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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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Credit and economic recovery*

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Abstract

It has become almost a stylized fact that after financial crises, economic activity recovers without a rebound in credit. We investigate the relationship between credit and economic activity over the business cycle. In a simple model we show that a rebound in the flow of credit has closer relationship with economic recovery than a rebound in the stock of credit. Using data from developed and emerging market countries we find that the flow of credit has a higher correlation with GDP than the stock of credit, in particular during recovery periods from financial crises.

1 Introduction

It has become almost a stylized fact that after financial crises, economic activity recovers without a rebound in credit (see for example International Monetary Fund (2009)). This phenomenon, termed the “credit-less recovery”, was first highlighted by Calvo, Izquierdo and Talvi (2006a, 2006b) in the context of emerging market economies, but is also a feature of business cycles in industrial countries (Claessens, Kose and Terrones 2008). Perhaps the most striking example of this is the U.S. experience after the Great Depression. A credit squeeze is thought to have been an important cause of the Great Depression (Bernanke 1983), and GDP and credit declined sharply in the U.S. in 1931–1933. Yet real GDP growth in the U.S. was 11% and 9% in 1934 and 1935 respectively, even though credit growth remained negative. This raises the question: given that the decline in credit during financial crises is so closely related to the decline in economic activity, how does the economy recover without a rebound in credit?

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In this paper we attempt to solve this apparent paradox by arguing that recoveries only appear credit-less when the *stock* of credit is compared to the *flow* of economic activity. To the extent that spending is credit financed, GDP will be a function of new borrowing, or the *flow* of credit. We find that the rebound in domestic demand after a financial crisis is highly correlated with the rebound in the flow of credit, even if it is poorly correlated with developments in its stock.

A consequence of this is that GDP growth should be related to changes in the flow of credit rather than the stock. We focus on changes in the flow of credit relative to economic activity, and we call this the “credit impulse”. We show that the behavior of the credit impulse can differ quite dramatically from that of changes in the stock of credit, particularly after recessions.

This is not to say that the stock of credit is not important for output. It is related to the capital stock, which in turn determines the level of potential GDP in the economy. However, focusing purely on the stock of credit misses the developments in the flow of credit that are more important for understanding the business cycle.

In this paper we start by introducing a theoretical model that demonstrates the potential importance of the credit impulse to domestic demand and GDP growth. This model slightly deviates from standard business cycle models. While we believe that these deviations help guiding intuition, they are not crucial for the result. In Appendix A we show that the results can be obtained in a standard Ramsey-type business cycle model. In the third section we investigate the correlation of GDP with credit growth and the credit impulse in a number of episodes across a range of countries. The final section concludes.

2 A simple model of credit and economic growth

Consider a two sector economy where one sector produces durable capital goods and the other non-durable consumption goods. Production levels of these goods are $Y_{i,t}$ and $Y_{c,t}$ respectively. Each sector is made up of a continuum of agents of mass one. I_t and C_t denote the domestic absorption levels of these goods and, as we assume a closed economy, $Y_{i,t} = I_t$ and $Y_{c,t} = C_t$. Therefore, total output is

$$Y_t = C_t + I_t.$$

The investment good is produced by households and purchased by firms. Supply of this good is infinitely elastic at price of one, and the quantity produced depends purely on demand. Firms purchase the durable investment goods from the consumers and use them for the production of non-durable consumer goods,

$$C_t = F(K_t) = AK_t \tag{1}$$

where C_t denotes the non-durable consumption good, K_t the capital stock, and A is a constant. We assume that the prices of the capital goods and the consumer goods are equal to unity. The capital good depreciates at rate δ , so that the capital stock in period t is given by

$$K_t = (1 - \delta)K_{t-1} + I_t \quad (2)$$

where I_t is the amount of additional capital goods purchased by the firms.

The market for consumer products is competitive and firms cannot retain earnings from which to buy the investment goods, instead they need to borrow funds from banks. At each period the firms therefore borrow an amount equal to I_t . The firms' profit maximization subject to (1) and (2) yields the interest rate as

$$r = A - \delta. \quad (3)$$

After paying interest rK_t , firms are left with income δK_t , which they use to repay a part of the accumulated stock of credit. Assuming that all investment has been financed via borrowing, the firms' credit dynamics are therefore

$$D_t = (1 - \delta)D_{t-1} + I_t. \quad (4)$$

Next consider the consumers. At the beginning of the period consumers sell the durable capital good to firms and save the proceeds, I_t . At the end of the period they pay for their consumption, $C_t = AK_t$, which they pay with the interest income, rD_t , and withdrawals of size δD_t . Therefore, the stock of consumers' savings evaluated at the beginning of each period develops in line with (4).

Finally, banks only act as intermediaries that lend funds to firms to buy the investment good and receive the savings that consumers made from selling the investment good.

We can now combine consumption and investment to an economy wide income. First, under the assumption that all investment has been financed by borrowing, we have from (1) and (3) that

$$C_t = AK_t = AD_t = (\delta + r)D_t. \quad (5)$$

Second, it follows from (4) that $I_t = \Delta D_t + \delta D_{t-1}$. Therefore,

$$Y_t = (\delta + r)D_t + \Delta D_t + \delta D_{t-1} = (1 - \delta)\Delta D_t + (2\delta + r)D_t. \quad (6)$$

GDP is therefore a function of the stock of credit, D_t , and the flow of credit, ΔD_t . For reasonable levels of δ and r the coefficient on the flow of credit is substantially larger than the coefficient on the stock of credit.

Rearranging (6) to obtain the growth rate of GDP, y_t , we have

$$y_t = \frac{Y_t - Y_{t-1}}{Y_{t-1}} = (1 - \delta) \frac{\Delta D_t - \Delta D_{t-1}}{Y_{t-1}} + (2\delta + r) \frac{\Delta D_t}{D_{t-1}} \frac{D_{t-1}}{Y_{t-1}} \quad (7)$$

Hence, GDP growth is a function of both the change in the flow of credit $\Delta D_t - \Delta D_{t-1}$, and the change in the stock of credit, ΔD_t . The first term is what we call the “credit impulse”, while the second term is the credit growth weighted by the size of credit relative to GDP. If credit changes at a stable rate ($\Delta D_t = \Delta D_{t-1}$), the credit impulse will be zero and GDP growth will be driven by credit growth. If credit growth is volatile, however, changes in the impulse could be as large as changes in credit growth. Given that $1 - \delta > (2\delta + r)$, for reasonable levels of δ and r the credit impulse would then be much more closely related to the business cycle. In the post-war U.S. experience the fluctuations in the credit impulse have been slightly larger than fluctuations in the credit growth, which amplifies the importance of the credit impulse.

Equation (7) gives us a flavor of the likely GDP growth dynamics if credit growth slows. Assume that ΔD_t is constant and positive for a number of years, then falls sharply and stabilizes at a new but lower level. This level could be close to zero, or even negative. In the first year of the credit slowdown, ΔD_t falls and $\Delta D_t - \Delta D_{t-1}$ turns negative. Both imply a reduction in GDP growth. In the second year, because ΔD_t has stabilized at this new but lower level, $\Delta D_t - \Delta D_{t-1}$ rebounds sharply. This implies that output growth rebounds, even though ΔD_t has not recovered. If the stock of credit is compared to the flow of GDP, the recovery appears to be credit-less. However, the rebound in GDP growth is perfectly consistent with the rebound in the credit impulse.

More formally, assume that the stock of credit grows at a rate α_t in year t . Then

$$\frac{(1 - \delta)K_{t-1} + I_t}{K_{t-1}} = (1 + \alpha_t)$$

and $I_t = (\alpha_t + \delta)K_{t-1}$.

Hence, using (5) we have that GDP is

$$Y_t = (\alpha_t + \delta)K_{t-1} + (\delta + r)K_t = \frac{(\alpha_t + \delta) + (1 + \alpha_t)(\delta + r)}{(1 + \alpha_t)} K_t,$$

and economic growth is

$$y_t = \frac{\alpha_t(1 + \delta + r) + 2\delta + r}{\alpha_{t-1}(1 + \delta + r) + 2\delta + r} (1 + \alpha_{t-1}) - 1. \quad (8)$$

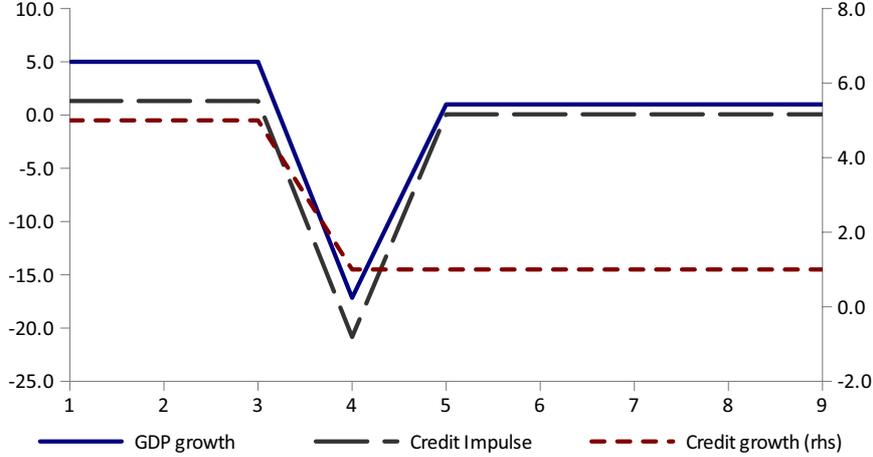
Given that $\alpha \geq -\delta$, which follows from (4) and from the fact that $I_t \geq 0$, we have that

$$\frac{\partial y_t}{\partial \alpha_t} = \frac{(1 + \delta + r)(1 + \alpha_{t-1})}{\alpha_{t-1}(1 + \delta + r) + 2\delta + r} > 0, \quad (9)$$

and

$$\frac{\partial y_t}{\partial \alpha_{t-1}} = -\frac{[\alpha_t(1 + \delta + r) + 2\delta + r](1 - \delta)}{[\alpha_{t-1}(1 + \delta + r) + 2\delta + r]^2} \leq 0. \quad (10)$$

Figure 1: Credit growth, credit impulse and economic growth: Scenario 1



Note: The graph shows credit growth, credit impulse and economic growth when credit growth decreases from 5% to 1% and remains at this level.

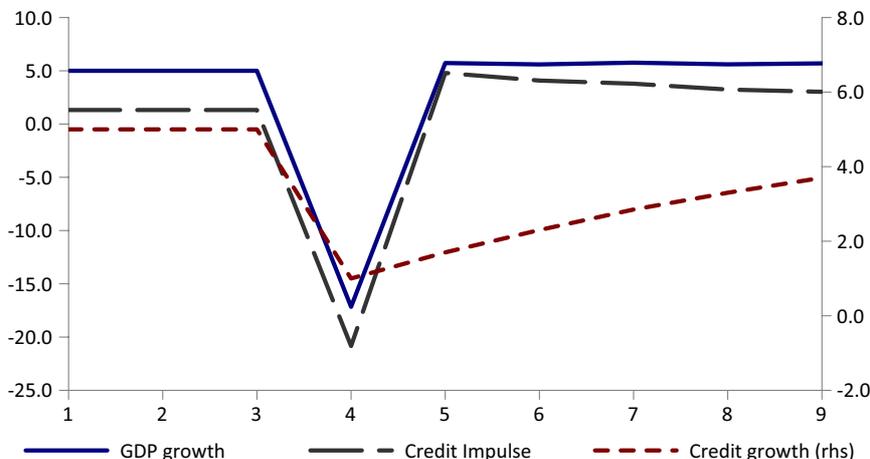
On the basis of (8), (9) and (10) three observations can be made.

1. If the stock of credit grows at a stable rate α , then GDP growth is also equal to α .
2. GDP growth is increasing in α_t and decreasing in α_{t-1} . If credit growth is stable at α_H and then falls to α_L , GDP growth falls from α_H to a level below α_L , and then rebounds to α_L . GDP growth rebounds without a rebound in credit growth.
3. If credit growth falls from α_H to α_L and then rebounds back to α_H , GDP growth will rebound to a level above α_H . For GDP growth to return to its pre-crisis level of α_H , credit growth needs to increase but only to a level below α_H .

To get a sense of the relative magnitude of the relationship between credit growth and GDP growth and between the credit impulse and GDP, consider the following simulations. Assume that credit growth falls from 5% to 1%, and then stabilizes at 1%, and for simplicity assume that $r = 0$. The impact on GDP growth is illustrated in Figure 1. As credit growth falls, both credit growth and the credit impulse decline, implying a reduction of GDP growth. Once credit growth stabilizes at the lower level, the credit impulse rebounds, and GDP recovers much of the fall that occurred during the downturn. The rebound in GDP growth is well correlated with the rebound in the credit impulse, but occurs without a rebound in credit growth.

If credit growth rebounds modestly, the rebound in GDP growth is even stronger. As Figure 2 shows, if credit growth falls from 5% to 1% but then

Figure 2: Credit growth, credit impulse and economic growth: Scenario 2



Note: The graph shows credit growth, credit impulse and economic growth when credit growth decreases from 5% to 1% and recovers thereafter.

recovers slowly, GDP growth in the credit recovery phase can exceed GDP growth in the earlier high credit growth phase, even if it takes many years for credit growth to reach its earlier levels. Note that these results do not depend on the specific set-up of our model. Using a standard Ramsey-type model we obtain comparable results as shown in Appendix A.

It remains to be shown empirically that the dynamics we present here represent features found in the data, and that our model adequately captures the credit and GDP dynamics in the early stages of recoveries from recessions. However, before moving on to the empirics, it is worth making two points of clarification. First, our model above is a closed economy model, and consequently any moves in demand are reflected in moves in GDP. In an open economy the relationship between credit and GDP may be weakened by cross-border flows in both goods and credit. Consequently our empirical work will focus on the link between credit and real domestic demand rather than credit and real GDP.

Second, our model does not suggest a causal direction from either credit to economic growth or vice versa. In many states of the world developments in domestic demand are likely to drive developments in credit, whereas during a credit crunch the causality could be reversed. Our aim here is not to prove causality, but to demonstrate that the close link between credit and domestic demand holds even during the recovery stage after financial crises.

3 Empirical evidence

If the dynamics captured in our model are an accurate representation of reality, we should see high correlation between the credit impulse and domestic demand or GDP growth through the business cycle. In particular, we should see that the rebound in GDP growth after financial crises is matched by a rebound in the credit impulse, even if the growth of credit remains unchanged.

We start by examining the periods that have been used as examples of credit-less recoveries. These include 22 emerging economies that suffered sudden stops of capital inflows, the U.S. during the Great Depression, previously analyzed by Calvo, Izquierdo and Talvi (2006a, 2006b), and the “big five” financial crises in developed countries (Reinhart and Rogoff 2008). Thereafter we consider the joint behavior of economic growth, credit growth, and the credit impulse in a time series of post-war U.S. data. We concentrate on the U.S. as it offers the longest time series of private credit in the form of the Federal Reserve Board’s flow of funds data.

3.1 Data

The notion of the credit-less recovery was first introduced by Calvo, Izquierdo and Talvi (2006a, 2006b) and we therefore start by investigating whether credit flows are more closely related to economic activity than the stock of credit in the episodes they investigate. This data set contains annual GDP and credit data, both as volume measures, for the U.S. Great Depression from 1929 to 1936 and for 22 systemic sudden stops episodes in emerging markets: Argentina (1982, 2002), Brazil (1983), Chile (1983) Cote d’Ivoire (1984), Ecuador (1999), Indonesia (1998), Malaysia (1998), Mexico (1983, 1995), Morocco (1995), Nigeria (1984), Peru (1983), South Africa (1983), South Korea (1998), Thailand (1998), Turkey (1994, 1999), Uruguay (1984), Venezuela (1983), El Salvador (1982), and Russia (1998), where the year in brackets is the trough of each crisis, and crisis dates have been determined by Calvo, Izquierdo and Talvi (2006a). We follow Calvo, Izquierdo and Talvi (2006a, 2006b) and use the data in levels. For the systemic sudden stop episodes they construct the average GDP level and the average level of credit, both as volume indices with the values at the respective trough of the crisis set to 100. Hence, we compare the level of GDP to the level of credit, D_t , and to the flow of new credit defined as $D_t - D_{t-1}$, which is the relationship implied by Equation (6) of our model.

Next we investigate the same relationship using aggregate data for the “big five” banking crises in developed economies that have been considered by Reinhart and Rogoff (2008). These are the crises in the Nordic countries in the early 1990s and the banking crises in Spain in the late 1970s to early 1980s and the financial crisis in Japan since the early 1990s. Descriptions

of these crises can be found in Basel Committee on Banking Supervision (2004).

Ideally, the credit measures should be based on the broadest possible measure of credit, and should capture only credit extended to the non-financial private sector. Such data are easily available in the countries that produce flow of funds statements (US, Japan, and the UK) but not in most others. For those without flow of funds statements, we use net credit extended by the banking sector to non-financial corporations, households, and non-profit institutions. Furthermore, we measure only credit extended to the private sector and, where possible, plot this against private sector real domestic demand growth.

We plot annual $C_t + I_t$ against the stock of credit, D_t , and credit flows, $D_t - D_{t-1}$. We obtained annual data for real consumption, real investment, nominal GDP, nominal credit, and the GDP deflator—detailed descriptions of the data are in Appendix B. We construct volume indices for consumption and credit

$$C_t + I_t = 100 \sum_{i=1}^N \frac{(C_{it}^r + I_{it}^r)}{(C_{it_0}^r + I_{it_0}^r)}, \quad (11)$$

where C_{it}^r is real consumption and I_{it}^r real investment for country i at time t , $i = 1, 2, \dots, N$, for $N = 5$ countries, and the subscript t_0 denotes the observation in the trough of the crises. Similarly, credit is

$$D_t = 100 \sum_{i=1}^5 \frac{D_{it}/P_{it}}{D_{it_0}/P_{it_0}}, \quad (12)$$

where D_t is nominal credit and P_t is the GDP deflator.

For the analysis of the post-war U.S. data we use quarterly data on real consumption, real investment, nominal GDP, nominal credit and the GDP deflator from 1952Q1 to 2008Q4, where details are in Appendix B. The variables are constructed as follows. Private demand growth as

$$y_t = 100 \frac{(C_t^r + I_t^r) - (C_{t-4}^r + I_{t-4}^r)}{(C_{t-4}^r + I_{t-4}^r)},$$

where C_t^r is real consumption and I_t^r real investment, and credit growth as

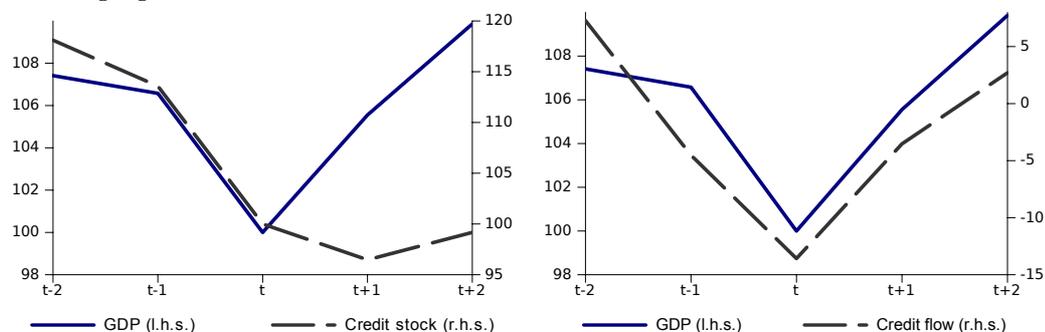
$$d_t = 100 \frac{D_t/P_t - D_{t-4}/P_{t-4}}{D_{t-4}/P_{t-4}},$$

where D_t is nominal credit and P_t is the GDP deflator. Finally, the credit impulse is defined as

$$ci_t = 100 \left(\frac{D_t - D_{t-1}}{Y_t^n} - \frac{D_{t-4} - D_{t-5}}{Y_{t-5}^n} \right),$$

where Y_t^n is nominal GDP.

Figure 3: Credit and economic recovery around systemic sudden stop crises in emerging markets



Note: The left panel shows the average of GDP and the average credit level across 22 episodes of systemic sudden stops. The right panel shows the average GDP and the average credit flow across the same 22 episodes. The charts are based on the data of Calvo, Izquierdo and Talvi (2006a). t denotes the trough of the respective systemic sudden stop episode.

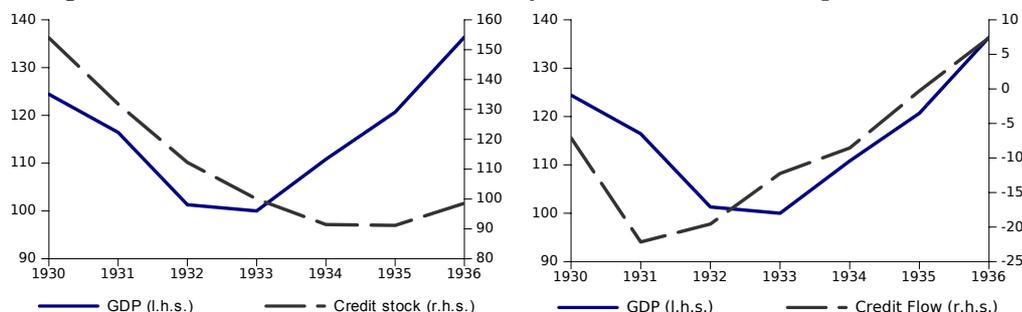
3.2 Event studies

In two influential papers Calvo, Izquierdo and Talvi (2006a, 2006b) investigate the behavior of a number of macroeconomic variables around episodes of systemic sudden stops in emerging markets. The graph on left panel of Figure 3 plots the average level of GDP against the average stock of credit. It is clear that while the stock of credit decreases with the level of GDP during the onset of a systemic crisis, it does not recover as GDP recovers, which lead Calvo et al. to suggest that these recoveries were credit-less.

However, equation (6) of our model suggests that GDP can rebound even if the stock of credit remains unchanged. The right panel of Figure 3 plots the average level of GDP against the average flow of credit. The chart shows that credit flows and GDP recover together, which confirms the conjecture that credit flows are more closely correlated with GDP at times of economic recovery than credit levels.

Calvo et al. (2006a, 2006b) compare the behavior of credit in the crises in emerging market economies to that of the U.S. during the Great Depression. They plot U.S. GDP (with 1933 = 100) against the level of credit, which we reproduce as the left panel of Figure 4. The apparent lack of any recovery in credit confirmed their conclusions that the recovery was without any impetus from the credit market. The right panel of Figure 4 plots the level of GDP against credit flows. It is evident from the right panel that the flow of credit began to recover even before the level of GDP started to recover thus confirming the conjecture of our model and suggesting a considerable importance of credit in the recovery from the Great Depression.

Figure 4: Credit and economic recovery in the U.S. Great Depression



Note: The left panel shows U.S. GDP (volume) and U.S. credit stock (volume) from 1930 to 1936. The right panel shows U.S. GDP (volume) and the U.S. credit flow for the same period. The charts are based on the data of Calvo et al. (2006a).

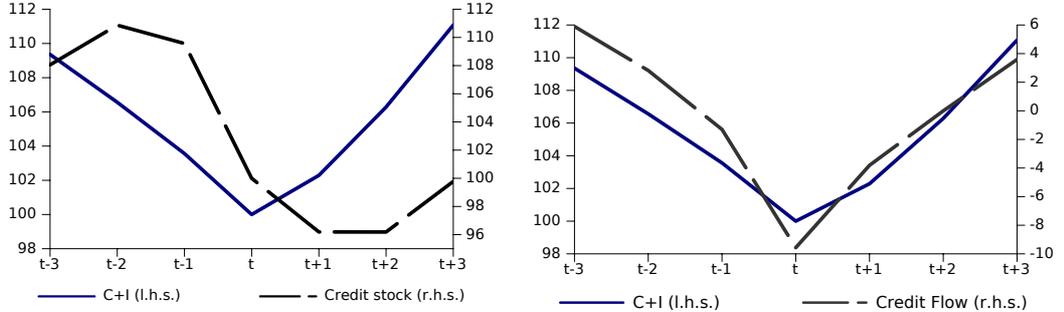
We now look at the same issue in the context of developed economies. Figure 5 plots the average level of consumption and investment against the average level of credit in the graphs in the left plot against the average credit flow in the graphs in the right plot for the years around the banking crises in Finland, Japan, Norway, Spain, and Sweden. Just as in the case of the Great Depression in the U.S. and in the sudden systemic stop crises in emerging markets, the left plot shows that developments in the stock of credit lags behind those in consumption and investment. It takes on average two years after the trough of the crisis before credit growth resumes. The plot on the right shows, however, that the flow of credit resumes at the same time as the economy starts to recover. Hence, these plots strongly suggest that new credit is closely related to economic growth during periods of economic recovery.

3.3 Analysis of U.S. credit data

The above analysis suggests that the recoveries of the U.S. after the Great Depression, the emerging market economies after systemic sudden stop crises, and the OECD economies after the “big five” financial crises were not creditless recoveries. In the following we take a closer look at the general correlation of credit growth, credit impulse and economic growth using data from the U.S from 1954 to 2008. The need to switch from levels to growth rates is necessary due to the trending nature of GDP and credit.

The series are plotted in Figure 6. The first graph plots private demand growth and credit growth and the second graph plots private demand growth and the credit impulse. Both credit series appear to be highly correlated with private demand growth. However, at a number of instances, most notably in the recession in the early 90s, the credit growth series seems to

Figure 5: Credit and economic recovery around banking crises in developed markets



Note: The graph on the left shows the average level of C+I and average level credit. The graph on the right shows the average level of C+I and the average credit flows. The average of over five financial crises is Finland, Japan, Norway, Spain and Sweden, where for each the level at the trough of the crisis is set to 100.

lag the private demand growth series while the credit impulse series moves contemporaneously with it.

In order to investigate this more comprehensively, we run a number of simple regressions. The results from our model above suggest that both credit growth and credit impulse will be correlated with economic growth but their influence will vary in different periods: when credit growth is stable it will be closely correlated with economic growth. However, during periods of abrupt changes in credit growth, the credit impulse will be correlated more closely with economic growth. Therefore, we run the following regressions. First, we regress demand growth on credit growth and credit impulse using all observations:

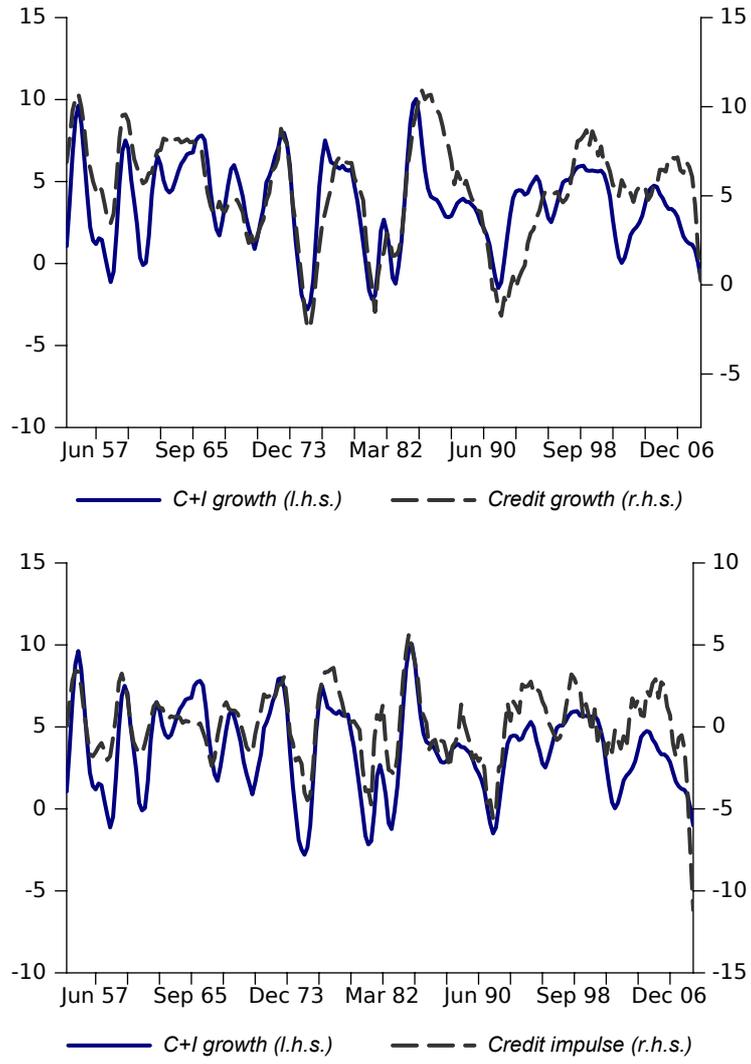
$$y_t = \beta_0 + \beta_1 d_t + \beta_2 ci_t + \varepsilon_t \quad (13)$$

where y_t is private demand growth, d_t is credit growth, ci_t is the credit impulse, and t , $t = 1, 2, \dots, T$, denotes time.

Second, in order to assess whether the credit impulse is more important during recoveries from downturns than credit growth, we run (13) for periods where growth is increasing after having been below 1% in the previous period, that is, we select observations where $y_{it} > y_{i,t-1}$ and $y_{i,t-1} < 0.01$. Finally, we run regressions for non-recovery periods, that is, where $y_t > 0.01$ and $y_{t-1} > 0.1$. The thresholds were chosen such that enough observations remained when considering recessions. The results appear robust to variations of the threshold. Note that we are interested in the conditional results and correction for sample selection is therefore not necessary.

As pointed out above, the regressions in this part of the paper should

Figure 6: U.S. demand growth, credit growth and the credit impulse



Note: The graphs shows U.S. growth in consumption and investment together with credit growth in the first plot and the credit impulse in the second plot.

Table 1: Regression results for U.S. quarterly data

	full sample	recovery	non-recovery
credit growth	0.153 (2.015)	-0.026 (0.333)	0.149 (2.548)
credit impulse	0.629 (7.131)	0.438 (6.204)	0.500 (5.598)
T	223	26	166

The Table shows the results of OLS regressions with quarterly C+I growth as the l.h.s. variable. The sample contains 223 quarterly observations from 1953 to 2008. Recovery periods are defined as periods of increasing growth following GDP growth of less than 1%. Non-recovery periods are characterized by growth of more than 1% in the current and the previous period. In brackets are absolute t -statistics based on Newey-West HAC standard errors. T denotes the number of observations. All regression additionally contain an intercept.

not be interpreted as suggesting any causal relationship from either credit growth or credit impulse to economic growth. It is likely that credit growth and impulse are endogenous variables and the parameters will therefore capture the impact of credit growth on economic growth and vice versa. However, these regressions are a test whether there is a statistical relationship between these variables irrespective of the direction of causation. Appendix C provides a proof for the validity of this procedure.

Table 1 reports the results for the regressions. The first column shows the results of a regression over the entire sample. As expected both variables have significant parameters. The second column shows the regression results for the recovery periods and, as predicted by our model, the credit growth parameter becomes insignificant while the credit impulse parameter remains significant, confirming the notion that after recessions the credit impulse is the more appropriate measure of credit for economic growth. The results for the non-recovery period are in the third column and show that also for these periods the credit impulse together with the credit growth is closely related to private demand.

This suggests that the credit impulse is an important variable at all times, whereas credit growth is relevant only during normal periods. Expressed in terms of levels, this implies that consumption and investment are mainly related to new credit, and this relationship is even more important during recovery periods.

4 Conclusion

This paper shows that in the context of a simple model a rebound in economic activity is closely related to a rebound in the flow of credit, rather than the stock of credit. The flow of credit can rebound even when the stock remains unchanged. When we examine this empirically, we find that our measure of the flow of credit, which we call the credit impulse, is well correlated with developments in domestic demand growth. In particular, we find that the rebound in domestic demand growth after a financial crisis is highly correlated with developments in the credit impulse.

This result leaves open a number of questions, such as whether it is the supply of credit, the demand for credit or both that is so drastically reduced during a recession and that drives the high correlation during a recovery, and why the supply or demand dries up and then recovers. While we leave these questions for future research, this paper suggests that these are important questions as credit in the form of new credit remains closely related to economic activity during periods of economic recovery from severe recessions.

A A Ramsey-type model of credit and economic growth

In this section we show that the results that we obtained in Section 2 do not depend on the specific set-up of the model, and that the results can be reproduced using a standard Ramsey-type model. Assume a representative agents maximizes discounted future utility,

$$\max_{C_t} \sum_{t=1}^{\infty} \beta^t U(C_t)$$

subject to $Y_t = F(A_t, K_t) = C_t + I_t$, $F(A_t, K_t) = A_t K_t^\alpha$ and $K_{t+1} = (1 - \delta)K_t + I_t$. The solution to this model is characterized by the Euler equation

$$U'(C_t) = \beta U'(C_{t+1})(1 - \delta + \alpha A_{t+1} K_{t+1}^{\alpha-1}),$$

and the budget constraint,

$$C_t = A_t K_t^\alpha + K_t - (1 - \delta)K_{t-1}.$$

Furthermore, we assume that technology, A_t , follows an AR(1) with autoregressive parameter $\rho_A = 0.5$. As in our model in Section 2 we introduce credit by assuming that investment can only be financed through borrowing, so that the stock of credit equals the stock of capital.

Due to its non-linear nature the model does not have an analytical solution. Therefore, we calculate steady state levels and impulse responses numerically. For this we need to parameterize the model, and we choose the following parameters:

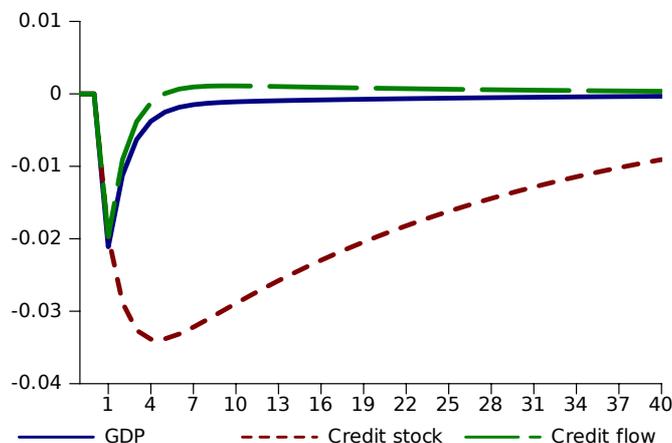
$$U(C_t) = \ln(C_t),$$

$$\beta = 0.99, \alpha = 0.33, \delta = 0.025.$$

Other parameter constellations we tried did not lead to qualitatively different results.

Now assume that the economy suffers from a negative technology shock of size -0.007 . This will reduce the value of capital and therefore investment in the subsequent periods. Due to the lower investment new credit will also be subdued. The impulse response functions to this shock are plotted in Figure 7. The top panel plots the behavior of GDP after a shock to productivity, the second panel that of the stock of credit and the bottom panel shows the behavior of the flow of credit. These impulse response functions show a striking resemblance to the credit charts 3–5. GDP recovers relatively quickly, whereas the stock of credit is much slower to recover to its pre-shock level. The flow of credit, in contrast, recovers in line with GDP.

Figure 7: Impulse response functions from a Ramsey-type model



The plots show the impulse response functions of GDP, the credit stock and the credit flow to an shock to productivity A_t . The model was calibrated using the Dynare software.

B Data appendix

U.S. Great Depression data and systemic sudden stop data For details on these data see Calvo et al. (2006a).

Big five financial crises data

- **Real consumption, real investment, and nominal GDP**
 Finland: Statistics Finland via Haver Analytics;
 Japan: from Economic Planning Agency National Accounts SNA68;
 Norway: Statistik Sentralbyra;
 Spain: Instituto National de Estadística;
 Sweden: Statistics Sweden via Haver Analytics.
- **Credit**
 Finland: IMF IFS line 32;
 Japan: Bank of Japan, Economic Statistics Monthly Table “Financial assets and liabilities accounts”;
 Norway: Norges Bank and IMF;
 Spain: Banco de España;
 Sweden: Sweden: IMF IFS line 32.
- **GDP deflator**
 For all countries the data are from the IMF IFS line 99.

U.S. post-war data The credit data for the U.S. post-war period are obtained from the Federal Reserve Boards flow of funds data, Table F.1 “Total Net Borrowing and Lending in Credit Markets” and are the sum of lines 3–6. The GDP data are from the Bureau of Economic Analysis, nominal GDP from Table 1.1.5, line 1, real consumption and investment from Table 1.1.6, line 2 and 6, and the GDP deflator from Table 1.1.4 line 1.

C Mathematical Appendix

In this appendix we show that OLS applied to an equation in a simultaneous equation model leads to a parameter estimate that, while biased, is only zero if both structural parameters are zero. We further show that the t -statistic of the OLS parameter from one equation is the appropriate test statistic to test whether both parameters are zero.¹

Consider the model

$$y_t = \beta x_t + \varepsilon_t, \quad \varepsilon_t \sim \text{iid N}(0, \sigma_\varepsilon^2), \quad (14)$$

$$x_t = \gamma y_t + \eta_t, \quad \eta_t \sim \text{iid N}(0, \sigma_\eta^2), \quad (15)$$

where y_t and x_t are observed scalar variables, β and γ the structural parameters, and $t = 1, 2, \dots, T$ indicates the observations.

It follows that

$$\begin{aligned} x_t &= \gamma(\beta x_t + \varepsilon_t) + \eta_t \\ &= \frac{\gamma \varepsilon_t + \eta_t}{1 - \beta \gamma}, \end{aligned}$$

and therefore

$$\text{E}(x_t \varepsilon_t) = \frac{\gamma \sigma_\varepsilon^2}{1 - \beta \gamma}.$$

The asymptotic estimate of β when OLS is applied to (14) is therefore

$$\begin{aligned} \hat{\beta} &= \beta + \sigma_x^{-2} \frac{\gamma \sigma_\varepsilon^2}{1 - \beta \gamma} \\ &= \beta + b, \end{aligned} \quad (16)$$

where $\sigma_x^2 = \text{E}(x_t^2)$, and b is the bias of the OLS estimate due to the endogeneity. Using $\beta = \hat{\beta} - b$, we have that

$$\begin{aligned} y_t &= \hat{\beta} x_t - b x_t + \varepsilon_t \\ &= \hat{\beta} x_t + u_t. \end{aligned} \quad (17)$$

¹We thank Jerzy Niemczyk for suggesting this simplification of our initial the proof. See Kiviet and Niemczyk (2007) for a more general treatment of OLS under endogeneity.

Furthermore,

$$\begin{aligned}
E(x_t u_t) &= E[x_t(-bx_t + \varepsilon_t)] \\
&= E\left[x_t\left(-\sigma_x^{-2} \frac{\gamma\sigma_\varepsilon^2}{1-\beta\gamma}x_t + \varepsilon_t\right)\right] \\
&= -\frac{\gamma\sigma_\varepsilon^2}{1-\beta\gamma} + E(x_t\varepsilon_t) = 0.
\end{aligned}$$

Therefore, the Gauss-Markov conditions hold for (17). Also note that u_t in (16) is asymptotically normal as it is a linear combination of the underlying normally distributed errors from the structural equations (14) and (15). Given that the Gauss-Markov conditions hold, the t -statistic based on $\hat{\beta}$ and $\hat{\sigma}_\beta^2 = \hat{\sigma}_u \left(\sum_{t=1}^T x_t^2\right)^{-1}$, where $\hat{\sigma}_u = \frac{1}{T-1} \sum_{t=1}^T (y_t - \hat{\beta}x_t)^2$ and $\hat{\sigma}_\beta^2$ is an estimate of the variance of $\hat{\beta}$, is the appropriate test for $H_0 : \hat{\beta} = \beta_0$. Furthermore, note from (16) that $\hat{\beta}$ is only zero if both β and γ are zero, that is, there is no causal link between y_t and x_t in either direction.

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