Financial Frictions, the Great Trade Collapse and International Trade over the Business Cycle

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Abstract

This paper investigates the impact of financial frictions on the dynamics of trade over the business cycle and their role in the great trade collapse of 2008-2009. The study introduces a financial accelerator for imports and exports into an open-economy general equilibrium model with heterogenous firms in which international trade is more dependent on external finance than domestic sales. The analysis demonstrates that endogenously driven countercyclical changes in the external finance premium amplify the effects of real and financial shocks on trade and help to explain the procyclicality of trade to GDP ratio. The paper shows that financial markets imperfections significantly contributed to the decline in trade during the recent financial crisis. The model developed is also able to account for the sharp deterioration in the labour wedge and for the changes in the relative prices of domestic to imported goods observed during the crisis.

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1 Introduction

The recent financial crisis was accompanied by a dramatic decline in international trade. In the second quarter of 2009 world trade fell by 17 per cent as compared to the previous year. This drop was about twice as large as the decline in global industrial production and about four times larger than the decrease in GDP in OECD economies during that period. While the fall in trade during the crisis was exceptionally large, the volatility of imports and exports is in general considerably higher than that of output (Engel and Wang, 2010). For most countries and for the world as a whole the estimates of the elasticity of real trade volumes with respect to real GDP during the last few decades lie between 1.5 and 2.5 (e.g. Freund, 2009; Irwin, 2002; Kwack *et al.*, 2007). Standard international business cycle models are not able to account for the high trade income elasticities and for the severe decline in trade during the recent crisis.

This paper investigates the impact of financial frictions on the dynamics of trade over the business cycle and their role in the great trade collapse of 2008-2009. The study introduces a financial accelerator for imports and exports into an open-economy DSGE model with heterogenous firms in which international trade is more dependent on external finance than domestic sales. The analysis demonstrates that endogenously driven countercyclical changes in the external finance premium amplify the effects of demand and productivity shocks on international trade and help to explain the procyclicality of the trade to GDP ratio. Furthermore, it shows that shocks originating in financial markets also significantly affect the relative price and volume of imports and exports, as compared to domestic sales.

A number of explanations have been put forward to account for the severe fall in world trade during the recent crisis and the strong procyclicality of the trade to GDP ratio in general. They focus on vertical production linkages (e.g. Bems *et al.,* 2010), compositional effects (Levchenko *et al.,* 2010; Engel and Wang, 2010; Eaton *et al.;* 2010; Erceg *et al.* 2008) and inventory adjustment (Alessandria *et al.* 2010). While taking these factors into account vastly improves our understanding of trade dynamics, a significant part of the decline in trade during the crisis is still left unexplained. This paper examines the role of trade finance in the great trade collapse and in the cyclical fluctuations of international trade. Surveys of banks and firms in both advanced and emerging economies reported substantial increases in the

cost of trade finance during the crisis (e.g. Dorsey, 2009; Malouche, 2009). Between 2007Q4 and 2009Q2 the average spreads on trade-related lending increased by about 50-70 basis points from their usual levels of 10-15 basis points over costs of funds (IMF/BAFT-IFSA Trade Finance Survey, July 2009; Auboin, 2009). A growing number of empirical studies based on aggregate data (e.g. Chor and Manova, 2009; Eaton *et al.*, 2010) and firm-level statistics (e.g. Bricongne *et al.* 2010; Paravisini *et al.*, 2010) suggest that these developments significantly contributed to the decline in trade in 2008 and 2009.

While usually absent from trade and macroeconomic models, trade finance plays a crucial role in facilitating international trade. According to Auboin (2009), 80-90 per cent of international transactions involve some form of credit, insurance or guarantee, whereby about 80 per cent of total trade credit is of short-term nature. The long time lags between production and the receipt of sales revenues involved in international trade, which result from long shipping times and the widespread use of an 'open-account' payment system in which the exporter is paid only after delivery, as well as the relatively high costs of assessing counterparty risk associated with foreign trading partners, means that trade is more dependent on external financing than are domestic sales (Amiti and Weinstein, 2009). Although first attempts have been made to provide microfoundations for trade finance and to understand its implications for the behaviour of international trade (Ahn, 2010), this paper is the first to examine the impact of financial frictions on trade within a general equilibrium framework.[1]

The paper develops a symmetric two-country DSGE model with heterogenous firms in which changes in the cost of trade credit,[2] driven by changes in macroeconomic conditions, affect the dynamics of international trade. The contribution of this study is two-fold. Firstly, the paper proposes a novel mechanism generating a countercyclical external finance premium which arises due to the presence of irreversible fixed costs of production, firms' cash-flow constraints and uncertainty concerning firm-specific level of productivity. In the model developed, financial frictions manifest themselves as labour wedges - discrepancies between the marginal

[1]The paper contributes to the growing literature on the role of financial market imperfections in the business cycle (notable examples include Bernanke, Gertler and Gilchrist, 1999, and Kiyotaki and Moore, 1997). However, in contrast to existing studies, its focus is on the implications of such frictions for the international exchange of goods.

[2]Throughout the paper, the notions 'trade credit' and 'trade finance' are used interchangeably and refer to any loans extended to firms in order to finance international trade.

rate of subsititution between consumption and leisure and the marginal product of labour. Chari, Kehoe and McGrattan (2007) show that these wedges account for a major part of business cycle fluctuations. Secondly, the paper demonstrates that as international transactions are more dependent on external finance than domestic transactions, changes in the cost of external financing in response to real and financial shocks affect the relative price of imports and exports, as compared to goods produced and sold domestically, and contribute to procyclical movements in the trade to GDP ratio.

The mechanism through which financial frictions influence the behaviour of international trade in the model suggested is very intuitive. There are two types of firms operating in each economy – domestic retailers, who sell their goods in the domestic market, and exporters, who sell their goods abroad. In order to operate in a given period, firms need to pay in advance the fixed cost of production. They also have to pay for a fraction of their variable costs of production before receiving revenues from sales. At the beginning of each period firms have no wealth and need to finance a part of their working capital externally, through short-term bank loans. Exporters have greater working capital financing requirements and therefore are more dependent on external finance than domestic retailers. Firms are heterogenous and face uncertainty concerning their individual level of productivity which is only revealed after the irreversible fixed costs of production have been paid and after loan contracts have been arranged. In consequence, in each period a fraction of firms with the lowest productivity incurs losses and defaults on their debt. In order to compensate for the losses generated by defaulting firms, commercial banks charge a premium on their loans. As the fraction of defaulting firms depends on aggregate macroeconomic conditions, the external finance premium varies over time and is negatively correlated with aggregate output.

Countercyclical changes in this premium affect firms' marginal costs and prices. Due to the fact that exporters finance a greater fraction of their working capital externally, their prices are more sensitive to changes in the cost of external finance than those of domestic retailers. As a result, the relative price of imported to domestic goods is countercyclical and the trade to GDP ratio moves procyclically. Furtheremore, due to the fact that the external finance premium contributes to the difference between the marginal rate of substitution between consumption and leisure and the marginal product of labour, changes in the cost of external finance for firms generate

procyclical changes in the labour wedge, which are well documented in the data (e.g. Hall, 1997; Shimer, 2009).

The prediction of the model that trade finance affects the behaviour of international trade through the marginal cost channel is consistent with the behaviour of relative prices during the financial crisis. Ahn *et al.* (2010) show that in 2008Q4 and 2009Q1, the period of the greatest decline in international trade, producer prices of exported goods in the European Union, the US and Japan increased substantially, as compared to producer prices of goods sold domestically. Haddad *et al.* (2010), who decomposed the decrease in international trade into changes in prices and quantities as well as product entry and exit for a number of countries, provide evidence that during the financial crisis import prices of manufactured goods increased, particularly in sectors highly dependent on external finance.

Not only are the model dynamics consistent with the behaviour of relative prices during the crisis but they are also in line with the movements in the labour wedge during that time. Kobayashi (2011) and Pescatori and Tasci (2011) demonstrate that the financial crisis was accompanied by a sharp decline in the discrepancy between the marginal rate of substitution between consumption and leisure and the marginal product of labour in the US. In the model developed, negative real and financial shocks calibrated to match the dynamics of output, loan write-off rates and relative prices during the crisis generate a decrease in the labour wedge of a similar magnitude to that observed in the data.

The study demonstrates that credit frictions are able to explain a significant part of the fluctuations of international trade over the business cycle. Changes in the external finance premium resulting from changes in macroeconomic conditions amplify the impact of demand and productivity shocks on trade. The behaviour of international trade is also directly influenced by financial shocks. An increase in the costs of financial intermediation and an increase in the loan financing costs for banks lead to large changes in trade relative to output. The analysis shows that financial frictions substantially contributed to the great trade collapse of 2008-2009.

The paper is structured as follows. Section two provides empirical evidence on the cyclical properties of international trade flows and on the changes in international trade, output and prices during the financial crisis of 2007-2009. Section three sets out the model developed for the purpose of the analysis. Section four discusses the mechanism through which financial frictions incorporated into the model affect

macroeconomic fluctuations. In section five, the calibration of the model parameters is outlined. Section six presents quantitative results. Firstly, the transmission of real and financial shocks to the economy is examined, with particular focus on the dynamics of international trade. Secondly, the extent to which credit market imperfections help to explain the decline in trade during the recent crisis is analysed. The final section concludes.

2 Empirical Evidence

It is a well documented fact that international trade is procyclical and more volatile than output. Engel and Wang (2010) analysed data for 25 OECD countries during the period between 1973 and 2006 and showed that real imports and exports are positively correlated with GDP and that their standard deviations are about two to three times as large as those of output. Kwack *et al.* (2007) estimated income elasticities of the demand for imports for 30 industrial and Asian countries during the period from 1984 to 2003. They found that both the median and the average elasticities are equal to 1.9 and that 80 per cent of the income elasticity estimates fall in the range from 1.4 to 2.7. Irwin (2002) and Freund (2009) examined the sensitivity of trade to GDP for the world as a whole and showed that the average elasticity of real trade to real income in the post-war period was equal to 1.7-1.8 and that the elasticity had increased to over 3.0 in the last two decades.

While an economic downturn is usually accompanied by a decrease in imports and exports which exceeds that of GDP, during the economic crisis of 2008-2009 world trade experienced an unprecedented decline, comparable in scale only to that which occured during the Great Depression.[3] Between September 2008 and March 2009, the six months following the Lehman Brothers' collapse, the volume of international trade decreased globally by 16 per cent (Figure A.1.1). The fall in trade was synchronised across countries and strongly affected both advanced and emerging economies (Figure A.1.2). While the financial crisis was accompanied by a strong decline in output, the decrease in imports and exports considerably surpassed that of industrial production and GDP (see Figure A.1.3 and Figure A.1.4).

It has been suggested that one of the factors contributing to the severe decline in international trade was the increased cost and reduced availability of trade finance

[3]The collapse in international trade is comprehensivey documented in Baldwin (2009).

during the crisis. The turmoil in financial markets was accompanied by a sharp, universal increase in the cost of trade finance instruments. According to the IMF/BAFT-IFSA Trade Finance Survey from July 2009, between 2007Q4 and 2009Q2 the price of trade-related lending and letters of credit increased by about 50-70 basis points from their normal levels of 10 to 15 basis points over the costs of funds, while the cost of export credit insurance rose by about 40 basis points (Figure A.1.5). In some emerging economies spreads on letters of credit increased to 250-600 basis points over the interbank rate (Auboin, 2009). The trade finance surveys indicate that banks' rising costs of funds and an increase in default risk associated with international trade were the main reasons behind the rising costs of trade finance instruments.

A number of empirical studies indicated that adverse credit conditions contributed to the decline in international trade in 2008 and 2009. Chor and Manova (2010) showed that countries with relatively higher interbank lending rates recorded relatively lower exports to the US and that exports of industries highly dependent on external finance in those countries were particularly severely affected during the crisis. Bricongne *et. al.* (2010) conducted a detailed study of the export performance of French firms during the time of the crisis using firm-level data matching firms' exports with their financial constraints. While the authors found that the decline in trade was predominantly due to a large negative demand shock, they also showed that the tightening of credit market conditions had a significant negative impact on the exports of financially constrained firms. Paravisini *et al.* (2010) analysed firm-level data for Peru and demonstrated that changes in the supply of credit during the crisis had a strong negative effect on Peruvian exports.

The negative impact of shocks originating in financial markets on international trade was not only a feature of the recent crisis, but was also observed during other periods of financial turbulence. Amiti and Weinstein (2009) showed that exports are more sensitive than domestic sales to financial sector shocks by using matched firm-bank data from the Japanese financial crisis of the 1990s. They found that Japanese firms reduced their exports relative to domestic sales when the financial situation of banks financing them deteriorated. The authors estimated that the financial shocks were responsible for about one-third of the decline in Japanese exports during the crisis. Iacovone and Zavacka (2010), who analysed data from 23 banking crises episodes in developed and developing countries between 1980 and 2000, also found that financial shocks are an important source of trade fluctuations. They demonstrated that

during a crisis in the banking sector, the exports of industries more dependent on external finance suffer relatively more than the exports of sectors less dependent on external financing.

A negative relationship between firms' external finance dependence and their performance during a financial crisis is not confined to exporting firms. Kroszner *et al.* (2007) using data from 38 developed and developing countries in the last quarter of the twentieth century found that during a banking crisis sectors which require extensive external financing tend to experience a substantially greater contraction of value added. Similar results were obtained by Dell'Ariccia *et al.* (2008). The degree of external finance dependence not only affects firms' performance during a banking crisis but also over the business cycle. Braun and Larrain (2005) examined production growth for 28 manufacturing industries in 111 countries over nearly four decades and showed that industries that are more dependent on external finance are more strongly affected during recessions. These results suggest that it is not necessarily the differences in the nature of financial instruments used to finance domestic and international transactions but rather the differences in the dependence on external financing associated with these transactions *per se* that make international trade more sensitive than domestic sales to real and financial shocks.

In view of the empirical evidence, the question arises as to what is the mechanism through which the degree of external finance dependence affects firms' export performance in response to shocks. Bricongne *et al.* (2010), Paravisini *et al.* (2010) and Haddad *et al.* (2010) showed that the fall in trade during the financial crisis of 2008 and 2009 was mostly along the intensive margin, which suggests that adverse financial conditions depressed exports mainly by affecting firms' marginal costs and their relative prices. As noted by Ahn (2010) and Ahn *et al.* (2010) the price dynamics during the crisis confirm that hypothesis. The increase in the cost of trade finance in 2008 and 2009 was accompanied by changes in the relative prices of export to domestic goods. Following the bankruptcy of the Lehman Brothers, in the period from September 2008 to March 2009, the producer price index of non-agricultural export goods in the US rose by 10 per cent as compared to the producer price index of all industrial commodities (Figure A.1.6). The relative export price increased despite the fact that the US dollar appreciated at the same time. An increase in the relative export price was also observed in the Euro Area. Between September 2008 and March 2009 domestic producer prices of manufactured goods decreased when compared to

the producer prices of goods exported to countries both inside and outside the Euro Area, which suggests that the relative price movements were not driven by changes in the exchange rate (Figure A.1.7).

Haddad *et al.* (2010) conducted a comprehensive analysis of imports to the United States, the European Union, Indonesia and Brazil during the period from 2008 to 2009. They found that while in all countries considered except for Brazil aggregate import prices decreased during the crisis, their decline was primarily driven by the fall in the prices of commodities. In all countries covered by the analysis the prices of manufacturing import goods increased, which indicates that supply shocks played a role. Haddad *et al.* (2010) show that in the United States the most significant price increases were recorded in sectors which are highly dependent on external finance, which supports the view that credit market imperfections contributed to the decline in trade during the crisis through the marginal cost channel.

An interesting feature of the financial crisis was a dramatic decline in the labour wedge. While the labour wedge is in general strongly procyclical, its decline during the crisis was exeptionally large. Kobayashi (2011) shows that the labour wedge in the US declined by 9.2 per cent (Figure A.1.9), whereas between 1948Q2 and 2009Q2 its standard deviation was equal to 2.4 per cent. This evidence is consistent with the view that financial market imperfections, which played an important role during the crisis, may manifest themselves as labour wedges.

In line with the empirical evidence, the next section develops a model in which due to differences in external financing needs associated with domestic and international transactions, changes in the cost of external finance driven by changes in macroeconomic conditions affect international trade through their impact on the relative price of exported and domestic goods.

3 Model

The paper introduces a financial accelerator mechanism for imports and exports into an open-economy flexible price general equilibrium model with heterogenous firms. The world economy consists of two identical countries: Home and Foreign. Each country is populated by households, entrepreneurs and bankers. Households consume goods and supply labour to firms and banks. Entrepreneurs set up and manage firms producing differentiated consumption goods which are sold in monopolistically

competitive markets either in the domestic or in the foreign economy. Bankers run perfectly competitive commercial banks which collect deposits from households and grant loans to firms. The economies are subject to real shocks to productivity and demand as well as financial shocks affecting the cost of credit in the economy.

3.1 Households

Each country is inhabited by a continuum of identical, infinitely-lived households located in the interval $[0, 1]$. A representative household has a utility function which is addively separable in consumption, C_t, and labour, L_t, and given by:

$$E_t \sum_{k=0}^{\infty} \beta^k \left[\frac{C_{t+k}^{1-\sigma}}{1-\sigma} e^{u_t} - \frac{L_{t+k}^{1+\varphi}}{1+\varphi} \right] \tag{1}$$

where $\beta \in (0, 1)$ is the intertemporal discount factor, u_t denotes a shock to the marginal utility of consumption such that $u_t = \rho_u u_{t-1} + \xi_t^u$ where $\rho_u \in \langle 0; 1)$ and $\xi_t^u \sim N(0, \sigma_u^2)$.

Households maximise their expected discounted lifetime utility subject to a sequence of budget constraints:

$$P_t C_t + E_t \left\{ Q_{t,t+1} D_{t+1} \right\} = W_t L_t + D_t + I_t + (R_H - 1) J_t \tag{2}$$

where P_t is the aggregate price level in the Home economy at time t , W_t denotes nominal wage and I_t is a lump sum component of households' income including dividends from the ownership of firms. $Q_{t,t+1}$ is the stochastic discount factor for one-period ahead nominal payoffs, D_{t+1} is the nominal payoff in period $t+1$ of the portfolio held at the end of period t, whereby it is assumed that in both countries households have unrestricted access to a complete set of contingent claims traded internationally. The last term on the right hand side of the equation denotes households' income from intra-period deposits held at commercial banks, where J_t denotes the value of these deposits and R_H is the return.

Households receive their salaries at the beginning of each period. Each household spends a fraction of its salary immediately to purchase Arrow-Debreu securities and to make advance payments for consumption goods. The rest of the salary is kept on short-term, intra-period deposits in banks, which in turn use them to finance loans

to firms. At the end of the period the deposits are withdrawn and used to pay for goods which are consumed in the same period. Due to the facts that holding bank deposits is risk-free, that deposits are held entirely within a period and that the only alternative to holding deposits is to keep cash, households' opportunity cost is equal to one and the deposits bear zero interest rate ($R_H = 1$), as in Carlstrom and Fuerst (1998).

Households' consumption aggregator in the Home economy, C_t, is of the CES form and is given by:

$$C_t = \left(\alpha^{\frac{1}{\theta}} C_{D,t}^{\frac{\theta-1}{\theta}} + (1-\alpha)^{\frac{1}{\theta}} C_{I,t}^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}} \tag{3}$$

where α is the home bias in consumption and θ is the elasticity of substitution between any two varieties. $C_{D,t}$ is the consumption aggregator of domestic goods such that:

$$C_{D,t} = \left[\int_0^1 C_{D,j,t}^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}} \tag{4}$$

$C_{I,t}$ is the corresponding consumption aggregator of imported goods:

$$C_{I,t} = \left[\int_0^1 C_{I,j,t}^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}} \tag{5}$$

where $C_{I,j,t} = C^*_{E,j,t}$ and $C^*_{E,j,t}$ is the consumption aggregator of varieties exported from the Foreign economy.[4]

The utility-based aggregate consumption price index is therefore equal to:

$$P_t = \left[\alpha P_{D,t}^{1-\theta} + (1-\alpha) P_{I,t}^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{6}$$

where

$$P_{D,t} = \left[\int_0^1 P_{D,j,t}^{1-\theta} dj\right]^{\frac{1}{1-\theta}} \quad \text{and} \quad P_{I,t} = \left[\int_0^1 P_{I,j,t}^{1-\theta} dj\right]^{\frac{1}{1-\theta}}$$

$P_{I,j,t} = S_t P^*_{E,j,t}$ where $P^*_{E,j,t}$ is the price of the variety produced by firm j, exported from the Foreign economy and expressed in Foreign currency, S_t is the nominal exchange rate, expressed as the price of one unit of the foreign currency in terms of the domestic currency.

[4]Throughout the paper, Foreign variables are denoted by an asterisk.

3.2 Firms

In each economy there is a large number of profit-maximising entrepreneurs. As in Fuerst (1995), it is assumed that entrepreneurs live only one period. At the beginning of each period entrepreneurs set up one-period firms. A continuum of entrepreneurs, ranging from 0 to 1, start up domestic retail firms, which produce differentiated goods for sale in the Home market, and a continuum of entrepreneurs ranging from 1 to 2 establish exporting firms, which serve the Foreign market. When starting up their businesses in a given period, entrepreneurs know neither the macroeconomic conditions prevailing in that period nor their own level of productivity, which is firm-specific. The realisation of both aggregate and idiosyncratic shocks is only revealed once production starts. Entrepreneurs face cash-flow constraints. They need to pay firm start-up costs and the variable costs of production at the beginning of the period, whereas they do not possess any initial wealth and they only receive a part of their sales revenues in advance. The production costs which cannot be covered from these sales pre-payments are financed externally, by borrowing funds from households through commercial banks. Exporters need to finance a greater fraction of their working capital externally than do domestic retailers.

3.2.1 Production function

Setting-up a firm is costly. Before a firm starts operating, entrepreneurs have to incur a fixed, irreversible cost equal to $F_{X,t}$ units of effective labour $Z_t L_{F,X,t}$, where $X \in \{D, E\}$. Throughout the paper, the subscripts D and E denote variables corresponding to domestic retailers and exporters, respectively. $L_{F,X,t}$ is the number of labour units employed in setting up a firm in sector X. Z_t is an aggregate level of labour productivity, which is subject to shocks such that $\ln Z_t = \rho_z \ln Z_{t-1} + \xi_t^z$ where $\xi_t^z \sim N(0, \sigma_z^2)$ and $\rho_z \in \langle 0; 1)$.Having paid the set-up costs, firms then produce differentiated goods using a simple production technology with constant returns to scale in which domestic labour is the only factor of production. The production function is given by:

$$Y_{X,j,t} = Z_t A_{X,j,t} L_{X,j,t} \tag{7}$$

where $Y_{X,j,t}$ is the output, at time t, of firm j in sector X, $L_{X,j,t}$ is the firm's labour input at time t. Firms' productivity depends on two components: Z_t, which is an

aggregate level of productivity at time t, common for all firms in the economy, and $A_{X,j,t}$, which is a firm-specific level of productivity.[5] Following Ghironi and Melitz (2005), it is assumed that the individual component of firms' productivity, A, is Pareto distributed[6] with the cumulative distribution function $F(A) = 1 - \left(\frac{A_{\min}}{A}\right)^k$. The parameters $A_{\min}$ and $k > \theta - 1$ determine the lower bound and the dispersion of firms' productivity, respectively. The firm-specific productivity distribution is the same for domestic retailers and exporting firms and is time-invariant.

3.2.2 External financing

At the beginning of each period firms need to pay for their fixed and variable costs of production and do not have sufficient internal funds to do so. Advance payments which firms receive for their goods at the beginning of each period cover a fraction of the variable costs of production equal to $(1 - d_D)$ in the case of domestic retailers and $(1 - d_E)$ in the case of exporters. In order to finance the remaining working capital, as well as the fixed costs of production, firms apply for short-term, intra-period bank loans, which are backed by their future revenues from sales.

The fraction of the variable costs of production which needs to be financed externally, given by d_X, is exogenous, sector-specific and it is assumed that $d_E > d_D$. The assumption that exporting firms have relatively greater working capital external financing needs reflects the fact that due to longer shipping times, additional time required to complete administrative procedures associated with imports and exports as well as differences in payment systems used in domestic and international transactions, the cash conversion cycle in international trade is longer than in domestic sales.

When applying for bank loans, entrepreneurs face uncertainty concerning the aggregate macroeconomic shocks as well as the firm-specific component of their productivity. However, as the expected profits are positive for all firms and banks are able to hedge against credit risk, all entrepreneurs are granted a loan. The debt contracts signed between entrepreneurs and commercial banks at the beginning of each period specify the size of the loan, $D_{X,j,t}$, the interest rate on the loan, $(R_{X,t} - 1)$, a fixed

[5] The assumption that firm-specific risk is a major source of firms' uncertainty is consistent with empirical evidence provided by Castoro *et al.* (2010) who show that idiosyncratic risk accounts for about 90 per cent of the overall uncertainty faced by firms.

[6] The assumption of a Pareto distribution for productivity draws implies that the distribution of firms' size is also Pareto, which, as shown by Axtell (2001), is consistent with US firm-level data.

financial intermediation fee, equal to $G_{X,t}$ effective units of labour, $Z_t L_{G,X,t}$, and the collateral, $T_{X,j,t}$, which the bank receives at the end of the period if firm j is not able to pay back the whole value of the loan with the interest due.

The loan contracts are signed before the aggregate and firm-specific shocks are observed, however; they are state-contingent. The interest rate on bank loans depends on the realisation of aggregate shocks in a given period, while the size of the loan and the collateral are determined by both the aggregate and firm-specific shocks. In the beginning of each period the expected profits are the same for all firms within a particular sector and, as a result, the cost of credit is also the same for all firms within each sector.

A loan granted by a bank can be interpreted as an open credit line. The size of firm j's loan, $D_{X,j,t}$ is chosen by firms optimally (with the constraint that it must cover at least the fixed costs of production), after their individual levels of productivity in a given period are revealed. In each period firms borrow funds which, for their given level of productivity, are needed to produce the profit-maximising level of output. The magnitude of the loan is therefore equal to the value of the fixed costs of setting-up a firm and receiving a loan as well as a fraction $d_{X,t}$ of the variable cost of production:

$$D_{X,j,t} = \frac{W_t}{Z_t}(F_{X,t} + G_{X,t}) + d_{X,t} Y_{X,j,t} \frac{W_t}{Z_t A_{j,t}} \tag{8}$$

The profit-maximising output of firm j at time t in sector X, given by $Y_{X,j,t}$, is equal to the demand for firm j's variety. In the case of domestic retailers, this demand is equal to:

$$C_{D,j,t} = \alpha \left(\frac{P_{D,j,t}}{P_t} \right)^{-\theta} C_t \tag{9}$$

where $P_{D,j,t}$ is the price of firm j's variety.

In turn, the demand for the variety produced by an exporting firm j is equal to:

$$C_{E,j,t} = (1-\alpha) \left(\frac{P^*_{I,j,t}}{P^*_t} \right)^{-\theta} C^*_t \tag{10}$$

where $P^*_{I,j,t} = \frac{1}{S_t} P_{E,j,t}$ is the price of firm j's variety in units of Foreign currency.

Both domestic retailers and exporters sell their goods in a monopolistically competitive environment. Their prices are set optimally and are equal to a constant markup over marginal cost:

$$P_{X,j,t} = \frac{\theta}{\theta - 1} \frac{W_t}{Z_t A_{X,j,t}} [(1 - d_X) + d_X R_{X,t}] = \mu \frac{W_t}{Z_t A_{X,j,t}} \widetilde{R}_{X,t} \tag{11}$$

where $P_{X,j,t}$ is the price of the good produced by firm j in sector X at time t, $\widetilde{R}_{X,t}$ is firms j's effective borrowing cost given by $\widetilde{R}_{X,t} = [(1 - d_X) + d_X R_{X,t}]$ and μ is the firm's markup $\mu = \frac{\theta}{\theta - 1}$.

The collateral that is offered to the bank on the loan to firm j, given by $T_{X,j,t}$, is equal to the value of firm j's sales revenues net of its labour costs of production:

$$T_{X,j,t} = Y_{X,j,t} P_{X,j,t} - Y_{X,j,t} \frac{W_t}{Z_t A_{j,t}} - \frac{W_t}{Z_t} (F_{X,t} + G_{X,t}) \tag{12}$$

At the end of the period, after receiving revenues from sales, firm j's profits, $\Pi_{X,j,t}$, amount to:

$$\Pi_{X,j,t} = Y_{X,j,t} P_{X,j,t} - Y_{X,j,t} \frac{W_t}{Z_t A_{j,t}} \widetilde{R}_{X,t} - \frac{W_t}{Z_t} (F_{X,t} + G_{X,t}) R_{X,t} \tag{13}$$

If $\Pi_{X,j,t} \geq 0$, firm j pays $D_{X,j,t} R_{X,t}$ to the bank and keeps the remaining profits. If $\Pi_{X,j,t} < 0$, then the firm declares bankrupcy and gets nothing whereas the bank receives the collateral, $T_{X,j,t}$. As the profit-maximising size of the loan, chosen by the firm, is uniquely determined by the firm-specific level of productivity, commercial banks are able to observe individual productivity levels. In the case of a firm's default they can then recover the full value of the firm's revenues net of labour costs. As firms live only one period, at the end of the period they transfer all their profits to households in the form of dividends.

3.3 Banks

In each economy, there is a large number of identical, perfectly competitive commercial banks. Banks hold households' deposits and provide loans to firms. Following Carlstrom and Fuerst (1998), it is assumed that both deposits and loans are held only within a period (intra-period deposits and loans). The deposits are put down at the beginning of the period and withdrawn at the end of the same period. Due to fact that they bear no risk and that households have no alternative investment opportunities within the time frame during which they are held, the interest rate on these deposits is equal to zero. Loans to firms are also granted and repaid in

the course of one period - the funds are transfered to entrepreneurs after the period started and are repaid before the period ends. Each bank provides loans to a large group of entrepreneurs. It is assumed that banks trade with each other in a complete set of financial securities backed by outstanding loans in such a way that for each of them the firm-specific credit risk is completely diversified away.

3.3.1 Loan financing costs

In each period banks are subject to exogenous death shocks occuring with probability ϖ_t which varies over time.[7] The timing of the bank death shocks is after households' have deposited their funds in the banks and before banks grant loans to entrepreneurs. A bank's death is associated with a deadweight loss equal to a constant fraction ψ of all deposits held at that bank. In order to ensure that bank deposits are risk-free, banks set up a deposit guarantee scheme. In each period they pay a fraction of their total assets into a mutual fund, which is then drawn upon in order to repay all households the full value of their deposits.

Due to the fact that in each period a fraction of banks dies and that the resulting deadweight loss is covered by the whole banking system, in order to provide one unit of loans to firms banks need to secure $\frac{1}{(1-\psi\varpi_t)}$ units of households' deposits. As a result, the marginal cost of financing a bank loan, given by M_t, is equal to:

$$M_t = \frac{1}{(1-\psi\varpi_t)} R_H = \frac{1}{(1-\psi\varpi_t)} \tag{14}$$

The cost of providing external finance to entrepreneurs in a given period is therefore determined by the time-varying probability of the bank death shock ϖ_t. The greater the probability of a bank's failure, the greater fraction of banks' assets is used to cover for the deadweight loss resulting from banks' collapse and the greater the loan financing costs. As the costs of providing external finance to firms are passed on to the entrepreneurs, they are reflected in the interest rates charged on bank loans.

3.3.2 Debt contract

After signing loan contracts with entrepreneurs, banks trade with each other in securities backed by the loans granted. It is assumed that there is a complete interbank

[7] The assumption of banks' death shocks is introduced in order to allow for exogenous financial shocks altering banks' costs of funds.

market for such securities and, as a result, there is perfect risk-sharing: all banks have an equal share in all loan contracts and, at the end of the period, they receive the same loan repayments.

The total value of loans granted to entrepreneurs in sector X is equal to:

$$\int_{A_{\min}}^{\infty} D_{X,j,t} dF(A)$$

In each period a fraction of firms in sector X with idiosyncratic productivity draws such that $A_{X,j,t} < \overline{A}_{X,t}$ incurs losses and defaults on their debt. $\overline{A}_{X,t}$ is the threshold level of idiosyncratic productivity at time t above which a firm in sector X is able to fulfill all its financial obligations. The threshold level of productivity $\overline{A}_{X,t}$ is determined by the condition that the profit of the firm with the idiosyncratic productivity $\overline{A}_{X,j,t} = \overline{A}_{X,t}$ is equal to zero:

$$Y_{X,j,t} P_{X,j,t} - Y_{X,j,t} \frac{W_t}{Z_t \overline{A}_{X,j,t}} \widetilde{R}_{X,t} - \frac{W_t}{Z_t} (F_{X,t} + G_{X,t}) R_{X,t} = 0 \tag{15}$$

At the end of the period banks receive from firm j the value $D_{X,j,t} R_{X,t}$ if $A_{X,j,t} \geq \overline{A}_{X,t}$ where $\Pr(A_{X,j,t} \geq \overline{A}_{X,t}) = 1 - F(\overline{A}_{X,t})$ and the value $T_{X,j,t}$ if $A_{X,j,t} < \overline{A}_{X,t}$ where $\Pr(A_{X,j,t} < \overline{A}_{X,t}) = F(\overline{A}_{X,t})$. The fraction of defaulting firms in sector X is equal to $N_{X,t} = F(\overline{A}_{X,t})$.

The interest rate $(R_{X,t} - 1)$ on a bank loan in sector X is determined by the condition that the total value of loan repayment, which banks receive at the end of the period, must be equal to the total cost of financing these loans. Banks' participation constraint is therefore given by:

$$\begin{aligned} & \int_{\overline{A}_{X,t}}^{\infty} D_{X,j,t} R_{X,t} dF(A_t) \\ & + \int_{A_{\min}}^{\overline{A}_{X,t}} \left[Y_{X,j,t} P_{X,j,t} - Y_{X,j,t} \frac{W_t}{Z_t A_{X,j,t}} - \frac{W_t}{Z_t} (F_{X,t} + G_{X,t}) \right] dF(A) \\ = \; & M_t \int_{A_{\min}}^{\infty} D_{X,j,t} dF(A) \end{aligned} \tag{16}$$

If the probability of banks' death, ϖ_t, is equal to zero, then $M_t = 1$ and hence the total value of loan repayment at the end of the period needs to be equal to the total value of loans extended at the beginning of the period. If the probability of a bank's collapse is positive ($\varpi_t > 0$), then $M_t > 1$ and the value of the repayment needs to be relatively greater in order to cover for the deadweight losses induced by banks' failure. Banks are perfectly competitive and, as a result, their profits from providing financial intermediation between households and firms are equal to zero.

Following Melitz (2003), we can define the following productivity averages. The average firm-specific level of productivity among defaulting firms in sector X is equal to:

$$A_{XL,t} = \left[\frac{1}{F(\overline{A}_{X,t})} \int_{A_{\min}}^{\overline{A}_{X,t}} A_t^{\theta-1} dF(A) \right]^{\frac{1}{\theta-1}}$$

The average firm-specific productivity among non-defaulting firms in sector X is given by:

$$A_{XH,t} = \left[\frac{1}{1-F(\overline{A}_{X,t})} \int_{\overline{A}_{X,t}}^{\infty} A_t^{\theta-1} dF(A) \right]^{\frac{1}{\theta-1}}$$

The average level of the idiosyncratic component of firms' productivity is time-invariant, the same for both sectors and equal to:

$$A_{XA} = \left[\int_{A_{\min}}^{\infty} A_t^{\theta-1} dF(A) \right]^{\frac{1}{\theta-1}}$$

Using the productivity distribution, the average productivities can now be expressed in terms of the threshold level of productivity and the default rate:

$$A_{XA} = \left[\frac{k}{k-(\theta-1)} \right]^{\frac{1}{\theta-1}} A_{\min} \tag{17}$$

$$A_{XH,t} = \left[\frac{k}{k-(\theta-1)} \right]^{\frac{1}{\theta-1}} \overline{A}_{X,t} \tag{18}$$

$$A_{XL,t} = \left[\frac{k}{k-(\theta-1)} \right]^{\frac{1}{\theta-1}} \left[\frac{1}{N_{X,t}} A_{\min}^{\theta-1} - \frac{(1-N_{X,t})}{N_{X,t}} \left(\overline{A}_{X,t} \right)^{\theta-1} \right]^{\frac{1}{\theta-1}} \tag{19}$$

After substituting the average productivity indices and the demand and price equations into (16), the banks' participation constraint for financing domestic retailers can be written as:

$$\begin{aligned}
& [1-N_{D,t}]\left[d_D\alpha\left(\mu\widetilde{R}_{D,t}\right)^{-\theta}\left(\frac{W_t}{Z_tA_{DH,t}}\right)^{1-\theta}P_t^{\theta}C_t+\frac{W_t}{Z_t}(F_{D,t}+G_{D,t})\right]R_{D,t} \\
& +N_{D,t}\left[\alpha\left(\mu\widetilde{R}_{D,t}\right)^{-\theta}\left(\frac{W_t}{Z_tA_{DL,t}}\right)^{1-\theta}P_t^{\theta}C_t\left(\mu\widetilde{R}_{D,t}-1\right)-\frac{W_t}{Z_t}(F_{D,t}+G_{D,t})\right] \\
= \; & M_t\left[d_D\alpha\left(\mu\widetilde{R}_{D,t}\right)^{-\theta}\left(\frac{W_t}{Z_tA_{DA}}\right)^{1-\theta}P_t^{\theta}C_t+\frac{W_t}{Z_t}(F_{D,t}+G_{D,t})\right]
\end{aligned}$$

In the case of loans for exporters, equation (16) can be expressed as:

$$\begin{aligned}
& [1-N_{E,t}]\left[d_E(1-\alpha)\left(\mu\widetilde{R}_{E,t}\right)^{-\theta}\left(\frac{W_t}{Z_tA_{EH,t}}\right)^{1-\theta}P_t^{\theta}C_t+\frac{W_t}{Z_t}(F_{E,t}+G_{E,t})\right]R_{E,t} \\
& +N_{E,t}\left[(1-\alpha)\left(\mu\widetilde{R}_{E,t}\right)^{-\theta}\left(\frac{W_t}{Z_tA_{EL,t}}\right)^{1-\theta}P_t^{\theta}C_t\left(\mu\widetilde{R}_{E,t}-1\right)-\frac{W_t}{Z_t}(F_{E,t}+G_{E,t})\right] \\
= \; & M_t\left[d_E(1-\alpha)\left(\mu\widetilde{R}_{E,t}\right)^{-\theta}\left(\frac{W_t}{Z_tA_{EA}}\right)^{1-\theta}P_t^{\theta}C_t+\frac{W_t}{Z_t}(F_{E,t}+G_{E,t})\right]
\end{aligned}$$

The banks' participation constraint (16), the firms' zero profit condition (15) and the equations determining aggregate productivities (17, 18 and 19) together determine the interest rate on bank loans, $(R_{X,t}-1)$, the threshold level of productivity, $\overline{A}_{X,t}$, and the default rate among firms, $N_{X,t}$, for given levels of aggregate shocks.

4 Financial frictions and the macroeconomy

The presence of financial markets' imperfections in the form of firms' cash-flow constraints in an open-economy general equilibrium framework with heterogenous firms has a number of implications for the steady state and the business cycle properties of the model. The aim of this section is to discuss the intuition behind the mechanism through which these frictions affect the equilibrium of the economy and macroeco-

nomic dynamics. For this purpose, it is first helpful to consider the case in which macroeconomic and financial shocks are symmetric across countries and in which the degree of external finance dependence of exporters and domestic retailers is the same, $d_E = d_D = d$.

The model has the property that as long as the fixed costs of production are large enough to generate a positive default rate among firms or there is a risk of a bank's failure, firms need to pay a premium on external finance, $(R_t - 1) > 0$. Due to the presence of credit risk and/or a positive probability of a bank's death, the interest rate charged on bank loans is greater than zero, even though banks pay zero interest on households' deposits. The loan repayments by firms with positive profits need to compensate for the losses generated by firms which are not able to pay back the total value of their debt and for the losses associated with a bank's death.

The external finance premium is countercyclical. Positive demand and productivity shocks resulting in an increase in output lead to higher profits and lower default rates among firms. In consequence, a smaller proportion of revenues received by profitable firms is sufficient to cover the losses that banks incur on loans granted to defaulting firms. As a result, the external finance premium decreases. In turn, during an economic downturn, banks need to raise borrowing costs in order to finance the losses induced by a greater number of defaulting firms and the external finance premium increases. This premium is also affected by financial shocks which lead to changes in banks' own costs of funds or the financial intermediation costs. It increases in the probability of banks' failure and in the financial intermediation fee.

If the external finance premium is positive, $R_t > 1$, and firms are cash-flow constrained, $d > 0$, then firms' effective borrowing cost is greater than one, $\widetilde{R}_t > 1$. Through its impact on the effective borrowing cost, firms' cash-flow constraints affect the aggregate level of output in the economy. This can be seen by considering firms' employment decisions and households' intratemporal consumption-leisure choice. Firms' profit maximisation requires that the real wage is equal to a constant fraction of the marginal revenue product of labour:

$$\frac{W_t}{P_t} = \frac{Z_t A_A}{\mu \widetilde{R}_t} \tag{20}$$

At the same time, in a perfectly competitive labour market the real wage is equal to the marginal rate of substitution between consumption and leisure:

$$\frac{W_t}{P_t} = C_t^{\sigma} L_t^{\varphi} \frac{1}{u_t} \tag{21}$$

To the extent to which the effective borrowing cost is greater than one, it generates a labour wedge - a discrepancy between the marginal rate of substitution between consumption and leisure and the average marginal product of labour across firms, equal to $Z_t A_A$. This wedge leads to an inefficiently low aggregate level of output. When the effective borrowing cost is greater than one, then for a given marginal product of labour, the real wage is lower than in the case when the effective borrowing cost is equal to one. As a result, the equilibrium level of labour supply, which equates the marginal rate of substitution between consumption and leisure with the real wage, is also lower, leading to a relatively lower level of output.

In a model with default and cash-flow constraints, losses incurred by defaulting firms are financed by loan repayments collected from non-defaulting firms. As all firms pay the same interest rate on their loans, firms with relatively higher productivity, output and hence also loans cover a relatively larger fraction of these losses. The fact that a firm's contribution to financing loan write-offs generated by the least productive firms depends on its individual level of output distorts firms' incentives and creates an externality. When taking their employment and production decisions, firms internalise the impact of the effective borrowing costs on their output and profits. However, they do not take into account the impact of their individual level of output on the aggregate output in the economy, which in turn affects the fraction of defaulting firms, the external finance premium, firms' borrowing costs and as a result also their profits.

The externality and inefficiency induced by credit market imperfections is positively related to the degree of firms' external finance dependence, d. This is due to the fact that the more cash-flow constrained firms are, the stronger is the impact of their individual level of output on their contribution to financing the losses generated by unprofitable firms. If $d > 0$ and $R_t > 1$ then firm $j's$ contribution to financing the loan write-offs is equal to $(R_t - 1)D_{j,t} = \frac{W_t}{Z_t}(F_t + G_t)(R_t - 1) + d_t Y_{j,t} \frac{W_t}{Z_t A_{j,t}}(R_t - 1)$ and it is an increasing function of the firm's level of productivity $A_{j,t}$. With a decrease in d_t the extent to which this contribution depends on firms' variable costs of production diminishes. In the extreme case when $d = 0$ and therefore when firms are able to finance their entire variable costs of production using internal funds coming

from households' advance payments for the consumption goods, the contribution of each firm to cover the default losses is equal to $\frac{W_t}{Z_t}(F_t + G_t)(R_t - 1)$ and is independent of firms' individual level of productivity. As a result, it does not affect firms' employment and production decisions and does not introduce inefficiency.

Due to the fact that the external finance premium is countercyclical, the effective borrowing cost is also countercyclical, which in turn leads to a procyclical labour wedge. This is an important feature of the model as it demonstrates that working capital financing frictions help explain the procyclical behaviour of the labour wedge, which proved difficult to reconcile with standard macroeconomic and labour market models (see e.g. Shimmer, 2009, for a review of the literature on this topic). It is also consistent with the findings by Chari Kehoe and McGrattan (2007) who showed that the labour wedge together with the efficiency wedge account for most of the cyclical output fuctuations.

The introduction of differences in the degree of external finance dependence of exporters and domestic retailers such that $d_E > d_D$ leads to discrepancies in the equilibrium level of output and prices in the two sectors of the economy. Firstly, differences in working capital external financing requirements result in differences in the steady state levels of the external finance premia and the effective borrowing costs of exporters and domestic retailers. As long as in both sectors firms' default rates are positive, the external finance premia are also positive in both sectors. However, the exporting sector, which is characterised by greater cash-flow constraints (and therefore higher d_X) is also characterised by greater inefficiency and lower steady-state output for any given realisation of aggregate shocks. Differences in the aggregate level of output in the two sectors of the economy lead to differences in the external finance premia as well as in the effective borrowing costs and prices which reduce the demand for exports relative to domestic sales and increase the discrepancy between the external finance premia in these two sectors even further.

Secondly, due to the fact that international trade is more dependent on external finance than domestic sales, the effective borrowing cost of exporters and, in consequence, also export prices are more sensitive to changes in macroeconomic conditions than the effective borrowing cost and prices of goods sold in the domestic economy. A decline in aggregate output in response to adverse macroeconomic shocks therefore leads to an increase in the relative price of exported to domestic goods and a decline in trade volume which exceeds that of output. An increase in aggregate output fol-

lowing positive shocks results in turn in the decline in the relative price of exports and an increase in the relative demand for these goods. As a result, the trade to GDP ratio is procyclical.

5 Model parametrisation

In order to illustrate the transmission of shocks in the framework developed and examine the role of trade finance in the trade collapse of 2008-2009, the model is calibrated to match US data.

The preference parameters are set to standard values adopted in the international real business cycle literature. The inverse of the intertemporal elasticity of substitution in consumption, σ, and the inverse of the Frisch elasticity of labour supply, φ, are equal to 2.0. It is assumed that $\alpha = \frac{1}{2}$; however, due to differences in the cost of external financing and the resulting differences in the relative prices of goods of foreign and domestic origin, the share of domestic goods in the consumption basket is greater than the share of imported goods. Following Bernard *et al.* (2003) and Ghironi and Melitz (2005), the elasticity of substitution between goods is set to be equal to $\theta = 3.8$, which was calibrated to match US plant and macro trade data. The parameters of firms' productivity distribution are set as in Ghironi and Melitz (2005). The parameter determining the dispersion of individual levels of productivity is equal to $k = 3.4$ in order to match the standard deviation of log US plant sales equal to 1.67, which is reported in Bernard *et al.* (2003). The lower bound for idiosyncratic productivity is normalised to one, $A_{\min} = 1$.

The fixed production costs are calibrated to match the average value of loan write-offs in the corporate sector in the US in the period from 1985Q3 to 2010Q3, which is equal to 0.93 per cent. The value of the fixed costs adopted implies that in the steady state about 6 per cent of the labour force is employed in setting-up firms and providing financial intermediation services. The costs of financial intermediation are assumed to be equal to 10 per cent of the firm start-up costs. The fixed firm set-up costs and the financial intermediation costs are assumed to be the same for domestic retailers and exporters: $F_D = G_D$ and $F_E = G_E$.

As 80-90 per cent of international trade relies on trade finance (Auboin, 2009), the fraction of working capital which exporting firms need to finance externally is set to be equal to $d_E = 0.8$. In turn, the external finance dependence of domestic

retailers is determined in such a way that it reflects the differences in working capital financing requirements associated with domestic and international transactions.

One of the main reasons why international trade is more dependent on external finance than domestic sales is the fact that exporters face longer time lags between the production of goods and the receipt of sales revenues due to the additional time needed to transport goods abroad and to complete administrative procedures involved in international trade. These longer time lags result in greater working capital financing needs. Hummels (2001) estimates that the average shipment time in US trade is equal to 10.5 days. Djankov *et al.* (2010) find in a sample of 126 countries that on average 30 days pass between the moment when goods are ready to ship at the factory and their loading onto a ship. Similar delays are involved in transporting goods from a port to its final destination. For developed countries the average time required is about 13 days. These estimates indicate that in the US the time lag between receiving a purchase order and revenues from sales in international trade are nearly two months longer than the corresponding time lags in domestic sales. Raddatz (2006) uses data for US public manufacturing firms to provide a measure of the cash conversion cycle, which is the time elapsed between when a firm pays for its inputs and its receipt of payment for the goods it sells, for four digit ISIC industries in the US during 1980–1989. He finds that for the median firm in the median industry the cash conversion cycle is equal to 97 days.[8] This estimate combined with the above statistics on international trade suggest that the time needed to obtain payment for a good sold in the domestic market is equal to about two-third of the time needed in the case of a good sold abroad. It is assumed that there are similar differences in firms' working capital external financing requirements and, as a result, the fraction of working capital financed externally for domestic retailers is set to be equal to $d_D = 0.5$.[9] The parameters determining the degree of firms' external finance dependence adopted in this paper are consistent with survey evidence from World Bank, which suggests that enterprises finance approximately 57 percent of their working capital requirements with external finance (Safavian and Wimpey, 2007).

In the steady state, the probability of a bank's failure is equal to zero, $\varpi = 0$ and it is assumed that during a financial crisis this probability becomes positive. The cost

[8] A three-month period is also commonly assumed in the inventory literature (e.g. Christiano, 1988)

[9] The approach to use industries' relative dependence on working capital to proxy their external finance dependence has also been adopted by Raddatz (2006).

of a bank's collapse in terms of the fraction of the banks' liabilities, ψ, is normalised to one.

6 Quantitative results

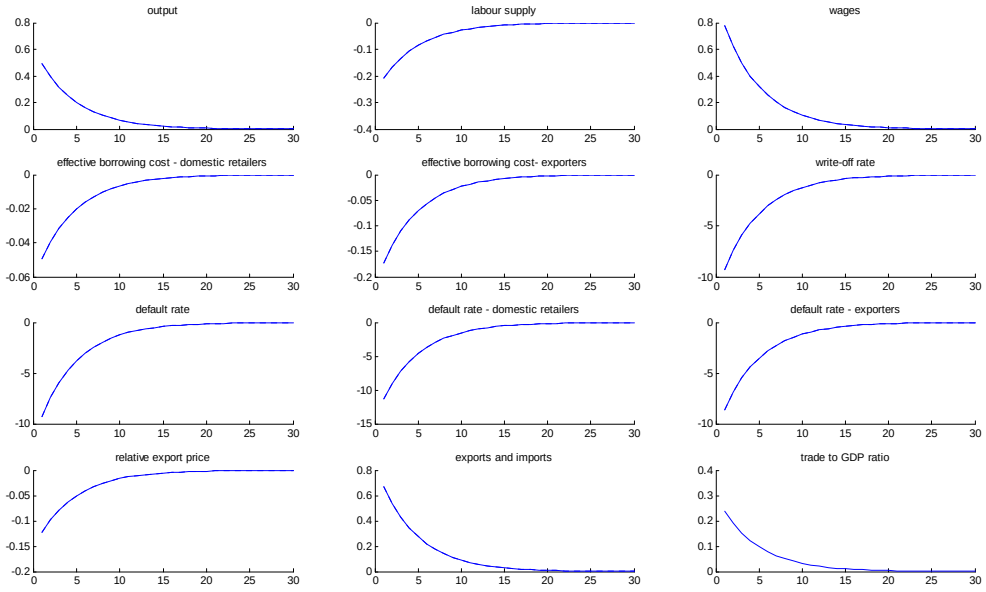
6.1 Trade over the business cycle

This section illustrates the impact of real and financial shocks on business cycle dynamics in the framework developed. In particular, it investigates how credit market frictions affect the transmission of shocks in the economy. First, real shocks to aggregate productivity and demand are analysed. Second, financial shocks affecting the cost of financial intermediation and the cost of funds for banks are considered.

6.1.1 Productivity shocks

Figure 1 shows the effects of a positive symmetric productivity shock which leads to an increase in world output by 0.5 per cent on a quarterly basis. The increase in aggregate productivity leads to a decline in the number of firms which default on their debt and a decrease in the value of loans which are written-off as a result of firms' default. The fall in the riskiness of bank lending reduces the cost of external finance for firms. As exporting firms are more dependent on bank loans than domestic retailers, the relative price of exports decreases, which boosts demand for imported goods. As a result, the trade increase is 1.4 times greater than that of output. The elasticity of trade to GDP generated by the model is therefore considerably higher than the unitary elasticity implied by a standard real business cycle model which does not take financial frictions into account.

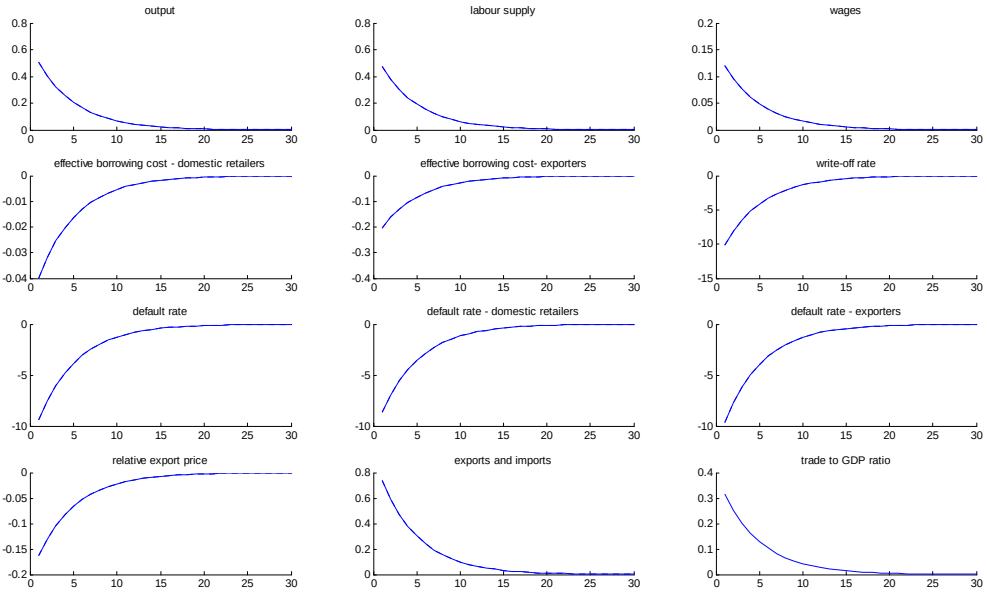
Figure 1. Impulse responses to a positive global productivity shock (in per cent).



6.1.2 Demand shocks

A positive demand shock has a similar effect on the trade to GDP ratio as a favourable productivity shock. Figure 2 illustrates the effects of a synchronised demand shock resulting in a 0.5 per cent increase in global output. The shock leads to a decline in firms' default rates, both in the domestic and in the exporting sectors, and a decrease in the loan write-off rates. Banks face reduced credit risk and the costs of insuring against this risk go down, which brings about lower costs of external finance for firms. As the decrease in firms' effective borrowing costs induces a decrease in the relative export price, the volume of international trade rises in relation to GDP - the change in real trade is 1.5 times larger than the change in real output.

Figure 2. Impulse responses to a positive global demand shock (in per cent).



6.1.3 Financial shocks

In the framework developed, not only real shocks but also shocks originating in the financial markets have a significant impact on trade flows. Figure 3 illustrates the effects of an increase in the financial intermediation fee by 5 per cent. Figure 4 shows the impact of a 1 per cent increase in the cost of loan financing for banks, which results from an exogenous increase in the probability of banks' default. Higher cost of funds for banks translate into higher borrowing costs for firms. Both shocks therefore lead to an increase in firms' marginal costs and prices. As prices of exported and imported goods are more sensitive to changes in the cost of credit than prices of domestic goods, the shocks lead to a decrease in the share of foreign goods in households' consumption basket and a substantial decrease in the trade to GDP ratio.

Figure 3. Impulse responses to a 5 per cent increase in financial intermediation costs (in per cent).

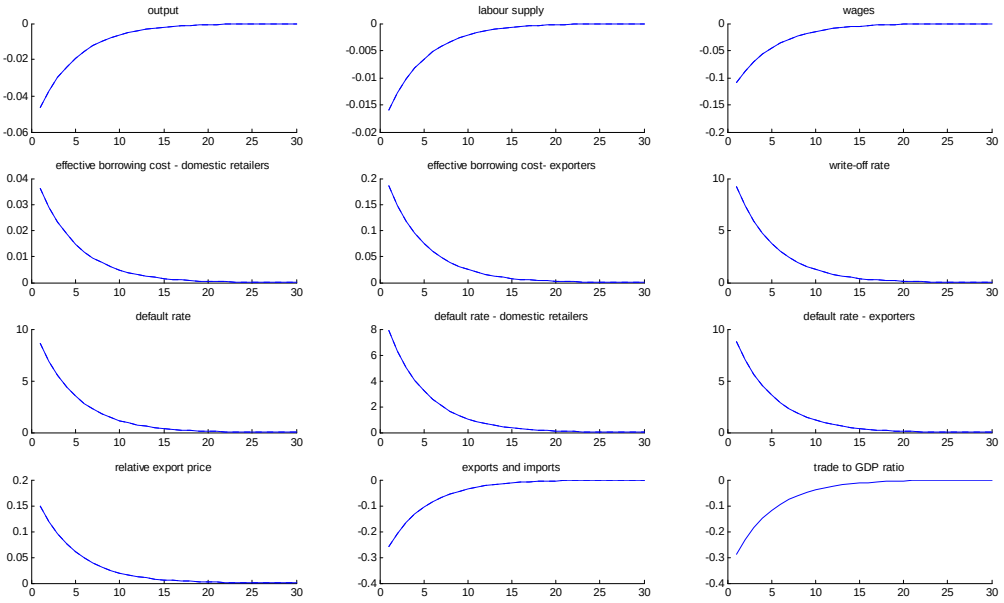
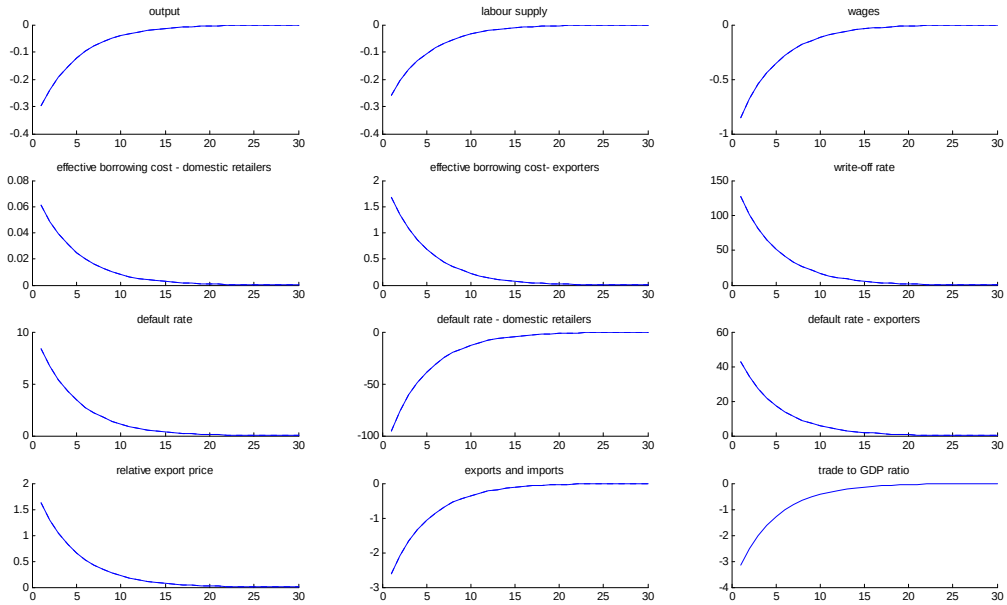


Figure 4. Impulse responses to a 1 per cent increase in banks' loan financing costs (in per cent).



6.2 The great trade collapse

The previous section demonstrated that credit frictions and differences in external financing requirements between domestic and international transactions significantly affect the transmission of shocks in the economy and the dynamics of international trade over the business cycle. This section examines to what extent the financial accelerator mechanism suggested in this paper helps to explain the collapse of trade during the recent financial crisis.

The financial crisis of 2008-2009 is modelled as a simultaneous occurence of a large global negative demand shock and a synchronised rise in the cost of funds for banks due to increased risk in the financial sector. The magnitudes of these two shocks are calibrated to match the US data on output, relative export prices and corporate loan write-off rates during the crisis. Between 2008Q2 and 2009Q2 US GDP declined by 4.1 per cent, there was an almost three-fold increase in the charge-off rate on business loans, from 0.8 to 2.3 per cent (Figure A.1.8), and US non-agricultural export prices increased by 8.6 per cent relative to producer prices for industrial commodities. At the same time US trade decreased by 20.6 per cent.

Figure 5. Impulse responses to a simultaneous negative global demand shock and a positive shock to banks' loan financing costs (in per cent).

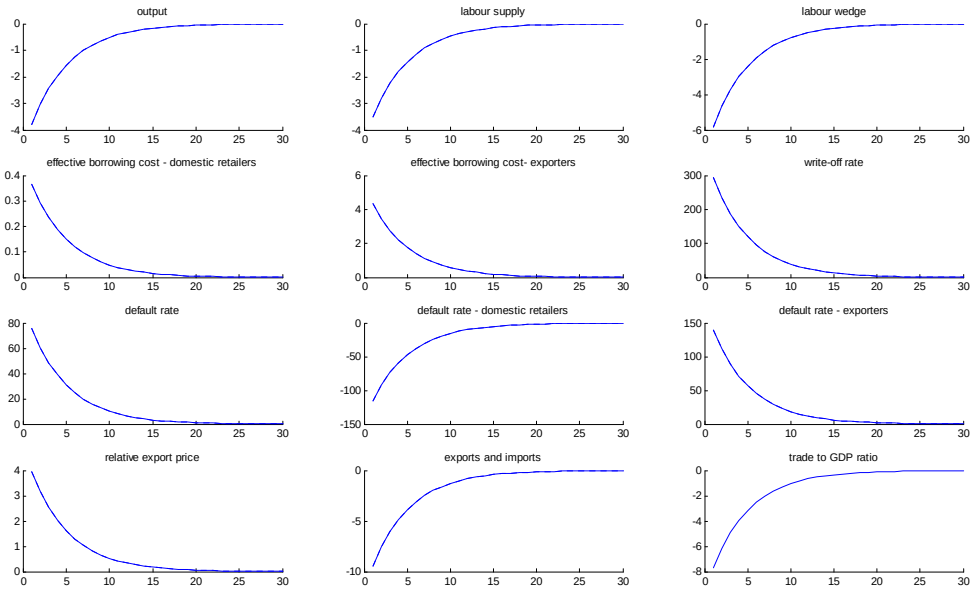


Figure 5 shows the responses of the main macroeconomic variables to a simultaneous demand and financial shock which leads, on an annual basis, to changes in macroeconomic variables similar to those observed in the data. The shocks increase the riskiness of bank lending and banks' own costs of funds and result in an increase in the cost of external finance for both domestic retailers and exporters. However, the increase in the effective borrowing cost is much greater for exporting firms. The changes in the relative financing costs lead to an increase in the relative price of imported to domestic goods. As a result, trade falls by 12 per cent and the decline in international trade is 2.9 times larger than the decrease in output.

The model is therefore able to explain 48 per cent of the decline in US trade during the crisis. 58 per cent of the decrease in trade generated by the model results from the presence of credit market frictions and is in addition to the usual effects of a drop in aggregate demand following a negative demand shock captured by a standard real business cycle model. The model therefore implies that financial factors explain 28 per cent of the decline in trade in 2008-2009. 8 per cent of this decline results from the financial accelerator mechanism and is due to the fact that credit market imperfections amplify the effects of a negative demand shock on trade. The remaining 20 per cent of the decrease in trade is caused by a financial shock increasing the cost of funds for banks and, as a result, also the cost of external finance for firms. The model generates a decline in the labour wedge of 5.8 per cent, as compared to the 9.2 per cent decrease in this wedge observed in the data.

The predictions of the model concerning the changes in trade volumes during the financial crisis are therefore a vast improvement on the predictions of a benchmark real business cycle model generating trade elasticity equal to one. The model provides an explanation of the great trade collapse complementary to those implied by recently developed models accounting for vertical production linkages and the composition of international trade which are able to explain 70-80 per cent of the fall in trade during the financial crisis (e.g. Eaton *et al.,* 2010; Bems *et al.,* 2010). Moreover, the model developed accounts for changes in relative prices and the labour wedge during the crisis which are not explained in other models.

7 Conclusions

The paper introduces credit market imperfections into an open-economy general equilibrium model with heterogenous firms. It then investigates the impact of financial frictions on business cycle fluctuations and, in particular, the dynamics of international trade. The role of financial market imperfections in the great trade collapse of 2008-2009 is also examined.

The paper suggests a novel mechanism generating a countercyclical external finance premium, which is the result of the presence of irreversible fixed costs of production, firms' idiosyncratic risk and cash-flow constraints. Changes in macroeconomic conditions affect the riskiness and cost of bank lending, which in turn leads to changes in firms' marginal costs and the labour wedge. Due to differences in the working capital financing needs of exporters and domestic retailers, the relative price of domestic and imported goods and the relative demand for these goods also change. As firms selling their goods abroad have longer cash conversion cycles and are more dependent on external finance than firms serving the domestic market, international trade is more sensitive to macroeconomic shocks than domestic sales.

The study shows that financial frictions significantly affect the transmission of shocks in the economy. Differences in firms' external financing requirements associated with international and domestic transactions help explain the strong procyclicality of the trade to GDP ratio observed in the data. Following shocks to demand and productivity, the elasticity of trade with respect to output generated by the model developed in this paper ranges between 1.4 and 1.5. Shocks to the cost of credit originating in financial markets have an even stronger impact on the relative volatility of international trade and output. The credit market imperfections and the financial accelerator mechanism suggested are able to explain about one-third of the decline in trade during the financial crisis of 2008-2009. They are also able to account for a significant part of changes in the labour wedge and in the relative prices of domestic to imported goods during the crisis.

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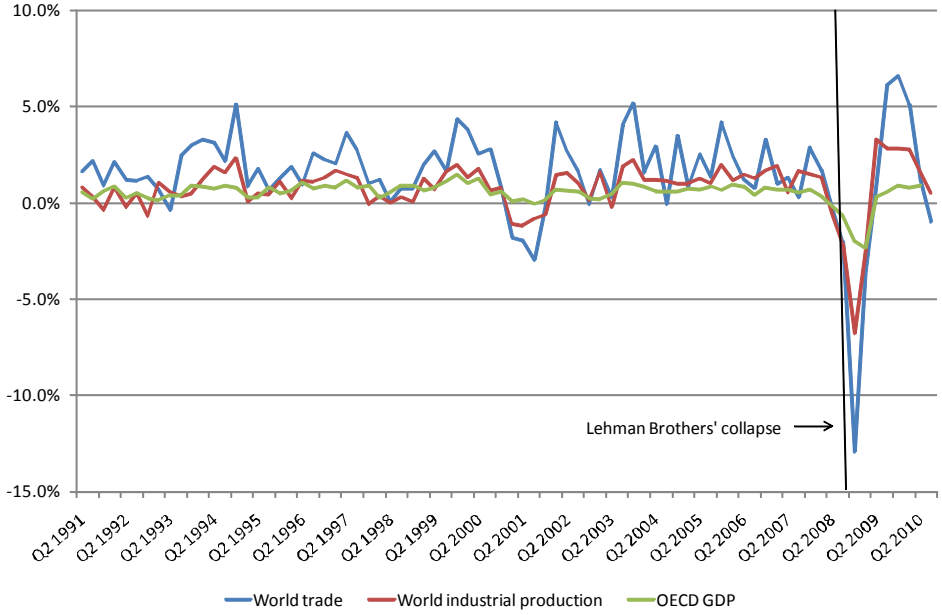
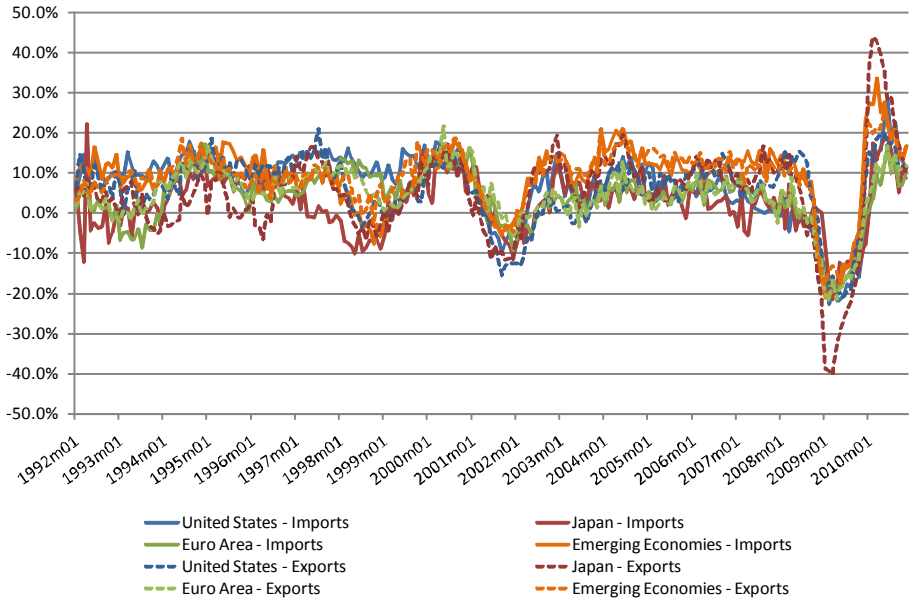
A Appendix

Figure A.1.1. Trade, industrial production and GDP - annual rate of growth.



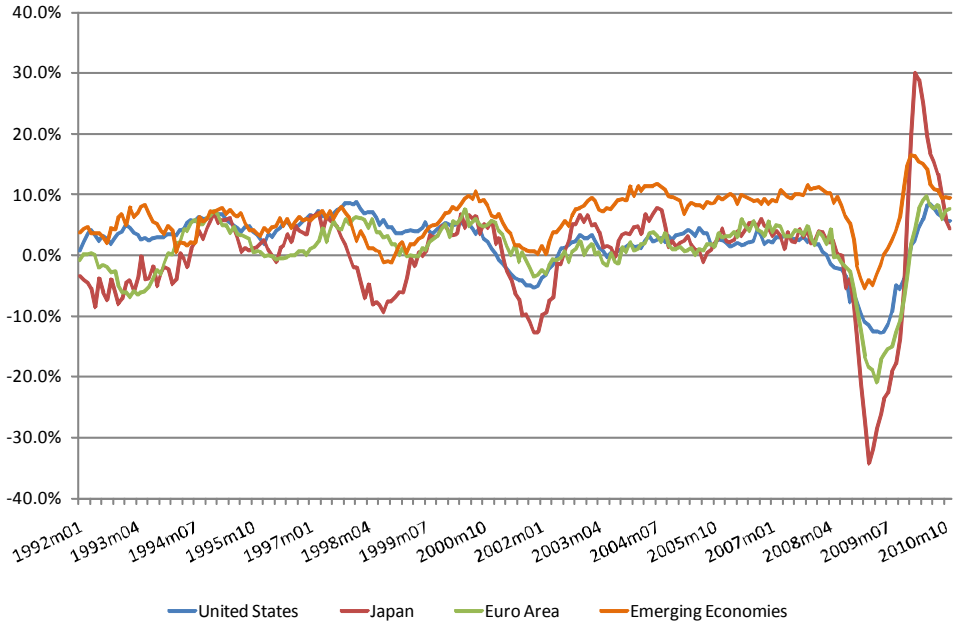
Source: Netherlands Bureau for Economic Policy Analysis (CPB), OECD Main Economic Indicators.

Figure A.1.2. Imports and exports - annual rate of growth.



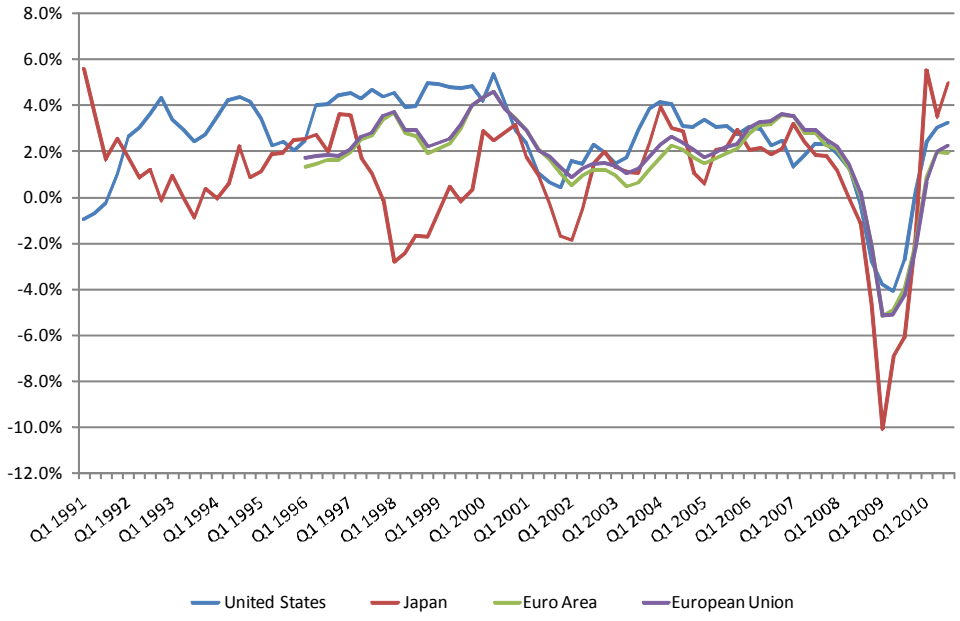
Source: Netherlands Bureau for Economic Policy Analysis (CPB).

Figure A.1.3. Industrial production - annual rate of growth.



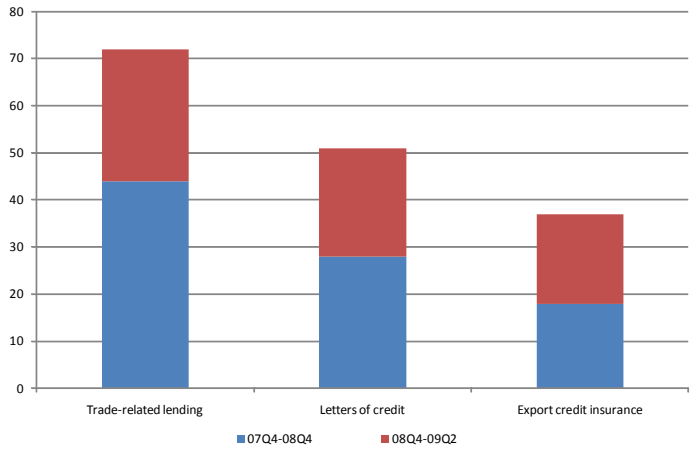
Source: Netherlands Bureau for Economic Policy Analysis (CPB)

Figure A.1.4. GDP - annual rate of growth.



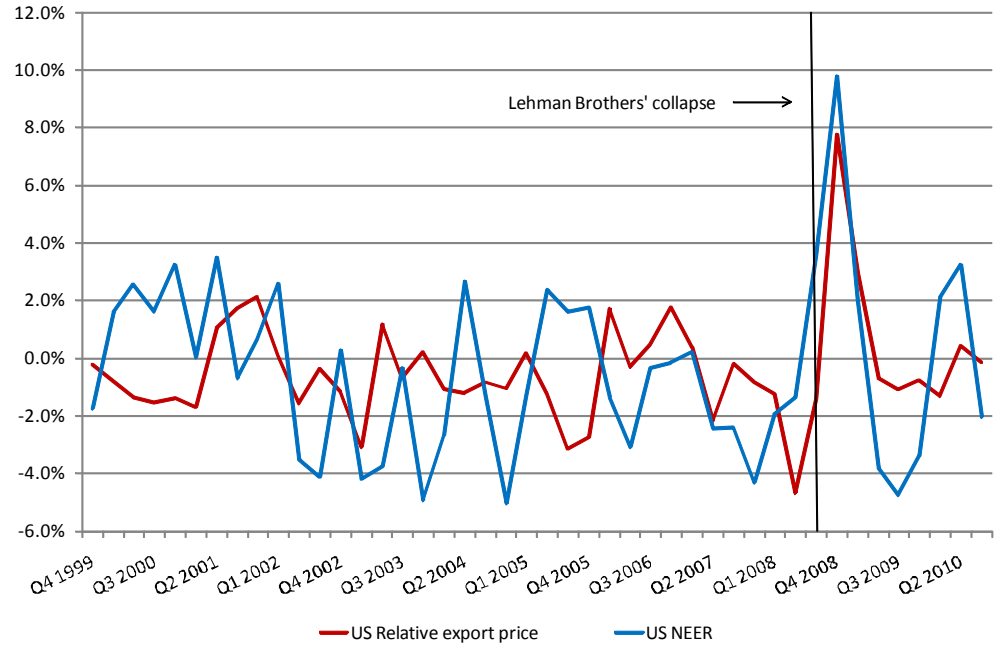
Source: OECD Main Economic Indicators.

Figure A.1.5. The cost of trade finance instruments - changes in basis points over the costs of funds.



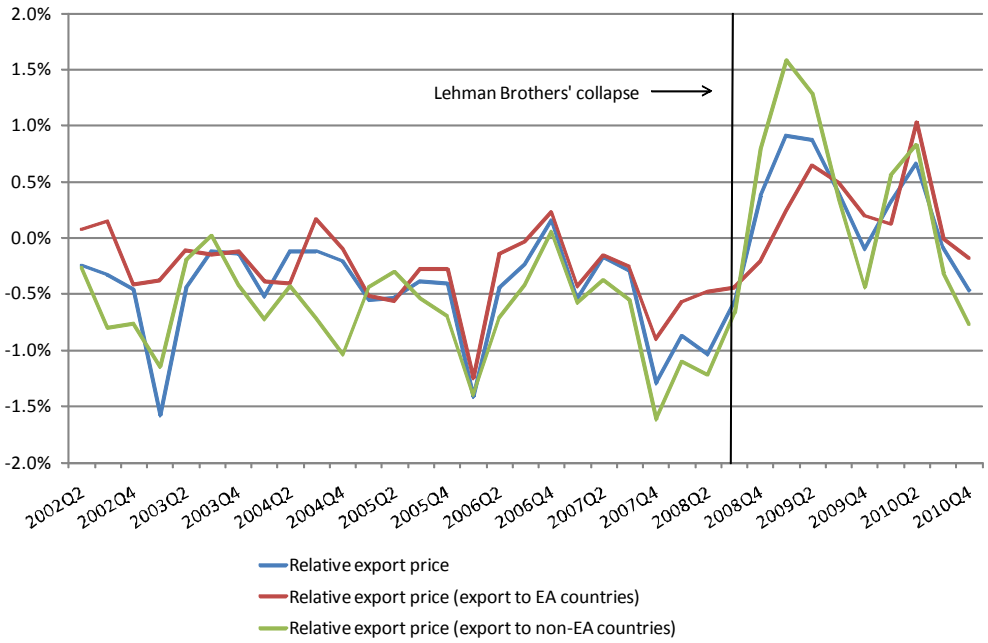
Source: IMF/BAFT-IFSA Trade Finance Survey, July 2009.

Figure A.1.6. The log of US non-agricultural export prices minus the log of producer prices for industrial commodities and the nominal effective exchange rate.



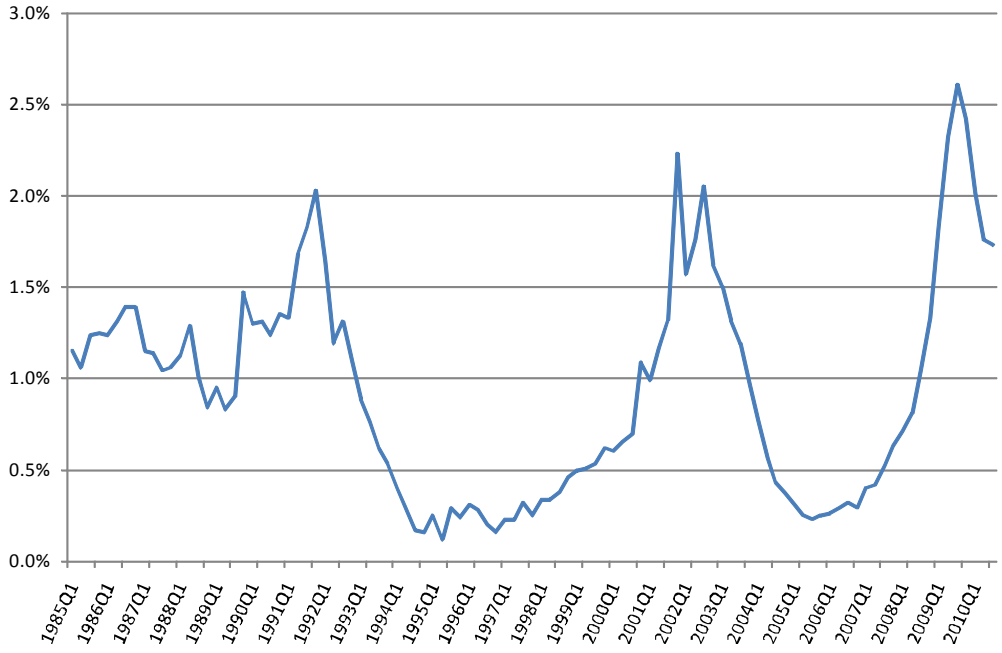
Source: Bureau of Labor Statistics, OECD Main Economic Indicators.

Figure A.1.7. The log of producer prices for exports minus the log of producer prices for domestic goods in the Euro Area



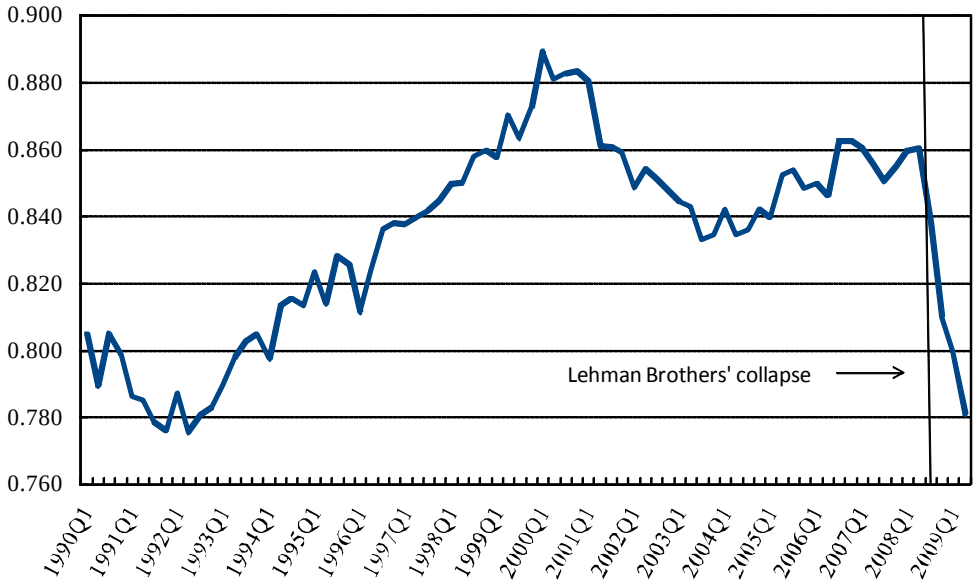
Source: Eurostat.

Figure A.1.8. Loan write-off rate in the corporate sector in the US.



Source: Federal Financial Institutions Examination Council (FFIEC).

Figure A.1.9. Labour wedge in the US.



Source: Kobayashi, 2011.