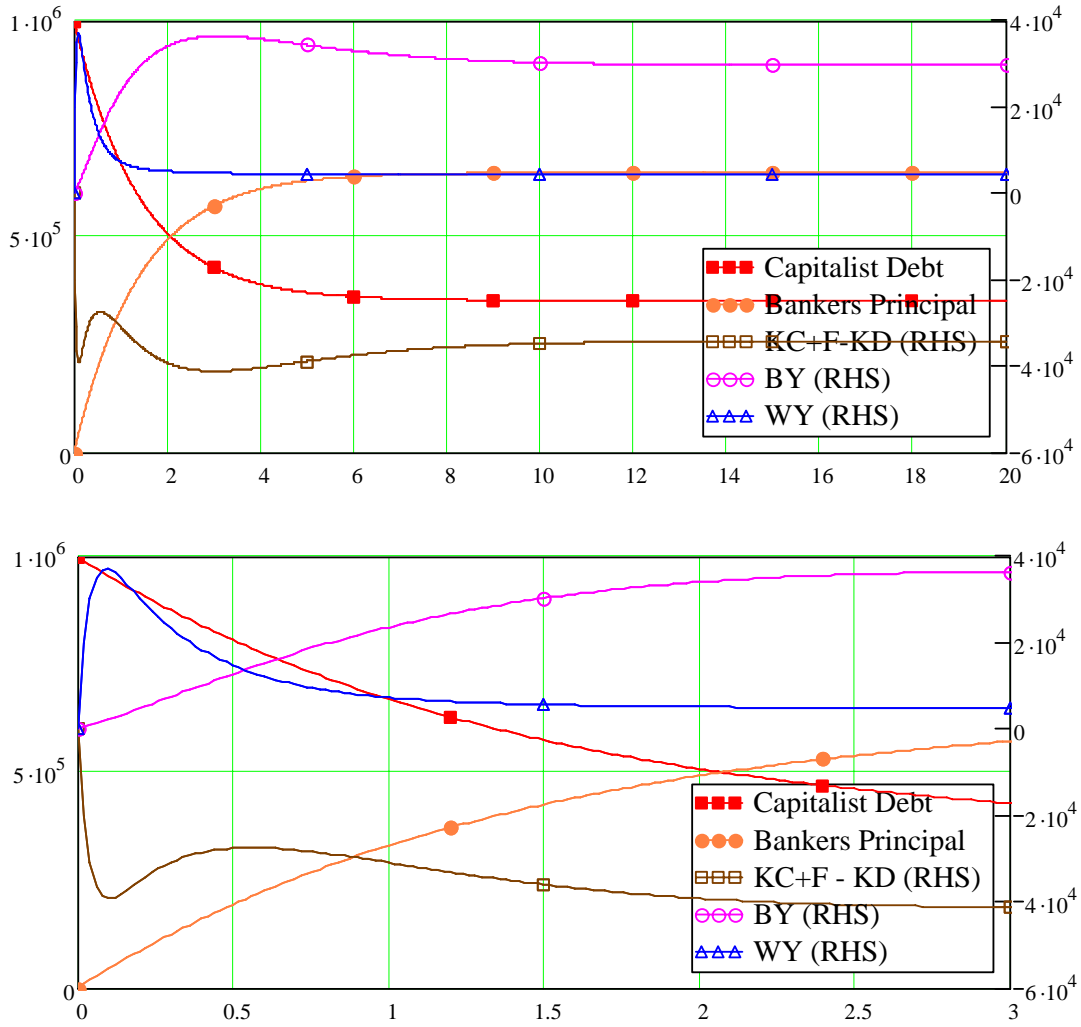


Figure 7: Sustained economic activity with relending of bank principal

Figure 8 confirms that the circulation of this fixed amount of money generates a continuous stream of income for all three classes in the model:

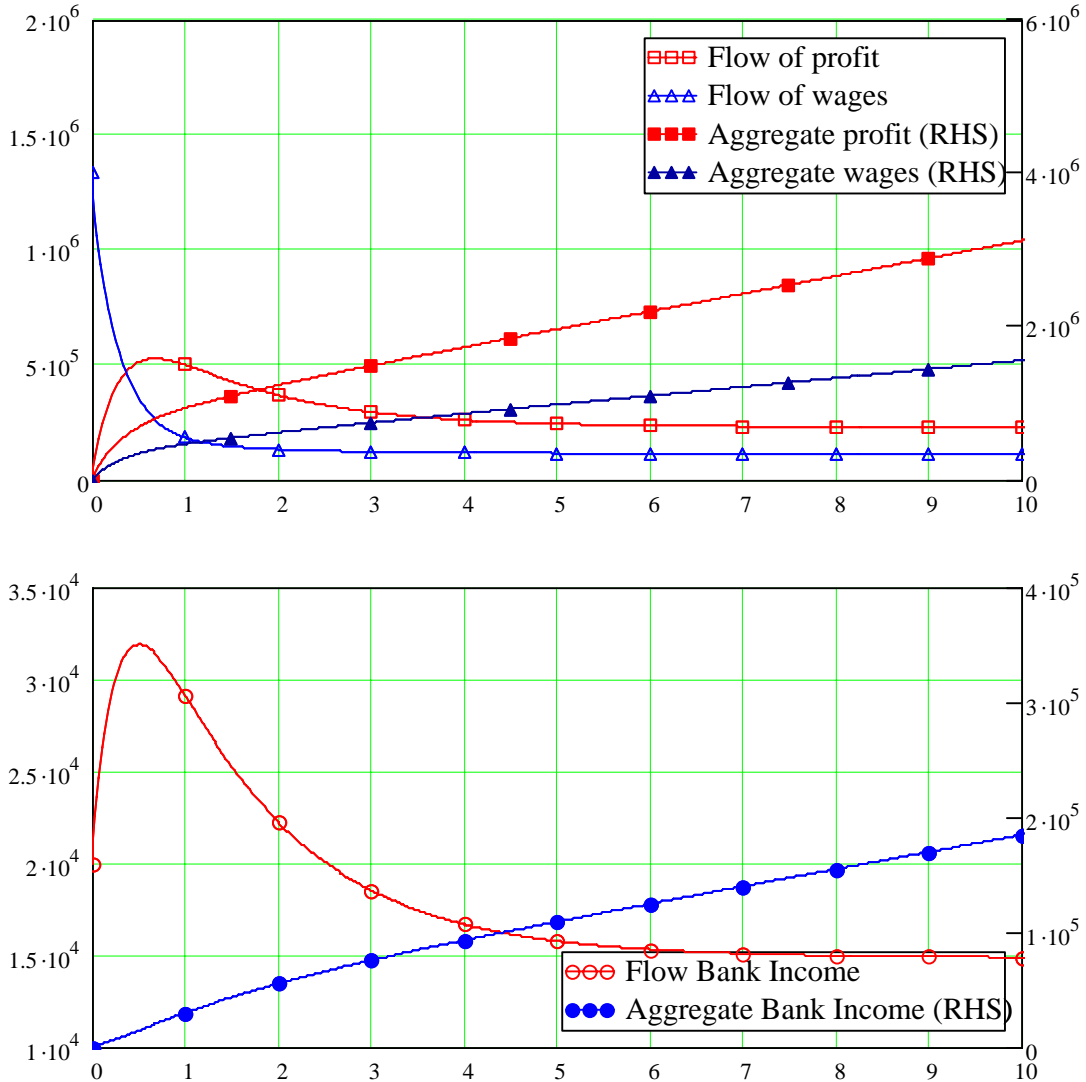


Figure 8: Sustained income flows with re-lending

Re-lending of principal only slightly alters the time pattern of aggregate income flows.¹² As Figure 9 shows, the capitalist: worker income ratio does not quite reach the rate of surplus value. The Profit:Bankers' income ratio, on the other hand, now tapers to 15.608—only slightly more than the 15.549 ratio that applied without re-lending.

¹² Aggregate income for a class at time t is the integral of the income from zero years to t .

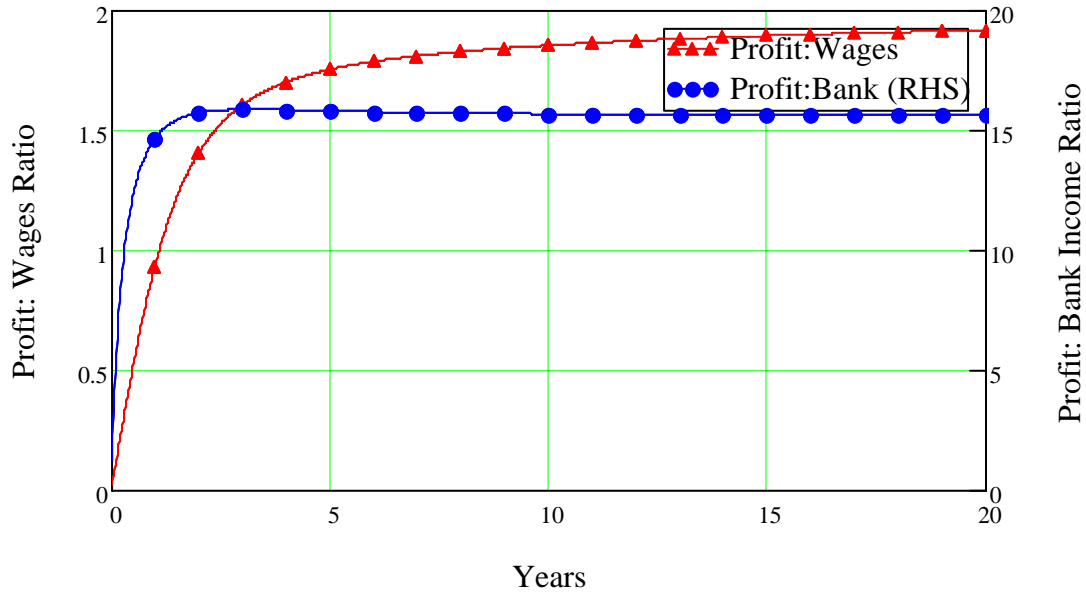


Figure 9: Ratio of aggregate incomes over time with re-lending

From Circuitist skeleton to the body economic

This is a deliberately skeletal model, designed only to show that the monetary circuit is internally consistent, and that it can explain both the endogeneity of credit money, and the phenomenon of monetary profit. In a full Circuitist model, new injections of money would be occurring all the time; flows between accounts would be determined by behavioral relations rather than fixed parameters; production would be multi-sectoral; prices and the distribution of income would be changing continuously; profits would rise and fall, and uncertainty about the future would lead to booms, slumps, bubbles, depressions, exceeded and dashed expectations, bankruptcy, and all the panoply of everyday actual capitalism.

We hope that, in providing this skeleton, we have enabled Circuitist thinking to transcend some early conundrums. We invite other Circuitists to join us in putting flesh on this skeleton.

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