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# International Trade and Real Transmission Channels of Financial Shocks in Globalized Production Networks

Hubert Escaith: WTO
Fabien Gonguet: École Polytechnique-ENSAE, Paris

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# International Trade and Real Transmission Channels of Financial Shocks in Globalized Production Networks

Hubert Escaith * [1]
Fabien Gonguet **

***Abstract:*** The article analyses the role of international supply chains as transmission channels of a financial shock. Because individual firms are interdependent and rely on each other, either as supplier of intermediate goods or client for their own production, an exogenous financial shock affecting a single firm, such as the termination of a line of credit, reverberates through the productive chain. The transmission of the initial financial shock through real channels is tracked by modelling input-output interactions. The paper indicates that when banks operate at the limit of their institutional capacity, defined by the capital adequacy ratio, and if assets are priced to market, then a resonance effect amplifies the back and forth transmission between real and monetary circuits. The paper illustrates the proposed methodology by computing a supply-driven indicator (IRSIC) and indirect demand-driven impacts on five interconnected economies of different characteristics: China, Japan, Malaysia, Thailand and the United States.

**JEL classification**: C67, F23, F36, G01, L16

**Keywords**: international supply chains, monetary circuit, real linkages, transmission channels of financial shock, Asian International Input-Output Tables

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[1] * Economic Research and Statistics Division-WTO, Geneva; ** Ecole Polytechnique-ENSAE, Paris. The views expressed in this document, which has not been submitted to formal editing, are those of the authors and do not represent a position, official or unofficial, of the WTO Secretariat or WTO Members.

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## I. INTRODUCTION

For the past 20 years, globalization has implied not only the expansion of international trade and finance, but also the geographical fragmentation of the production processes within networks of firms associated through contractual arrangements or belonging to trans-national corporations. Nowadays, specific industrial operations, from the conception to the assembly of final products, are no longer undertaken by a single establishment but increasingly outsourced within these global value chains, giving place to what is known as "trade in tasks" (Baldwin, 2006).

It is becoming common practice for firms to send their unfinished goods to an affiliate or non affiliate for processing. Sometimes the material is sent to firms within the domestic economy; sometimes the material is sent abroad. This process is very common among processing industries such as chemical, electronic and metallic manufacturing. In the industry, the process is often referred to as toll manufacturing, toll processing or custom manufacturing. Indeed, most of the enormous growth in trade recorded in the last 20 years consisted in relatively similar goods (manufactures) between relatively similar countries; moreover, this feature is robust to the level of disaggregation: no matter how finely industries are defined, a high proportion of trade takes place within industries rather than between them (Neary, 2009). In 2007, almost half of the world trade in merchandises, excluding oil, was attributed to intermediate goods. This proportion (relative to imported goods) raised to 68% for Malaysia and 61% for China.

These linkages have been taking more and more importance in what has been called the "new economy", characterised by a rapid pace of technological change, and a closer integration of capital, labour and product markets. Vertical integration helps firms to improve their efficiency and to be able to react more rapidly to changes in international market situations. However, the greater interconnection has also provided greater and faster channels of propagation of adverse external shocks. Because production is internationally diversified, adverse external shocks can affect firms not only through final demand (a sudden decline in exports), but also through a rupture in the flow of inputs received from their suppliers.

While the financial and macroeconomic channels of transmissions have received much attention, the role of industrial linkages as vectors of contagion remains to be thoroughly investigated. The disruptive potential of a failure in the international supply chain is becoming larger with time: trade in manufactures represented a quarter of the world industrial output in 2000, this proportion doubled in only five years. Almost 30% of this trade relates to the exchange of intermediate inputs and goods for processing, either traded between establishments pertaining to the same multinational enterprise, or exported to contracting parties for processing, then re-imported.

The objective of the paper is to focus on the real transmission channels of financial shocks. More precisely, it analyses how monetary restrictions, in particular a credit crunch initiating in a particular country and disrupting selected productive activities, can affect worldwide production processes and lead to self-sustained debt deflation. To do so, the paper develops a stock-flow approach of the short term sectoral dynamics, that builds on two concepts which have a long tradition that can be traced to the Physiocrats of the XVIIIth Century: the "Tableau Économique", or supply-use analysis, and the monetary circuit.

By combining the two concepts of international I-O analysis and monetary circuit, the paper will describe and model the sequence of financial and productive interactions along the international value chain. Because firms rely on suppliers in carrying out part of the production process (out-sourcing or off-shoring), and/or because they sell their production to other firms, the smooth realisation of production plans from initial investment to final sales depends on the availability of credit at all stages of the production chain. An initial exogenous monetary shock, for example when a bank shuts down an

existing line of credit will, therefore, replicate through the productive chain. Through this "real transmission channel", the initial financial shock will propagate itself along the productive chain, affecting all firms in the supply-chain network. Modelling how these supply-driven impulses propagate through open economies and feed-back into the monetary circuit are the main objectives of the paper. An application is made on the USA-Asian case, using international I-O matrices developed for China, Japan, Malaysia, Thailand and the USA. A section of conclusions presents the main findings and the shortcomings of the proposed methodology.

## II. THE CONCEPTUAL BUILDING BLOCKS: MONETARY CIRCUIT, INPUT-OUTPUT AND CREDIT TRANSITION

### 1) INTER-INDUSTRY VALUE CHAIN AND THE MONETARY CIRCUIT.

The methodology used in this essay builds on two concepts introduced by the Physiocrats – supply-use matrix and monetary circuit – to jointly model the interactions between "real" and "monetary" processes in an open economy. Physiocrats viewed money solely as a medium of exchange, a mere "signe représentatif" (token money) while the alternative approach favoured by Mercantilists considered money as exogenous, an asset (gold) available in fixed quantities. In the "entrepreneur" economy described by the Physiocrats, credits make deposits and money is a means, not an end. [2] Money circulates in the economy as a counterpart of the exchange of goods and services. The monetary counterpart of production begins with credit granted by the banks to the producers, and it ends when the goods that were produced are sold and the initial loan is reimbursed (money is "destroyed" at the end of the circuit).

After several years of relative neglect during the 1980s when the focus of macroeconomics was the control of inflation (exogenous money was central to monetarist policies), the contagion of financial crisis in the late 1990s and the present situation of financial crisis and debt deflation call for new responses. It is certainly not a coincidence if endogenous money is making a "come back" in the recent macro-economic literature, like the New Institutional Economics (Stiglitz and Greenwald, 2003) and the Post Keynesians (Godley and Lavoie, 2007).

From the practitioner's perspective which guides this essay, the monetary circuit and its close links to production are attractive features when analysing the actual functioning of a credit economy. Indeed, the concept of endogenous money is at the core of financial regulations such as minimum reserve requirements, which aim at controlling the capacity of banks to extend new loans. [3]

The basic concepts behind the monetary circuit are simple and closely match the economy's production process. This process is divided into a finite number of stages, so that the output of one stage constitutes the input of the next —with the final stage yielding consumable output. All firms depend on credit to finance the current production costs (wages, intermediate consumption and use of capital goods). The monetary model starts with a request for credit by a productive firm to a bank in order to start a production process, and ends when the loan is reimbursed. The "*temps du circuit*", the elapsed time between money creation and its destruction, is closely related with the production time.

Since the intermediate goods produced are not commodities, but are specific to the client's need, it is not easy —and it is certainly costly— to shift to another supplier. As a corollary, the failure of any single

[2] The concept of the circuit was used by the Physiocrats in their arguments against the Mercantilists on the choice between real wealth and pecuniary wealth (Bloomfield, 1938). It was also at the centre of the controversy between the Banking School, partisan of the endogenous or circuit approach, and the Currency School (exogenous money) in England during the XIXth century.

[3] Reserves are designed to satisfy withdrawal demands and affect the potential of the banking system to extend new loans (the money multiplier is equal to the inverse of the reserve ratio). Higher reserve requirements reduce credit-money creation.

supplier will affect the entire productive chain in the short and medium term. At best, as a result of this supply shock, the client-firm will suffer an increase in costs of production when shifting to an alternative supplier; at worse, it will have to stop its production. In times of crisis, the firms with a greater market power (and financial capacities) will help their key suppliers in resolving their cash-flow problems, even when it means worsening their own cash-flow situation (see Box 1 for a recent example on the automobile industry).

***Box 1: Financing suppliers in times of crisis: Automaker's aid.***

According to the Head of the European suppliers organization, CLEPA, it takes time to change one supplier for another. The changeover can take six months to a year, depending on how complicated the part is to produce and a customer has to protect the weaker supplier until a stronger one learns how to produce the inputs according to the automaker's requirements.
Thus, many automakers have undertaken specific actions to help the suppliers they want to protect from the credit crunch. According to the reference article, here is a sample of actions taken by some leading automakers to protect their key suppliers during the credit crunch:

- BMW: Encourage stronger suppliers to take over weaker ones; Pay in advance for parts; Speed up payments; Temporarily pay higher price for parts
- Ford: Give loans; Speed up payments
- Daimler: Temporarily pay higher price for parts; Provide advice on how to cut cost; Provide advice on how to improve efficiency
- Porsche: Help finance production tooling
- PSA: Speed up payments; Pay in advance for parts; Buy raw materials for them; Help them find financing; Advise on possible alliances, mergers
- Renault: Speed up payments
- VW group: Form special team in purchase department to prevent suppliers collapsing.

*Source:* Automotive News Europe
December 8, 2008.
http://www.autonews.com/apps/pbcs.dll/article?AID=/20081208/ANE03/812079905/1179

Because production and commercialisation take time and payments are not immediate, credit money is needed to start and oil the system.[4] Thus, a higher level of production implies a higher level of lending. For reasons that will be developed later, a higher level of lending implies a higher probability of default over the full business cycle. To avoid too strong an exposure to risk, regulators force banks to respect a series of minimum liquidity and asset-liability ratios. In this scheme, banks play a pivotal role and a sudden change in their supply of credit over the business cycle will affect the entire productive chain.

In a globalized productive network, the financial and productive establishments constituting this interlinked network need not be localised in the same country. As mentioned, the current centrifuge forces that characterise the geographical distribution of the productive activities mean that the individual links will be distributed among different countries, most probably at different levels of development, in order to capture the opportunities offered by the different relative costs of labour *vis-à-vis* the costs of capital. A corollary is that the participating economies may be at a different phase of their business cycle and that macro-economic risks also include an exposure to exchange rate fluctuation. In addition, the quality of the available information on the financial credentials of the

[4] In a modern industrial system, firms cannot finance investment and production costs on their accumulated assets (initial capital plus retained earnings) and have to borrow the funds. Actually, national accounts present the productive sector with net borrowing requirements. In the real world, funding comes from loans rather than issuing bonds or equities. Due to imperfect and asymmetric information, the Modigliani-Miller theorem does not hold and when firms are denied bank credit, they usually do not wish, nor are able, to raise capital by issuing new equity (Stiglitz and Greenwald, 2003. p34).

overseas suppliers and clients is lower than in the case of other domestic counterparts. Thus firms incurring in import or export operations will need to request special lines of credit (or guarantees) from the banking sector or specialised financial institutions in order to realise their international operations.

Considering that in average the time needed for production will be longer when international operations are involved, because of higher transaction costs (communication and transport, in particular), any productive network involving overseas operators will require more credit than a pure domestic one (see Table 1). Because business cycles and capital adequacy ratio may differ from country to country and will also fluctuate rather independently, the probability of facing credit rationing at any point of the productive chain is greatly increased.

*Table 1 Costs of exporting merchandises, 2007 or most recent survey period*

| Grouping or Region | Time for export (days) | Cost to export (US$ per container)[a] |
|---|---|---|
| World (country average) | 26.1 | 1,230 |
| East Asia & Pacific | 24.5 | 885 |
| Eastern Europe & Central Asia | 29.3 | 1,393 |
| Latin America & Caribbean | 22.2 | 1,108 |
| Middle East & North Africa | 24.8 | 992 |
| OECD | 9.8 | 905 |
| South Asia | 32.5 | 1,180 |
| Sub-Saharan Africa | 35.6 | 1,660 |

*Notes*: [a] Cost is recorded as the fees levied on a 20-foot container, excluding tariffs or trade taxes.
*Source*: World Bank Doing Business Project

Finally, the model relates mainly to the goods producing sector. Even if the services sector is also increasingly engaging into international operations and is spreading across different countries, the specificities of services (e.g., prevalence of wages in the cost structure, low technical coefficients and stock requirements, coincidence of production and consumption) imply that their credit requirement by unit of output is lower than in the more traditional manufacturing sector. But the international provision of transportation and business services is rising, and plays an increasing role in smoothing the operation of the production chain. Indirectly, the share of domestic services in the value added content of exports is also high in industrialized countries (Daudin et alii, 2006). Thus any adverse shock affecting a key service provider may also affect the productive chain.

### i) The basic monetary circuit

A canonical version of the monetary model starts with a request for credit by a firm to a bank in order to start a production process. In order to simplify the model, without modifying the reasoning, it will be assumed that all profits made by the firm are redistributed to owners, so that there is no retained earnings and that all the value added created in the production process goes back to households as wages or distributed profits. [5]

The bank's decision to grant the loan rests on (i) the macroeconomic perception of the systemic risk attached to the business cycle; (ii) a sectoral evaluation of the market prospects, (iii) a microeconomic component proper to its evaluation of the firm's capacity to manage properly the project and reimburse its debt, and (iv) the status of its capital adequacy ratio, reflecting its previous loan activity (a stock variable) in relation to capital requirements set by the prudential or regulatory authorities.

[5] In a complete model, value added is also used to pay taxes and finance reserves. The payment of interest to the banking sector is treated, under the system of national account (SNA2008) as intermediate consumption of services.

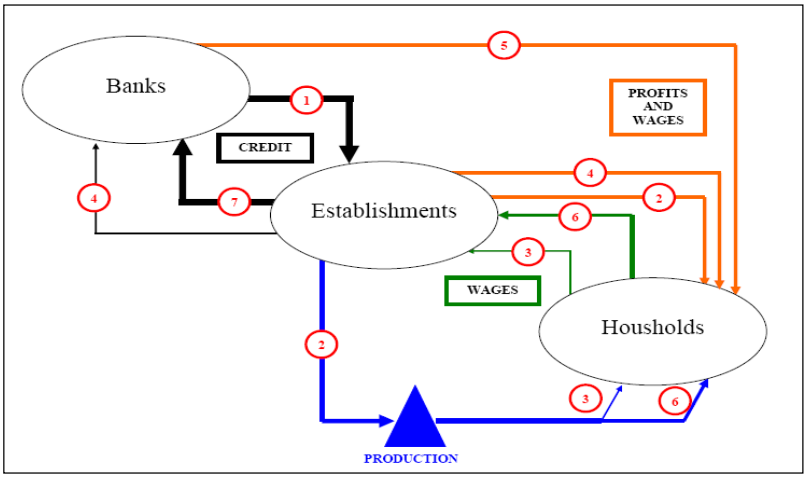
Using the borrowed money, the firm purchases inputs and pays workers to produce the merchandises. The goods produced are sold to consumers or to other firms (if the firm produces investment or intermediate goods). When the firm is paid, it uses the money resulting from the sale to repay its debt to the bank (plus interest rate), and its own suppliers if they had extended payment facilities. But we saw that at systemic level, the quasi-credit extended among productive establishment will eventually result in increasing the total amount of credit extended by the finance sector to the producers.

The repayment of outstanding loans not only "destroys money", but also allows the bank to extend new credit within the limit of the prudential loans/assets ratio. Since this is credit money, any money injected in the circuit is balanced by a debt obligation. The record of debt and its ratio with respect to the bank's assets (gold in the Physiocrats' perspective, or any asset considered as secure by the regulatory authorities in a contemporary context) is a key feature of our model. [6] As we will see, it acts as a bridge between flows and stocks, between real and monetary stocks, and between micro and macro effects.

Because the price of the asset is also linked to the macroeconomic conjuncture (business cycle), the regulatory process is pro-cyclical: in phases of boom, asset prices go up, increasing the lending capacity of banks; when the business cycle is downward oriented, asset prices go down and banks have to cut on their credits in order to respect the prudential ratio. [7]

In a dynamic perspective, the monetary circuit can be presented from a graphical and a tabular format as follows:

*Figure 1A schematic presentation of the monetary circuit*




*Note*: Arrows numbers correspond to the flows described in Table 2

[6] Keen (2007) presents a Monetary Accounting matrix with a similar distinction between assets and liabilities, albeit within a different framework.

[7] Under Basel II, banks determine the required capital of lending by applying the risk weight that correspond to the borrower's rating and then by multiplying the risk weight by the (usually 8%) minimum requirement of capital. Because risks and the market value of assets are strongly (and negatively) correlated, the position in the business cycle has a strong pro-cyclical effect on the banks' propensity to extend new loans. In practice, however, there are ways of circumventing the regulations through, *inter alia*, off-balance-sheet operations. Tenants of the pure endogenous money theory doubt about the actual binding effect of these requirements, and consider that banks which are willing to extend credit can always do it. Others maintain that Basel II is probably pro-cyclical (Repullo and Suarez, 2008). Accounting practices are also pro-cyclical (fair-value accounting, provisioning for expected losses on loans, etc.).

*Table 2* Simple monetary circuit in a closed economy

| Time | Capital Adequacy Ratio | Flow of Funds | | |
|---|---|---|---|---|
| | | Bank Account | Firm Account | Households |
| 0. Initial situation | A | 0 | 0 | 0 |
| 1. Credit | $A/\alpha L$ | 0 | L | 0 |
| 2. Production | $A/\alpha L$ | 0 | L-W | W |
| 3. First round of sales | $A/\alpha L$ | 0 | $L-W+Q_1$ | $W-Q_1$ |
| 4. Firm pays interest and distributes profit | $A/\alpha L$ | rL | $L+Q_1-W-rL-pQ$ | $W-Q_1+pQ$ |
| 5. Bank pays employees and distributes profits | $A/\alpha L$ | 0 | $L+Q_1-W-rL-pQ$ | $W-Q_1+pQ+rL$ |
| 6. Second round of sales | $A/\alpha L$ | 0 | L+Q-W-rL-pQ | W-Q+pQ+rL |
| 7. Firm repays loan | A | 0 | Q-W-rL-pQ | W-Q+pQ+rL |

*Notes:* A: initial assets of the bank,
L: Loan from the bank to the firm to finance the production costs,
$\alpha$: risk weight attached to the loan (credit rating)
W: wages needed to produce Q,
Q: value of merchandises produced by the project; $Q_1$ is the value sold during the first round (corresponding to wages paid by firms), $Q_2$ is the amount that is sold later after profits are distributed and employees from the financial sector are paid. There is no savings, all profits are distributed and $Q=Q_1+Q_2$
r: interest rate
p: rate of profit after wages and operating costs

The first column is simply a book entry that tracks the net asset situation of the banking system, because the bank does not actually loan money out of its capital. Each loan weighs on the adequacy ratio according to the risk attached to the loan. In turn, this risk, while specific to each firm (its own financial situation and that of its clients and key suppliers), depends also on the macroeconomic situation and the particular sensitiveness of the sector to downturns.

Credit money is created *ex nihilo* when a loan is granted to the firm and its account is credited with a sum (L) that the firm will be able to use in order to pay for the goods and services it needs. The system is sustainable as long as (i) the production plan pays its costs and remunerates the stakeholders (salaries and distributed profits), i.e (Q-W-rL-pQ) is positive or nil, and (ii) the banking system does not exceed its adequacy ratio.

Because all profit is distributed to households and all income is consumed, the last position (No. 7) is equivalent to the initial one (0), closing the circuit from a dynamic perspective. All credit money has been destroyed when the loan is repaid in full, and net flows sum up to zero. For money to be destroyed, all real transactions should take place as planned, i.e. there is no unsold final or intermediary goods. This characteristic of the monetary circuit provides an insight on an important property of the system: any stock of goods remaining in the "real" system (and reported as investment in national accounts) has a counterpart in outstanding credit money in the financial circuit.

Outstanding stocks can be voluntary, or "desired", when firms wish to smooth production and sales (i.e., to protect themselves from disruption in their production chain, or to be able to face a surge in demand). But stocks can be undesired when they correspond to major negative shocks or when production plans based on ex-ante previsions prove to be too optimistic when confronted with the ex-post situation. Any accumulation of stocks, either desired or undesired, must be financed out of retained profits or bank credit. In practice, because firms have a structural saving gap, any increase in their stocks (assimilated to gross investment in national accounts) will increase their net demand for credit.

### ii) The open monetary circuit

The previous part has introduced a very simple model, which grossly underestimates the complexity of the actual circuit. [8] In reality, a multiplicity of simultaneous production plans are in place and the closure of the system (the sale of the production) does not depend on the wages and profits distributed by the producer, but on a stream of activities going on in the rest of the economy. In the same way, firms are not homogeneous: some produce final goods, others investment or intermediate goods. As seen before, even within the same sector of activity, the productive process can be fragmented among various establishments. Indeed, banks themselves pay wages and distribute profits, consume goods and services produced by other firms or pay an interest rate on time deposits from household and firms. Therefore the productive and monetary circuit are longer, and the elapsed time between initial and final positions (the "*temps du circuit*") is increased. The longer the circuit, the larger the number of individual firms participating in the supply chain, the higher the probability of outstanding credit money.

When the economy is open, domestic production competes with imports, but it can also be exported. Additionally, domestic production of final goods may include imported intermediate inputs. This increases the complexity of the process, and the length of the circuit. As complexity increases, so does the probability of facing problems.

Disregarding any differences in exchange and interest rates, a very simplified circuit involving two firms and two countries (a firm in home country producing a final good, and its supplier located in a foreign country) would look as in Table 3.

When the system is open to the rest of the world, a series of complications arises. Part of the purchasing power created during the production process is distributed in the foreign country while the final goods are sold in the home country. If Q is not exported to the rest of the world and purchased by foreign households, then the quantity produced will be greater than the quantity sold ($Q > Q_1+Q_2$) even if there are no savings in the home country and all profits are distributed. Unless these final goods are exported and sold to the foreign households, undesired stocks of finished products ($Q - [Q_1+Q_2]$) will accumulate in the home country, associated to outstanding credit, while foreign households will accumulate savings for the amount of wages and profits created when processing the intermediate goods (Ww+rLw). Differently from the previous case (closed economy), the situation described by the final row is not identical to the initial one. In terms of national accounts, this appears as a trade deficit in the balance of payments of the home country (and a surplus for the rest of the world). [9]

The funds borrowed to finance production are used to purchase intermediate goods and services from other firms that may be located in different countries. In the same way, the production process depends on the capacity of the respective supplier firms to obtain credit from their own banks and deliver in time

[8] Godley and Lavoie (2007) offer a complete and detailed presentation of a complete stock-flow representation of the circuit. Albeit their approach is clearly build from a Post-Keynesian perspective regarding the capacity of banks to modulate their supply of credit, their description can be adapted to many other non-Walrasian theoretical settings, such as the loanable funds theory that competed with Keynesian theory since the 1930s or the Austrian school. Indeed, it is the flexibility of the monetary circuit in adapting to a number of theoretical settings that makes it very attractive from the practitioner's perspective.

[9] Opening the monetary circuit to cover balance of payments operations involve a series of complex interactions that are not treated in this very simple model. See Godley and Lavoie (2007) for an example.

Table 3 *Simple monetary circuit in an open economy*

| | Home Country | | | | Rest of the World | | | |
|---|---|---|---|---|---|---|---|---|
| Time index | Capital Adequacy Ratio | Bank Account | Firm Account | Households | Bank Capital Adequacy | Bank Account | Firm Account | Households |
| 0. Initial situation | $A^d$ | 0 | 0 | 0 | $A^w$ | 0 | 0 | 0 |
| 1. Credit production in home country | $A^d/\alpha^d . L^d$ | 0 | $L^d$ | 0 | $A^w$ | 0 | 0 | 0 |
| 2. Credit intermediate inputs in RofW | $A^d/\alpha^d(L^d)$ | 0 | $L^d$ | 0 | $A^w/\alpha^w.L^w$ | 0 | $L^w$ | 0 |
| 3. Production intermediate inputs M | $A^d/\alpha^d(L^d)$ | 0 | $L^d$ | 0 | $A^w/\alpha^w.L^w$ | 0 | $L^w–W^w$ | $W^w$ |
| 4. Import of inputs and production of Q | $A^d/\alpha^d(L^d)$ | 0 | $L^d - W^d -M$ | $W^d$ | $A^w/\alpha^w.L^w$ | 0 | $L^w+ M –W^w$ | $W^w$ |
| 5. First round: sales of Q1 | $A^d/\alpha^d(L^d)$ | 0 | $L^d +Q_1- W^d -M$ | $W^d –Q_1$ | $A^w/\alpha^w.L^w$ | 0 | $L^w+ M –W^w$ | $W^w$ |
| 6. Firms pay interest and distribute profit | $A^d/\alpha^d(L^d)$ | $rL^d$ | $L^d+Q_1- rL^d - W^d –M–pQ$ | $W^d +pQ–Q_1$ | $A^w/\alpha^w.L^w$ | $rL^w$ | $L^w+M–rL^w–W^w- pM$ | $W^w+pM$ |
| 7. Banks pay employees and distribute profits | $A^d/\alpha^d(L^d)$ | 0 | $L^d+Q_1– W^d – rL^d –M–pQ$ | $W^d +pQ+ rL^d –Q_1$ | $A^w/\alpha^w.L^w$ | 0 | $L_i^w+M–rL^w–W^w- pM$ | $W^w+pM+ rL^w$ |
| 8. Second round of sales (Q2) | $A^d/\alpha^d(L^d)$ | 0 | $L_f^d+Q– W^d – rL^d –M–pQ$ | $W^d +pQ+ rL^d –Q$ | $A^w/\alpha^w.L^w$ | 0 | $L^w+M–rL^w–W^w– pM$ | $W^w+pM+ rL^w$ |
| 9. Firms reimburse loans | $A^d$ | 0 | $Q_1 W^d – rL^d –M –pQ$ | $W^d +pQ+ rL^d –Q$ | $A^w$ | 0 | $M–rL^w–W^w– pM$ | $W^w+pM+ rL^w$ |

*Notes:* Same notations as Table 2 before, except:
$\alpha$: risk adjusted weights
Subscripts:
d: domestic; w: rest of the world.
M: intermediate goods produced in the rest of the world.

their intermediate inputs.

Because of the complexity and intricateness of the simultaneous production plans existing at any moment in an economy, there is always a large amount of outstanding credit money. Since this outstanding credit money has a counterpart in the capital adequacy ratio of banks, a limit may be reached (either because "too much" credit has already been extended –in relation to bank's assets– or because the underlying quality of the borrowing firms has deteriorated), constraining the supply of new loans and the renewal of existing lines of credit. In their most severe forms, the binding constraints may cause a "credit crunch".

The procyclical nature of prudential ratios is a central feature of the model, and the object of much debate. In many reports on the implications of minimum capital-requirements, the potential restrictions are often qualified by mentioning that most banks hold capital in excess of the regulatory minima or are able to circumvent the binding constraints. According to Repullo and Suarez (2008), this "benign neglect" of the potential procyclical effect is due to a series of misconceptions. Indeed, the global crisis of 2008/2009 showed that larger than expected market swings, with deteriorating balance-sheet quality, limit severely the access to equity and financial markets. As mentioned by Krugman (2008), in time of crisis, the core problem is capital rather than liquidity.

Since international transactions are more complex and riskier than domestic ones (because of the exchange rate risks), they may weigh more in the Capital Adequacy Ratio of banks, and will require additional guaranties such as separate trade credit or insurance to cover the transaction with the foreign country. It is also well known that international transactions may add very significant costs to the chain of supply (tariffs, but also administrative and waiting time, shipping, freight and insurance, etc.). The additional cost can be very high when the supplier is located in a developing country, as seen previously in Table 1. As a consequence, trade-related loans (e.g, import and export credits), especially for transactions with developing countries, are particularly affected by credit crunch. The probability of an exogenous credit shock on these transactions (loan $L^w$ in Table 3) is therefore higher in times of crisis. [10]

### iii) Incorporating credit rating in the monetary circuit

The rating of a firm can take several values, for example from AAA to CCC and Default. Banks extend credit according to these ratings and to the situation of their prudential ratios. When a firm is downgraded, it affects its capacity to obtain new credit, reducing the creation of credit money in the circuit. But rating migration affects also the systemic variable represented by the capital adequacy constraint. The riskier the loan ($L_i$), the heavier its weight ($\alpha_i$) on the prudential ratio $[A/\Sigma(\alpha_i L_i)]$. For example, the weight is 0.2 for loans to firms rated AAA to AA, 0.5 from A+ to A-, 1.0 from BBB+ to BB-.

By deteriorating both the ratings of firms and the quality of the loan portfolio detained by the banks, supply shocks equally affect financial stocks and flows. Real shocks affecting the production chain will initially change the ratings of all the firms belonging to the network, reducing the probability of having their loan requests accepted, or their existing loans renewed. In addition, the downgrading of some of the existing loans will reduce the profitability of the bank, because it must increase its asset holdings and provision for losses. It may eventually upset the overall capacity of banks to extend new credit, irrespective of the individual credit rating of the requesting firms, when banks are operating close to their "credit capacity" as it must be expected under normal conditions of profit maximization. This will in turn reverberate into an additional credit shock, and so on and so forth. An initial exogenous monetary shock (e.g., when a bank unexpectedly shuts down an existing line of credit) will, therefore, replicate endogenously through the productive chain.

[10] The Institute for International Finance was forecasting a 50% reduction in capital flows to emerging markets in 2009.

This dynamic is also embedded in the methodology used by rating agencies. The credit rating of individual firms and their migration to higher or lower status are based on a combination of (i) micro-economic considerations, directly related to the financial situation of the firm and the quality of its management; (ii) sectoral specificities, such as the cyclical nature of the business in which the firm operates; and (iii) macro-economic considerations, such as the probability of expansion or recession.

Because these components are not independent, there is a resonance phenomenon. Small micro-shocks reverberate through the macro-waves and amplify them. When the business cycle is upward oriented, the price of assets is increasing, improving the prudential ratio $[A/\Sigma(\alpha_i L_i)]$, while firms and banks have a lower rate of underperforming clients. Thus both micro and macro components lower the perception of risk affecting firms (independently of their individual situation). This state of affairs pushes the banks to extend further loans, creating a positive environment (Krugman, 2008).

On the contrary, when the business cycle is downward oriented, asset prices detained by banks (when priced to market) tend to decrease and the perception of risks increases, resulting in a downward migration of credit rating. As a consequence, banks are increasingly adverse to risk, and less likely to extend credit for similar projects. The resulting effect on the credit rating of these micro-decisions can lead to a credit crunch and even to a recession.

## 2) PRODUCTIVE CHAINS, NATIONAL ACCOUNTS AND INTERNATIONAL INPUT-OUTPUT MATRIX

On the supply side, firms produce intermediate goods and final goods that are sold domestically or exported; on the demand side they use intermediate inputs (either domestic or imported) including financial and non-financial services and generate value added which is used to compensate employees, pay taxes and generate (distributed and retained) profits. In actual terms, production involves a continuum of individual projects that are closely interrelated and take place in different countries.

The System of National Accounts allows us to describe and model these supply-demand interrelations. As seen earlier, the interdependence is not only real, but also financial and the flows of goods and services captured by the productive accounts have their counterpart in the monetary circuit.

### i) The basic circuit of goods and services

In a simple two-sector economy, the real flows of goods and services (including factorial services, i.e, labour and capital) are as follows:

*Table 4 Flows of goods and services in a simple two-sector economy*

| Sectors | Intermediate demand 1 | Intermediate demand 2 | Final demand | Exports | Total output |
|---|---|---|---|---|---|
| Sector 1 | $Q_{11}$ | $Q_{12}$ | $F_1$ | $X_1$ | $Q_1$ |
| Sector 2 | $Q_{21}$ | $Q_{22}$ | $F_2$ | $X_2$ | $Q_2$ |
| Imports | $M_1$ | $M_2$ | $M_f$ | | |
| Value Added | $VA_1$ | $VA_2$ | | | |
| Total inputs | $Q_1$ | $Q_2$ | | | |

*Notes:* $Q_{ij}$: intermediate consumption of products from sector i by j; $F_i$: final demand for products produced by i = 1,2 or imported from rest of the world ("RoW"); $X_i$: exports of i to "RoW"
$M_i$: imports of intermediate goods used by i from "RoW"; $Q_i$: total production of i
$VA_i$: value added (factorial services, corresponding to wages and profits)

The horizontal lines show the use of goods and services to supply other firms, final consumers and rest

of the world (exports). The vertical columns describe the requirements by sector j: purchases from domestic and rest of the world suppliers needed to produce the goods, remuneration of factors of productions (capital and labour, equal to the generation of value added). Following the recommendations of the SNA2008, the payment of financial services is considered as an intermediate consumption.

Inter-sectoral relationships are represented by the coefficients $Q_{ij}$. The technical coefficients conforming the input-output matrix (I-O) are derived by normalizing the intermediate coefficients $Q_{ij}$ by the value of total production ($a_{ij}= Q_{ij}/Q_i$). These I-O coefficients present the direct requirements of inputs from "i" for producing one unit of output of industry "j". For example, to produce one unit of output, sector 2 will require $a_{12}$ units from sector 1.

The technical coefficients tell only part of the story of the productive chain. In order to be able to produce the $a_{12}$ units demanded by sector 2, the productive sector 1 will need inputs from sector 2 ($a_{21}.a_{12}$ units). To satisfy the demand created by one additional unit of output in sector 2, individual firms in each sector 1 and 2 will also require inputs produced by suppliers operating from the same sector ($a_{22}$ and $a_{22}.a_{12}$). And so on, as the indirect demands generated at every step create in turn additional requirements.

It can be shown that the feed-back sequence resulting from the initial demand injection can be obtained by the series $I + A + A^2 + A^3 + \ldots + A^n$

Where:
I is an identity matrix representing the initial demand injection and A is the input-output matrix.
$A^n$ is the progressive impact of initial demands at the $n^{th}$ stage of the production chain.

When n tends towards infinity, the series has a limit (known as Leontief Inverse Matrix) $L=(I-A)^{-1}$
The coefficients $l_{ij}$ of the Leontief Inverse measure the depth (intensity) of the backward linkages between sectors. They describe entirely the direct and indirect flows of intermediate products involved by the productive chains.

### ii) The open circuit of goods and services

In an open economy where firms are vertically integrated, firms can import their intermediate inputs from external suppliers or sell goods for processing to other non-resident industries. International I-O matrices extend the description of inter-sectoral linkages by disaggregating imports and exports between intermediate and final goods, identifying for intermediate goods their countries and sectors of origin/destination.

A two-country two-sector model would look like Table 5.

*Table 5* Flows of goods and services in a two-country two-sector model.

| Sectors/country | Country a Intermediate demand 1 | Country a Intermediate demand 2 | Country b Intermediate demand 1 | Country b Intermediate demand 2 | Final demand (a+b) | Exports to Rest of the World | Total output |
|---|---|---|---|---|---|---|---|
| Country a Sector 1 | $Q^{aa}_{11}$ | $Q^{aa}_{12}$ | $Q^{ab}_{11}$ | $Q^{ab}_{12}$ | $F^{a}_{1}$ | $X^{a}_{1}$ | $Q^{a}_{1}$ |
| Country a Sector 2 | $Q^{aa}_{21}$ | $Q^{aa}_{22}$ | $Q^{ab}_{21}$ | $Q^{ab}_{22}$ | $F^{a}_{2}$ | $X^{a}_{2}$ | $Q^{a}_{2}$ |
| Country b Sector 1 | $Q^{ba}_{11}$ | $Q^{ba}_{12}$ | $Q^{bb}_{11}$ | $Q^{bb}_{12}$ | $F^{b}_{1}$ | $X^{b}_{1}$ | $Q^{b}_{1}$ |
| Country b Sector 2 | $Q^{ba}_{21}$ | $Q^{ba}_{22}$ | $Q^{bb}_{21}$ | $Q^{bb}_{22}$ | $F^{b}_{2}$ | $X^{b}_{2}$ | $Q^{b}_{2}$ |
| Imports from R. of World | $M^{a}_{1}$ | $M^{a}_{2}$ | $M^{b}_{1}$ | $M^{b}_{2}$ | $M_{f}$ | | |
| Value Added | $VA^{a}_{1}$ | $VA^{a}_{2}$ | $VA^{b}_{1}$ | $VA^{b}_{2}$ | | | |
| Total inputs | $Q^{a}_{1}$ | $Q^{a}_{2}$ | $Q^{b}_{1}$ | $Q^{b}_{2}$ | | | |

*Notes:* See Table 4

These international I-O matrices can be used to measure vertical integration of production processes. For example, Hummels, Ishii and Yi (2001) proposes a VS index based on the imported content of exports (VS= M.L.X). When based on the Leontief-Inverse, these measures imply that all linkages take place in the same time (or that all the transactions take place within the unit of time chosen to measure M and X, usually a year). Inomata (2008) corrects for this short-coming and derives from international I-O tables a new measurement for international fragmentation of the production process that takes also into consideration the depth of vertical integration (the average propagation length of inter-industry linkages).

International I-O matrices such as the ones described in Table 5 provide a complete picture of the intensity of both macro-economic and inter-industry linkages across borders that sustain the open monetary circuit presented in Table 3. While business circles affect cross-border activity through changes in final demand (domestic and exports), the modelling of inter-sectoral linkage through I-O matrices allows to complete the picture and simulate the propagation of shocks in demand through the vertical integration of production processes.

### iii) Measuring the transmitted impact

The international I-O matrices allow to model the real transmission channels of a financial shock occurring at any stage of the value chain, when this shock breaks the inter-industry linkages that translate final consumption into a network of intermediate demands. Leontief models are demand-driven and simulate the transmission of demand shocks through backward linkages; to simulate supply-driven shocks through forward linkages, I-O matrices have to be adapted into what is known as "Ghosh" matrix (see Box 2)

The "real channel impact" from country “a” to country “b” will therefore be proportional to (i) the final demand of exported consumer goods and services to "a", and (ii) the sum of Ghosh-Inverse coefficients linking industries from both countries. The second part, which measures the real impact through the supply chain, is larger than a simple measure based on the value of imported intermediate goods from "a", because the Ghosh-Inverse considers both direct and indirect impacts.

Ignoring final demand effects (the usual "Leontief approach" based on backward linkages), the intensity of inter-country transmission of financial shocks following a credit crunch affecting the productive

sectors will differ according to the degree of vertical integration, as measured by the strength and depth of forward industrial linkages. Ignoring also quantitative disruption effects that would prevail when no substitution among inputs is possible, the imported real supply-driven impact coefficient (IRSIC) is proportional to the imported content of domestic production.

$$IRSIC = \%\Delta P/P = \Delta Q.(I-B)^{-1} \bullet 1/Q \qquad [1]$$

Q: line vector of initial sectoral output
ΔQ: line vector of supply shocks
$\Delta P/P$ : vector of price shocks in percentage
$(I-B)^{-1}$: Ghosh matrix
● : Hadomard product [11]

It should be clear that, because of the inherent limitations of the Ghosh matrices, only one type of supply-driven shocks will be captured at macroeconomic level: shocks which are translated into an increase in production prices. The model simulates only non-disruptive supply shocks initiating from the default of a supplier; client firms are always able to find a substitute supplier instantly, but at a higher cost. The price shock hypothesis is obviously well-suited for segmented markets, with monopolistic characteristics, but is also compatible with standard neoclassical hypotheses, as long as marginal costs are increasing in the short term.

The additional production cost is related to the elasticity of technical substitution in production, including elasticity of substitution between domestic and imported inputs (Armington elasticity). [12] When Armington elasticities are low, large price changes are required to accommodate small changes in quantities. This is typically the case when manufactured intermediate inputs are differentiated and client-specific, at the difference of commodities like oil and minerals. Substitution is difficult and takes time in the long run; in the short-run framework of this essay, it takes money.

The Ghosh multipliers simulate the transmission of the higher production costs caused by the initial shock through the entire supply chain. By factoring-in the direct and indirect cost effects, it provides the analyst with an adequate "tracking methodology".

Dealing only with price effects may be seen as a limitation. Severe shocks that translate into critical disruption of the supply chain, creating bottlenecks and a decline in the volume of production, are excluded. Even a moderate negative supply shock, but close enough to the initial demand impulse (final demand), may impede the normal implementation of the initial production project if the producer cannot easily redeploy their demand for intermediate goods to other suppliers. [13]

Nevertheless, in open economies with large numbers of suppliers, systemic disruptive shocks are not common, except perhaps when the supply restriction affects strategic commodities like oil. In addition, it should be noted that the distance of the supply-shock to the final demand is taken into account, because the Ghosh matrix ponders the suite of technical coefficients according to the proximity of each round to the initial demand. The closer the shock, the larger the impact. [14] It is even possible to model secondary demand-driven shocks using a similar approach (see Annex II).

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[11] This entrywise product ($a_1.b_1$, $a_2.b_2$, ..., $a_n.b_n$) is similar to a Kronecker product on two matrices or vectors of same dimensions.

[12] While Input-Output models suppose perfect inter-sectoral complementarities of inputs (zero technical substitution), they do not restrain intra-sectoral substitution between domestic and foreign inputs. The estimate of these elasticities, in particular through the Armington specification, plays a central role in the flourishing CGE literature.

[13] It takes at least a year to redeploy the production of critical parts in the automotive industry, according to Automotive News Europe (see Box 1 again).

[14] Because technical coefficients are normalized and less than unity, $A^n$ (the impact of initial demands at the $n^{th}$ stage of the production chain) rapidly tends to 0 when n increases.

***Box 2. Demand-Driven and Supply-Driven Input-Output Models***

The well-known "demand-driven" model was developed by Wassily Leontief in the 1930s; two decades later, Ambica Ghosh adapted the I-O model to analyse supply shocks. I-O models assume that all inputs are complementary (the production function is such that inputs should be used in a fixed proportion, with no substitution at least in the short time), and the demand impulses are transmitted primarily through backward linkages. When the final demand for a product "q" is altered exogenously, the primary impact is felt on the demand for those sectoral outputs and commodities that are used as inputs for the production of the product "q". The backward linkages trigger a series of secondary demand effects that progressively die down and are captured by the Leontief-inverse matrix $(I-A)^{-1}$.

The Ghosh approach states that each intermediate output is sold to a series of productive sectors in fixed proportions. When the production of an intermediate product "q" is exogenously altered, the primary effect is felt by those sectors that need "q" as input. This will trigger forward effects, either direct (to the sectors requiring "q" as input for their production) or secondary (sectors depending on intermediate goods that had required "q" as input). As in the Leontief case, the iterative process dies down to reach another equilibrium.

The accumulation of impacts can be measured by the Ghosh inverse $(I-B)^{-1}$. As in the Leontief case, the matrix B is build using the inter-sectoral transaction matrix $Q_{ij}$, but the allocation coefficients are normalized in line (destination of output) by the value of production, and not in column as for technical coefficients (origin of productive factors used in the production).

The Leontief logic for backward linkage is based on standard economics: sectors do respond to changes in demand, they increase their production when demand is higher and reduce it when demand is lower. The Ghoshian approach is much weaker, and its theoretical aspects are somewhat contentious. In absence of a change in effective demand, pushing-up production through additional supply of inputs would have the same effect as pushing on a string. Indeed, the theoretical reservations about the Ghosh model led to its relative demise as a macroeconomic modelling tool in the quantity space.

Nevertheless, the Ghosh approach is still useful in the price space, considering that it can be used to model the transmission of shocks to the costs of production (Mesnard, 2007). It is particularly true for short-term analysis, when firms have limited capacity for substituting the disrupted input by shifting to alternative and more expensive suppliers. The mechanism is as follows: a quantity restriction on any single intermediate good forces the client-firm to shift to other suppliers (foreign or domestic). While this is always possible in our model, it has a cost, as alternative suppliers will supply the needed quantities at a higher price.

The final impact on production costs depends on a conjunction of quantitative and qualitative factors. The quantitative factor is proportional to the contribution of the disrupted input in the production function and is captured by the allocation coefficients of the I-O matrix. The qualitative factor is microeconomic in nature, and is determined by the particular market structure for this product, in particular by the possibility of substitution. The supply elasticity is usually determined by the time frame allowed for substitution, by the spare production capacity available to alternative suppliers and their level of stocks, and by their technical capabilities (including the ownership of critical patents). The stronger the constraint (for example when the initial supplier had a *de facto* monopoly), the higher the potential rise in production cost. At the limit, when no substitution exists, then all the adjustments along the supply chain have to be done in the quantity space, proportionally to the bottleneck.

The elasticity of substitution between similar inputs, from various countries of origin are known as Armington elasticities. Estimating these elasticities has generated an abundant literature, especially in areas linked with international trade literature and computable general-equilibrium models, A review of existing results show that the elasticities (estimated using multilateral trade data) for the intermediate inputs industries tend to be higher than those for the final consumption goods industries (Saito, 2004).

In practice, one should expect a mixture of price and quantity effects, as demand for higher priced products —intermediate input or the resulting final good— will go down. The modelling of the sectoral reactions to changes in relative input prices and the related structural interactions would ideally have to be realized using computable general-equilibrium models.

## 3) CREDIT CONTAGION AND THE FEED BACK FROM REAL TO FINANCIAL CHANNELS.

The previous two sections presented, from a monetary perspective and a supply-chain perspective, the linkages that exist within and between globalized industrial systems. The following section will formalise the connections between both financial and real circuits, through the modelling of the "$\alpha$" parameter in the Capital Adequacy Ratio that appears originally as a simple accounting device in the monetary circuit (see Table 2 and Table 3). This institutional ratio constrains the total amount of credit that a bank may issue. As mentioned, international standards, issued by the Bank for International Settlements (BIS), set a 8% threshold for total risk-weighted assets.

### i) Banks' assessment of business risks: Unifying the two circuits

We saw that the monetary circuit starts with a request for credit by a firm to a bank in order to finance a production process. The bank decisions of granting the loan is based on a mix of (i) macroeconomic perception, (ii) the sector of activity of the firm, (iii) a microeconomic component proper to the firm and (iv) the institutional capacity of the bank to extend new credit within the limit of its ratio loans/assets. These components are not independent; as we shall see, they are closely interrelated.

The microeconomic component of the bank's decision-making process is based, *inter alia*, on the direct business connections of the firm requesting a loan. In a vertically integrated production chain, the default of a client can cause distress to its suppliers, and the difficulties of a key supplier can jeopardise the viability of a production plan. Some industrial sectors (like construction or automobiles) are more "pro-cyclical" than others. According to the strength of its backward and forward linkage, the credit worthiness of a pro-cyclical firm will reflect, through the microeconomic channel, on its direct clients and suppliers, even when they do not operate in the same sector.

Also, because risks and the market value of assets are strongly (and negatively) related, the position in the business cycle has a greatly inflated pro-cyclical effect on the banks' propensity to extend new loans. Indeed, when a downward phase develops into a recession, the price of assets may drop below a critical value, forcing banks to stop any new credit activity, cancelling existing credit arrangements to reduce risk exposure irrespective of the merit of investment projects and firms credit worthiness. This situation defines what is called a "credit crunch". Obviously, when a firm's request for credit is turned down and it must scale down production, it affects in turn its suppliers and even its clients through the supply chain, and affects final demand through lower household income (wages and profits).

For the most vulnerable sectors, that are both cyclical and vertically integrated, the conjunction of two waves of shocks, supply and demand driven, can lead to a resonance effect. The total effect of the shock is then a multiple of each component taken in isolation. Second, according to the monetary circuit described in Table 3, the shock will affect both flows variables (additional demand for credit money to cope with the shock) and stock or state variables (the credit rating of individual firms requesting additional loans, and the capital adequacy ratio of the banks extending loans). Thus, in a recessive cycle, the conjunction of real supply and demand shock, on the one hand, and of stock-flow financial shocks, on the other hand, may have large systemic effects, even when the initial shocks are rather limited in scope.

Thus, even if initially a financial shock is exogenous, its effects on the industrial chain will cause this shock to reverberate through the real circuit, affecting in turn the monetary circuit through the default risks, as perceived by the financial sector. The size of the multiplier effect depends on the initial balance sheets of the financial intermediaries. Actually, modelling the weights "$\alpha_i$" (the financial rating of productive sectors) in the Capital Adequacy Ratio ($A/\Sigma L_i\alpha_i$) synthesizes most of the real-monetary dynamics embedded in the present approach, including stock-flow interactions:

- From a "flow" perspective, the "$\alpha_i$" are the result of a credit rating process that considers both

financial and productive aspects, associated with (i) the firm itself and its management (what we called the microeconomic dimension), (ii) its mode of insertion in the productive economy and the related risks of supply-driven shocks transmitted through the supply-chain and (iii) its exposure to the macroeconomic business cycle, as captured by the demand-driven shocks.

- From a "stock" perspective, the real shocks translate into the accumulation of undesired stocks and extend the life expectancy of credit money, with the related accumulation of liquidity, because loans are not reimbursed in full. [15] Not only money is not destroyed as expected, but on the financial side, the accumulation of bad debts deteriorates the banks' balance sheet (loss provisions) and its Capital Adequacy Ratio ($A/\Sigma L_i\alpha_i$).

The "stock" effect on the Capital Adequacy Ratio is not limited to the domestic sector. In a globalized economy such as described in our model, the national financial sectors are also closely integrated and all economies now share "leveraged common creditors". In such a context, balance sheet contagion become pervasive (Krugman, 2008).

## 4) A REDUCED-FORM INDICATOR OF CONTAGION

The previous sections identified the three conceptual building blocks used to define contagion of financial shocks through the productive chain: monetary circuit, international input-output matrices and credit transition. Those three components show a high degree of cross-causality, as we saw. Because our main objective is not to build a complete stock-flow model but to simulate the contagion of a shock initiating in the monetary sphere, a simplifying option is chosen. It starts from an hypothetical steady state in which all stocks and all flows are held constant, and explores what would happen if the credit required by a production programme is not granted for an exogenous reason (such as a "credit crunch", typical of the 2008/2009 international conjuncture).

The chain of causalities is as follows:

(a) The shock initiates in the monetary circuit (e.g., an existing line of credit is unexpectedly shut down), and it affects the production plans of a firm that is inserted at some point in a larger productive chain; because both its clients and suppliers cannot shift to other producers immediately and at no cost, the discontinuity in the production flow will reverberate through higher costs across the system represented by the I-O matrix. The real shock, once it has fully reverberated through the entire supply chains, is proportional to the Ghosh coefficients that factor-in the sum of direct and indirect forward effects.

(b) Exogenous supply shocks also affect demand because increases in production costs reflect into higher prices and lower demand. As previously mentioned, the resulting negative demand-driven secondary shocks can be modelled individually using traditional Leontief model (final demand impulses), or by capturing the backward (demand) sectoral effects of supply-driven multipliers (Papadas and Dahl, 1999). Annex 2 explores the relationship between the initial supply impulse and the secondary demand shocks.

(c) The real shock, then, feeds back into the monetary circuit through (i) the building-up of undesired stocks of finished and intermediate goods through the supply chain, leading to the accumulation of outstanding credit-money in the circuit; and (ii) the contagion of financial risks affecting the rating of firms. Because the capacity of banks to create new money is limited by their capital adequacy ratio, the latter reduces in turn the capacity of banks to extend new credit, initiating a vicious circle. This obviously affects the most vulnerable firms (those more closely connected to the sector of activity affected by the initial shock), but has a systemic impact that reduces the banks' systemic capacity to extend new credit, regardless of the individual merits of the investment programmes. [16]

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[15] As mentioned, the core problem in the present 2008/2009 financial crisis is capital, not liquidity.

[16] When the adequacy ratio is reaching a critical limit, the banking sector turns down most requests and flight for safety by investing in good quality government bonds, especially US bonds. The flight for quality that

In conclusion, a reduced model of contagion through the supply chain only requires two variables to simulate and track the systemic implications of an exogenous financial shock: one variable of flow (IRSIC constructed on the real circuit, possibly augmented for secondary demand driven effects) and one of stock (Capital Adequacy Ratio) derived from the monetary circuit. Because the stock-variable is partially dependent on the flow-variable, the strategic variable to be measured in order to evaluate the risk of contagion is the imported real impact coefficient (IRSIC).

## III. APPLICATION TO THE US-ASIA COMPACT

International I-O matrices are necessary to measure IRSIC. Building these tables from national I-O data is a painstaking exercise, requiring the harmonization of national formats and classifications, the inclusion additional information such as disaggregating imports into sectoral intermediates and final goods and, finally, the compilation of all national tables into a single I-O matrix. We build our case study on a series of interlinked economies, China, Japan, Malaysia, Thailand and the USA, which are all key international and regional traders at different stages of industrial development and with strong specificities in terms of their insertion in the global economy.

### 1) THE DATA

We use a sub-set of the Asian I-O tables developed by the JETRO's Institute for Developing Economies. [17] The original Asian I-O tables are available for year 2000 in US$, and are disaggregated into 76 sectors of activity. [18] To facilitate data manipulation, the table was rearranged to include only 10 sectors of particular interest for our purpose: Agriculture (IDE's sectors 001 to 007), Mining (008 to 011), Textile, apparel and leather products (018 to 023), electronic products (049 to 054), transport equipment (055 to 058), other manufactures (012 to 017, 025 to 048, 059 and 060), basic services (electricity, gas and water: 061 and 062), construction (063 and 064), trade and transport (065 and 066), and services (067 to 076).

Inter-industrial flows based on year 2000 are nevertheless inadequate to analyze the present state of interdependence between those economies, considering in particular that China joined the WTO only in 2001. Using the estimations produced by Pula and Peltonen (2009), we derive an input coefficient matrix from the 2000 table, by incorporating updated information on multilateral trade and national accounts aggregates in current US$ for 2006 (see annex 1).

The content of imported inputs in sectoral output can be obtained for each country by adding, for each domestic sector, the imports from the other four partners in the international I-O matrix, plus the total imports from the rest of the world (Table 6). Because inputs purchased from another domestic sector also include imported goods, the best estimate is given by panel b of Table 6, which includes the direct and indirect imports [19]. A first review of the data shows that sectors differ with respect to their openness and reliance on imports. Manufactures are more reliant on imported inputs, the maximum being reached by the electronic sector in which more than 60% of raw products and intermediate goods needed for sectoral production in Malaysia and Thailand are imported.

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followed the 2008 subprime crisis and the subsequent melting down of the international banking system illustrate this point and explain why the dollar appreciated despite the fact that the US economy was at the core of the crisis.

[17] See IDE-JETRO (2006) for details on the I-O coverage and the statistical treatments.

[18] IDE-Jetro, updating the Asian tables to year 2006.

[19] By multiplying the line vector of import-weights by the Leontief-Inverse, it is also possible to compute the imported content of final production, after factoring all inter-sectoral backward effects corresponding to the supply chain.

*Table 6 Direct and indirect shares of imported inputs in sectoral production, 2006 (percent)*

| | Direct share of imported inputs in total output | Agriculture | Mining | Textile | Electronics | Transport Equipment | Other Manufactures | Electricity Water Gas | Construction | Trade Transport | Other Services |
|---|---|---|---|---|---|---|---|---|---|---|---|
| a. Direct share of imported inputs in sectoral output [a] | | | | | | | | | | | |
| China | 5.0 | 6.5 | 7.1 | 11.4 | 6.6 | 7.3 | 6.5 | 6.0 | 4.9 | 6.5 | |
| Japan | 11.9 | 3.0 | 9.1 | 9.1 | 4.5 | 9.7 | 10.6 | 8.1 | 4.0 | 3.1 | |
| USA | 5.5 | 6.7 | 8.1 | 12.2 | 10.4 | 7.9 | 6.5 | 3.9 | 2.8 | 3.1 | |
| Malaysia | 20.3 | 19.1 | 31.1 | 54.4 | 29.5 | 26.2 | 18.1 | 24.2 | 19.4 | 19.9 | |
| Thailand | 7.5 | 20.2 | 14.0 | 64.1 | 41.9 | 27.7 | 18.8 | 22.3 | 5.3 | 19.4 | |
| b. Direct and indirect share of imported inputs in sectoral output [b] | | | | | | | | | | | |
| Chine | 16.1 | 19.4 | 20.3 | 26.0 | 20.9 | 20.5 | 19.9 | 20.1 | 16.9 | 19.6 | |
| Japon | 17.0 | 9.3 | 16.6 | 17.4 | 14.2 | 17.2 | 15.0 | 14.6 | 6.9 | 6.2 | |
| Etats-Unis | 9.9 | 10.0 | 13.9 | 16.9 | 16.8 | 13.0 | 10.4 | 9.0 | 5.5 | 5.8 | |
| Malaisie | 34.0 | 27.9 | 48.0 | 62.3 | 43.9 | 42.3 | 30.1 | 40.7 | 29.8 | 31.3 | |
| Thaïlande | 17.4 | 30.9 | 30.5 | 68.3 | 53.8 | 38.9 | 30.3 | 34.2 | 16.0 | 30.2 | |

*Notes* a/ Imports of intermediate goods of the branch, relative to the value of total output, including factorial services (capital and labour), based on the estimated input-output matrix in current US$; b/ direct and indirect content of imported inputs, based on the estimated Leontief-inverse matrix.
*Source:* authors' calculation, based on IDE-Jetro data and Pula and Peltonen (2009)

These indicators of direct and indirect import contents are closely related to the vertical specialization indices presented in Hummels, Ishii et Mu Yi (2001). [20] Assuming homogeneity of final production for domestic market and for export, Table 6 provides information on the import content of sectoral exports (or, conversely, on the domestic value added content of exports). Based on a simple average of sectoral values, Malaysian and Thai exports are the most intensive in imports (39% and 35%, respectively), followed by China (20%). Conversely, the developed economies of Japan and the USA are relatively closed (13% and 11%); in other words, the domestic value added content of exports represented in average respectively 87% and 89% of the value of the Japanese and US sectoral exports in 2006.

2) SECTORAL IMPACTS

Supply shocks occurring in the regional sourcing network, like those which would result from a sudden disruption of trade due to lack of trade finance, are modelled as price shocks emanating from one of the five economies linked in the international I-O matrix. An arbitrary value of 30% will be used for all sectors. [21]

In our simulation, all four manufacturing sectors (textile and clothing, electronic products, transport equipment, and other manufactures) are shocked. The simulation computes the domestic impacts and its transmission to the other regional partners through the imported real impact coefficient (IRSIC) as described page 14. As IRSIC uses the inverse-Ghosh matrix, the sectoral impacts include primary and secondary effects (i.e., the real transmission channel follow both direct and indirect forward linkages).

[20] See Inomata (2008) for a discussion and extension of measurements of international fragmentation.

[21] This conservative option may underestimate the price impact of a supply shock for developed countries, as it is more probable that the alternate suppliers will have to be found in the domestic market, for a relatively much higher cost (see Annex A2 for alternative parameters).

As seen in Table 7, the largest secondary impacts are felt domestically. The relative effect of the shock on the domestic economy depends on its degree of openness, and also on the relative size of the originating sector in relation to the rest of the economy. Thus, despite their relative inward-oriented economies, a supply shock originating from the Japanese and American manufacturing sectors has a relatively lower impact because Japan and the US are mostly services-oriented economies. On the contrary, Malaysia and Thailand are less exposed to a domestic shock because of their openness and reliance on imported inputs.

Table 8 presents a summary of the results obtained for shocks initiating from the manufacturing sectors, which are more integrated in international supply chains. Imported and exported supply shocks are expressed as a weighted average of the national increase in sectoral production costs resulting from an initial 30% price shock on the manufacturing sectors. Based on the existing inter and intra-industrial linkages, in 2000 and 2006, Japan is potentially the largest exporter of supply shocks (1.6% and 1.4%, respectively). Malaysia and Thailand, on the other hand, are the largest importers of such shocks, because of the high degree of integration of their manufacturing sectors and reliance on imported inputs from the other partners.

The other outstanding results relate to China, with a notable increase in both forward international linkages and domestic backward linkages. First, China's influence as an exporter of "shocks" (i.e., a supplier of intermediate goods to the other economies via the supply chain) between 2000 and 2006 has increased (in 2006, China shares the highest influence with Japan), while its vulnerability to an imported shock remained relatively stable. Second, the large increase in the overall feed-back impact of its domestic sector itself shows that Chinese manufacturing sectors are relying more and more on domestic suppliers for their industrial inputs.

Table 7 Transmission of an initial 30% supply-driven price shock from manufacture sectors, 2000 and 2006 [a]
(percentage)

| Origin of the shock, year. | From all manufacturing sectors, 2000 [b] | | | | | From all manufacturing sectors, 2006 [b] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *From China to:* | China | Japan | USA | Malaysia | Thailand | China | Japan | USA | Malaysia | Thailand |
| Agriculture | 13.9 | 0.1 | 0.1 | 0.3 | 0.3 | 25.7 | 1.0 | 0.6 | 3.5 | 0.7 |
| Mining | 14.0 | 0.1 | 0.1 | 0.1 | 0.1 | 29.0 | 0.5 | 0.3 | 2.5 | 1.8 |
| Textile and clothing | ... | 0.9 | 0.5 | 2.1 | 1.5 | ... | 1.5 | 0.8 | 3.7 | 2.1 |
| Electronics | ... | 0.4 | 0.4 | 1.1 | 2.2 | ... | 0.9 | 0.7 | 2.6 | 2.6 |
| Transport equipment | ... | 0.3 | 0.4 | 0.7 | 0.6 | ... | 0.8 | 0.7 | 2.6 | 1.0 |
| Other manufactures | ... | 0.3 | 0.2 | 0.7 | 0.6 | ... | 0.7 | 0.5 | 2.5 | 1.1 |
| Utilities (water, gas, elect.) | 17.7 | 0.1 | 0.1 | 0.2 | 0.1 | 27.8 | 0.4 | 0.3 | 2.9 | 1.7 |
| Construction | 30.3 | 0.2 | 0.3 | 0.6 | 0.7 | 36.1 | 1.0 | 0.5 | 2.5 | 1.8 |
| Trade and transport services | 18.9 | 0.1 | 0.1 | 0.1 | 0.2 | 28.2 | 0.3 | 0.3 | 2.0 | 0.7 |
| Other services | 16.2 | 0.1 | 0.1 | 0.3 | 0.2 | 28.6 | 0.4 | 0.3 | 2.9 | 1.9 |
| *From Japan to:* | China | Japan | USA | Malaysia | Thailand | China | Japan | USA | Malaysia | Thailand |
| Agriculture | 0.3 | 10.3 | 0.2 | 1.1 | 0.7 | 0.8 | 9.5 | 0.1 | 0.7 | 0.9 |
| Mining | 0.6 | 13.9 | 0.2 | 0.6 | 0.6 | 1.0 | 13.8 | 0.1 | 0.5 | 1.8 |
| Textile and clothing | 1.1 | ... | 0.4 | 4.2 | 2.4 | 1.1 | ... | 0.2 | 2.9 | 2.5 |
| Electronics | 1.7 | ... | 1.3 | 0.9 | 1.0 | 1.5 | ... | 0.9 | 0.7 | 1.0 |
| Transport equipment | 1.8 | ... | 1.5 | 8.1 | 9.4 | 1.5 | ... | 1.0 | 5.6 | 9.0 |
| Other manufactures | 0.9 | ... | 0.4 | 2.4 | 2.2 | 1.1 | ... | 0.2 | 1.6 | 2.3 |
| Utilities (water, gas, elect.) | 0.7 | 6.7 | 0.1 | 0.7 | 0.5 | 1.1 | 6.5 | 0.1 | 0.5 | 1.7 |
| Construction | 1.0 | 14.8 | 0.3 | 2.5 | 2.4 | 1.2 | 14.4 | 0.2 | 1.8 | 2.3 |
| Trade and transport services | 0.6 | 4.7 | 0.1 | 0.5 | 0.9 | 1.0 | 4.5 | 0.1 | 0.5 | 1.2 |
| Other services | 0.6 | 5.3 | 0.1 | 0.6 | 0.8 | 1.1 | 5.1 | 0.1 | 0.5 | 1.7 |
| *From USA to:* | China | Japan | USA | Malaysia | Thailand | China | Japan | USA | Malaysia | Thailand |
| Agriculture | 0.2 | 0.2 | 9.8 | 0.4 | 0.4 | 0.4 | 0.2 | 6.9 | 0.6 | 0.4 |
| Mining | 0.2 | 0.2 | 4.9 | 0.3 | 0.2 | 0.5 | 0.2 | 5.0 | 0.4 | 0.3 |
| Textile and clothing | 0.3 | 0.5 | ... | 2.2 | 1.4 | 0.4 | 0.5 | ... | 1.7 | 1.2 |
| Electronics | 0.8 | 0.8 | ... | 0.4 | 0.3 | 0.7 | 0.8 | ... | 0.4 | 0.3 |
| Transport equipment | 0.5 | 0.8 | ... | 1.2 | 1.2 | 0.5 | 0.8 | ... | 1.0 | 1.1 |
| Other manufactures | 0.4 | 0.4 | ... | 1.1 | 0.9 | 0.5 | 0.4 | ... | 1.0 | 0.8 |
| Utilities (water, gas, elect.) | 0.3 | 0.1 | 3.3 | 0.4 | 0.2 | 0.5 | 0.1 | 3.1 | 0.4 | 0.2 |
| Construction | 0.4 | 0.2 | 12.6 | 0.9 | 0.5 | 0.5 | 0.2 | 12.1 | 0.8 | 0.4 |
| Trade and transport services | 0.3 | 0.1 | 4.0 | 0.4 | 0.2 | 0.4 | 0.1 | 4.0 | 0.4 | 0.2 |
| Other services | 0.3 | 0.1 | 4.0 | 0.5 | 0.3 | 0.5 | 0.1 | 4.1 | 0.5 | 0.3 |

Continued .../...

Table 7 Transmission of an initial 30% supply-driven price shock from manufacture sectors, 2000 and 2006 [a]
(Cont.)

| Origin of the shock, year. | From all manufacturing sectors, 2000 | | | | | From all manufacturing sectors, 2006 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *From Malaysia to:* | China | Japan | USA | Malaysia | Thailand | China | Japan | USA | Malaysia | Thailand |
| Agriculture | 0.0 | 0.0 | 0.0 | 7.0 | 0.2 | 0.2 | 0.1 | 0.0 | 8.7 | 0.3 |
| Mining | 0.1 | 0.0 | 0.0 | 1.2 | 0.1 | 0.2 | 0.0 | 0.0 | 2.5 | 0.6 |
| Textile and clothing | 0.1 | 0.1 | 0.1 | ... | 0.8 | 0.2 | 0.1 | 0.1 | ... | 0.9 |
| Electronics | 0.4 | 0.2 | 0.3 | ... | 0.2 | 0.3 | 0.3 | 0.2 | ... | 0.2 |
| Transport equipment | 0.1 | 0.1 | 0.1 | ... | 0.3 | 0.2 | 0.1 | 0.1 | ... | 0.4 |
| Other manufactures | 0.1 | 0.1 | 0.0 | ... | 0.4 | 0.2 | 0.1 | 0.0 | ... | 0.5 |
| Utilities (water, gas, elect.) | 0.1 | 0.0 | 0.0 | 5.0 | 0.1 | 0.2 | 0.1 | 0.0 | 6.1 | 0.6 |
| Construction | 0.1 | 0.1 | 0.0 | 12.2 | 0.4 | 0.2 | 0.1 | 0.0 | 11.7 | 0.6 |
| Trade and transport services | 0.1 | 0.0 | 0.0 | 3.2 | 0.1 | 0.2 | 0.0 | 0.0 | 3.8 | 0.3 |
| Other services | 0.1 | 0.0 | 0.0 | 3.4 | 0.1 | 0.2 | 0.0 | 0.0 | 4.3 | 0.7 |
| *From Thailand to:* | China | Japan | USA | Malaysia | Thailand | China | Japan | USA | Malaysia | Thailand |
| Agriculture | 0.0 | 0.0 | 0.0 | 0.2 | 7.1 | 0.1 | 0.1 | 0.0 | 0.6 | 7.0 |
| Mining | 0.0 | 0.0 | 0.0 | 0.1 | 5.9 | 0.1 | 0.1 | 0.0 | 0.3 | 6.2 |
| Textile and clothing | 0.1 | 0.1 | 0.2 | 1.5 | ... | 0.1 | 0.2 | 0.2 | 1.4 | ... |
| Electronics | 0.2 | 0.1 | 0.1 | 0.1 | ... | 0.2 | 0.1 | 0.1 | 0.3 | ... |
| Transport equipment | 0.1 | 0.2 | 0.1 | 0.4 | ... | 0.1 | 0.2 | 0.1 | 0.6 | ... |
| Other manufactures | 0.1 | 0.1 | 0.0 | 0.4 | ... | 0.1 | 0.1 | 0.0 | 0.6 | ... |
| Utilities (water, gas, elect.) | 0.1 | 0.0 | 0.0 | 0.1 | 4.8 | 0.1 | 0.0 | 0.0 | 0.3 | 3.6 |
| Construction | 0.1 | 0.0 | 0.0 | 0.4 | 10.6 | 0.1 | 0.1 | 0.0 | 0.6 | 8.6 |
| Trade and transport services | 0.0 | 0.0 | 0.0 | 0.1 | 7.0 | 0.1 | 0.0 | 0.0 | 0.3 | 6.9 |
| Other services | 0.1 | 0.0 | 0.0 | 0.1 | 6.6 | 0.1 | 0.0 | 0.0 | 0.4 | 5.3 |

*Notes:* a/ Impact of an increase in 30% of the cost of inputs originating from the manufacturing sectors on the respective sectoral production costs. b/ The manufacturing sectors from where supply shocks originate are: Textile, Electronics, Transport Equipment, and Other Manufacturing.
*Source:* authors' calculations.

*Table 8. Imported and exported shocks from/to the manufacturing sectors [a], 2000 and 2006*

| **2000** To: / From: | China | Japan | USA | Malaysia | Thailand | Exported shocks |
|---|---|---|---|---|---|---|
| China | ... | 0.3 | 0.3 | 0.9 | 1.0 | 0.6 |
| Japan | 1.1 | ... | 0.7 | 2.1 | 2.6 | 1.6 |
| USA | 0.5 | 0.6 | ... | 0.9 | 0.8 | 0.7 |
| Malaysia | 0.1 | 0.1 | 0.1 | ... | 0.4 | 0.2 |
| Thailand | 0.1 | 0.1 | 0.1 | 0.3 | ... | 0.1 |
| Imported shocks | 0.4 | 0.3 | 0.3 | 1.1 | 1.2 | |
| **2006** To: / From: | China | Japan | USA | Malaysia | Thailand | Exported shocks [b] |
| China | ... | 0.8 | 0.5 | 2.6 | 1.5 | 1.4 |
| Japan | 1.2 | ... | 0.5 | 1.5 | 2.7 | 1.4 |
| USA | 0.5 | 0.6 | ... | 0.8 | 0.8 | 0.7 |
| Malaysia | 0.2 | 0.1 | 0.1 | ... | 0.5 | 0.2 |
| Thailand | 0.1 | 0.1 | 0.0 | 0.5 | ... | 0.2 |
| Imported shocks [b] | 0.5 | 0.4 | 0.3 | 1.3 | 1.4 | |

*Notes:* a/ Weighted averages of domestic sectoral shocks; b/ Simple average of country shocks.
*Source:* Calculations based on Table 7

Nevertheless, some patterns tend to emerge. According to the observed 2000 production structure, the electronics sector is much more internationally integrated than the transport equipments and textiles sectors, with an IRSIC (excluding domestic effects) twice higher. [22] This means that firms operating in the electronics sector are much more exposed to a risk of breakdown in the international supply chain.

3) FURTHER IMPLICATIONS FOR REAL-CHANNEL TRANSMISSION OF FINANCIAL SHOCKS IN THE ASIA-US SUB-REGION

One should remember than IRSIC only captures part of the shock transmission. First, it measures the non-disruptive supply-driven impact, maintaining constant production levels. Second, it ignores the secondary demand-driven impacts resulting from lower activity levels. This section explores these effects in the Asian-USA inter-industrial compact.

**i) Disruptive vs. Non-Disruptive Shocks.**

The previous simulation was based on non-disruptive supply shocks translating into a standard impact of 30% of prices for the affected intermediate inputs. But the countries analysed in the case study differ widely in their level of development, particularly regarding their technological capacity, while the previous sections showed large differences in the domestic value-added content of production.

These characteristics have two types of implications on the effect of an imported supply shock:

- For the relatively less developed countries, if the shock originates from an industrial country, it might become disruptive in case the affected firm cannot shift to another supplier, since it does not have the technological capacity to substitute the inputs, at any price.
- For the most advanced industrial countries, while there is always the possibility of substituting domestically an intermediate input produced in a less developed country, the increase in

[22] The 2006 update of the sectoral IO tables derives in part from the observed 2000 technical coefficients (Annex1).

production costs may be much higher than the standard 30% used in the simulation, due to, *inter alia*, the difference in the cost of factorial services.

As discussed previously, the input-output framework is inappropriate to measure the first type of disruptive shocks because the combination of strict complementarities of inputs and forward linkages would progressively bring the economy to an almost complete halt. In a more realistic scenario, one can consider that most of the export-oriented activities would stop, generating a severe macroeconomic shock to the economy.

For Japan and the US, the induced rise in domestic prices due to a shutdown of their Asian suppliers of intermediate manufacture goods is significant when differences in production costs are imputed. This is the case especially for the textile and clothing sectors (see Annex 3 for details on the calculation). The disruption of supply chains in the manufacturing sectors of the three developing Asian countries would lead to a 2% average increase in the price of sectoral outputs in the textile, electronics and transport equipment sectors. Japan would be more affected than the US in all sectors, and the average increase in prices would reach 2.5% (against 1.5% for the USA). Considering that only a minority of firms engage in off-shoring, this average impact will fall disproportionately on a few firms probably the most dynamic with potentially large disruptive impact. The results of this simulation also show the potential gains those firms were able to obtain by out-sourcing in the first place.

**ii) Demand-driven secondary impacts.**

Even in a static input-output framework, one cannot expect quantities to remain constant when prices change. The increase in production costs should reflect into higher output prices and, therefore, lead to lower final demand (considering a constant nominal income). Annex 2 illustrates these effects in the Asian-US context. [23] Demand-driven secondary impacts differ widely across country, but the summary results obtained tend to indicate that increases in output prices caused by a disruption of the supply chain in China would have significant implications for all the partner countries, with the exception of the USA. Disruptions originating in Japan also have important implications, and shock originating from the USA would affect more developing Asia than Japan.

## IV. CONCLUSIONS

The international economy is a situation where the global financial crisis which started in 2008 could possibly replicate the pattern of Japan's lost decade, in particular its negative transmission mechanisms between the financial sectors and the real economy. In this context, the aim of the present study was to analyse the role of international supply chains as transmission channels of a financial shock from the monetary circuit into the real economy. The existence of feed-back effects between the two circuits may amplify the initial shock when the financial sector is facing credit-adequacy constraints. In such a case, credit restrictions affecting the production or the trade activity of a single firm participating in a production network has systemic "across the board" real and financial impacts. In an endogenous money framework, a credit-crunch situation is compatible with the accumulation of liquidity in the monetary circuit, as counterpart of the accumulation of unexpected inventories of unfinished goods in the supply chain.

Because individual firms are interdependent and rely on each other, either as supplier of intermediate goods or client for their own production, an exogenous financial shock affecting a single firm, such as the termination of a line of credit, reverberates through the productive chain. The transmission of the shock through real channels can be tracked, at macroeconomic level, by modelling input-output interactions. Using an international version of the input-output matrices, the paper proposes the calculation of an indicator of supply-driven shocks based on forward linkages.

[23] Results are offered only for illustration, since a complete modelling of the supply-demand interactions would require a general equilibrium framework.

Assuming that the initial credit-crunch shock that constrains the productive capacity of some individual firms is not disruptive at macroeconomic level, the intensity of the real sectoral shock transmission is proportional to the direct and indirect increases in production costs. In the price space, the initial supply shocks are transmitted through the Ghosh matrix, while the transmission of the secondary demand shocks responds to the Leontief methodology.

As the initial monetary shock reverberates through the productive chains and affects final demand, more and more firms will face difficulties in completing their production plans or selling their output. These disruptions occurring in the real economy feed-back into the monetary circuit. The disruption of the productive chain and the building-up of undesired stocks impede the expected destruction of money and determine the accumulation of outstanding loans as well as a further downgrading of the exposed firms. Since the downgrading of an indebted individual firm affects the capital adequacy ratio of its banker, both flows and stocks are affected in the monetary circuit and all firms see their access to credit potentially restricted. Thus a limited credit shock initiating in the monetary circuit will be spread across various sectors and various countries through the supply chain, and then will feed-back into the monetary circuit with amplified effects.

The paper suggests that if banks were originally operating at the limit of their institutional capacity, defined by the capital adequacy ratio, and if assets are priced to market, then a resonance effect amplifies the back and forth transmission between real and monetary circuits, leading to strongly non linear results. The chaotic behaviour of the international financial system at the end of 2008, and its dire consequences on the real economy observed in 2009, are examples of such resonance and amplification. In that light, the present crisis should provide an opportunity to address problems of macro-prudential pro-cyclicality to minimize the risks of boom and bust cycles initiating from the financial sector.

The paper illustrates the proposed methodology by computing a supply-driven indicator (IRSIC) and the resulting demand-driven impacts on five interconnected economies of different characteristics: China, Japan, Malaysia, Thailand and the United States. Calculations are based on the international Input-Output matrices prepared on the basis of 2000 data, and an estimate for 2006. Results indicate that the real transmission effect through the international supply-chain linking firms among these economies were heterogeneous across countries and across sectors.

The largest impacts, as expected, are felt domestically. The relative size of the shock on the domestic economy depends on its degree of openness, and also on the relative size of the originating sector in relation to the rest of the economy. Based on the existing inter- and intra-industrial linkages, Japan was the largest exporter of potential supply shock, while Malaysia and Thailand were the most vulnerable to such shocks, because of the high degree of vertical integration of their manufacturing sector. Between 2000 and 2006, China registered a notable increase in both international forward linkages and domestic backward linkages, which increased her influence as an exporter of "shocks" while her vulnerability to an imported shock remained relatively stable. Indeed, the Chinese manufacturing sectors are relying more and more on domestic suppliers for their industrial inputs.

The methodology used to estimate real transmission effects is fairly easy to implement. The Leontief and Ghosh models are very powerful statistical tools, which allowed us to obtain interpretable results quickly. Contrary to what was believed previously, we also showed that it is possible to model jointly, albeit not simultaneously, both forward and backward supply shocks in both price and quantity spaces. While intensive in data, the method is quite straightforward and the increasing availability of international I-O data for most OECD and large emerging economies should allow to identify the real sectoral impacts of a financial shock on all the real sectors on our globalized economy.

The main weakness is on the normative side. This partial modelling approach remains eclectic and does not provide easily for a simultaneous and integrated modelling of both physical and financial flows. It is intended only as a tracking device, and do not provide information on economic implications nor welfare changes. The paper also identifies the macroeconomic and sectoral determinants of the

credit-migration matrices, but falls short of integrating them into the monetary circuit. Incorporating the various micro, sectoral and macroeconomic dimensions into computable general equilibrium models would be an option, but these models have limitations in their financial components. In particular, the reductive assumption of exogenous money typical of CGEs would have to be abandoned for the endogenous approach characterising monetary circuits.

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**ANNEX 1: Updating the IO Matrices**

The Asian IO tables compiled by JETRO's Institute of Developing Economies that we use in our simulations contain data from year 2000 and, at the time of writing, these tables are the latest available. World trade value has more than doubled since 2000, while merchandise exports from Asia increased even more rapidly (125%), making it necessary to update the information. Thanks to the procedure developed by Pula and Peltonen (2009), we have been able to estimate and updated IO table for year 2006 by incorporating changes in trade data between 2000 and 2006.

Our starting point was the *intermediate demand block* compiled by Pula and Peltonen, which contains changes in intermediary trade, aggregated at country level between 2000 and 2006. This *block* covers all intermediate inputs (domestic + imported) as well as value added, freight, insurance and import duties. To obtain the 2006 value in a specific cell, Pula and Peltonen have multiplied the 2000 value in this cell by the nominal growth rate in 2000-2006.

More precisely:

- Growth rates of imported inputs were calculated by using two data sources – National Accounts statistics (which includes total trade of goods and services) and COMTRADE data (which provides information on bilateral flows by reporters).
- Growth rates of value added in each country were taken from National Accounts statistics.
- Growth rates of freight, insurance and import duties are also based on National Accounts statistics.
- Total output was estimated by applying the output/VA ratio in the manufacturing sector to the total economy's value added. .
- Domestic intermediate consumption was calculated by subtracting updated values for imported intermediate inputs, value added, freight, insurance and import duties from updated total output. [24]

We have adapted this *intermediate demand block* to our study by reducing the number of countries down to only five (consolidating the matrix by adding imports from the five other countries to the imports from the rest of the world) and by distributing freight and insurance in each country among the different sources of imported inputs to obtain CIF values. [25]

Starting from Pula and Peltonen's aggregated country-level update, our next step was to impute updated sectoral values. For each country, this was done by estimating the relative contribution of each sector in the total 2000-2006 increase of intermediary trade. On the basis of sectoral 2000 and 2006 value added data in a selection of six sectors (agriculture, mining and manufacturing, construction, wholesale and retail trade, transport, other activities), we derived the shares of each of these sectors in the evolution of total value added. [26] These values were rearranged to calculate a sectoral table, by dividing and reallocating the initial six sectors among the ad-hoc ten sectors disaggregation used in our study, depending on the weight of each of the ten sectors in the 2000 total output of each country (see Table A1.1).

[24] Full methodology details on the *intermediate demand block* can be found in Appendix A.2 of Pula and Peltonen (2009).

[25] The value of duties and taxes was also redistributed in order to compute the 2000-2006 growth rate consistently with the 2000 aggregated tables.

[26] Source: UN Statistical Division website.

Table A1.1 Estimated sectoral contribution in the increase of total value added, 2000-2006 (percent)

| | Agriculture | Mining | Textile | Electronics | Transport Equipment | Other Manufact. | Electricity Water Gas | Constructn | Trade Transport | Other Services |
|---|---|---|---|---|---|---|---|---|---|---|
| China | 9.2 | 7.6 | 3.6 | 4.4 | 2.0 | 18.1 | 9.1 | 5.7 | 4.3 | 35.9 |
| Japan | 5.4 | 0.1 | 0.7 | 5.0 | 4.6 | 19.0 | 2.1 | 19.9 | 10.4 | 32.7 |
| USA | 9.1 | 1.2 | 0.9 | 3.4 | 4.8 | 18.4 | 2.4 | 1.1 | 6.3 | 52.5 |
| Malaysia | 13.3 | 7.1 | 1.3 | 16.4 | 1.7 | 17.9 | 2.9 | 2.9 | 6.1 | 30.4 |
| Thailand | 0.8 | 4.4 | 0.7 | 0.9 | 0.4 | 2.7 | 11.6 | 5.7 | 4.6 | 68.2 |

*Source:* Authors' calculation on the basis on UNSD national account data.

Based on the hypothesis of invariant coefficients for the supply-use table between 2000 and 2006, we have used these shares to estimate sectoral gross output and total intermediate consumption. Then, we proceeded to distribute sectorally the increases of input trade in China, Japan, the US, Malaysia and Thailand (based on observed trade statistics). The domestic sectoral intermediate consumption among is obtained as a residual from the total intermediate consumption and imported inputs estimated for each sector.

**ANNEX 2: Incorporating secondary demand-driven impacts**

A complete simulation of the transmission of supply-driven shocks should ideally include quantities effects, even when production plans are unrestricted. One way of introducing quantitative effects in our initial framework is to revert to the initial Leontief demand-driven approach, noting that the supply-driven shock will eventually affect demand.

Indeed, the exogenous increase in production costs will reflect into higher prices for a series of final products, and a decrease in their demand. Noting that ISRIC is the percentage price increase in output prices, the resulting negative demand-driven secondary shocks could be modelled using traditional Leontief model (final demand impulses), in the following way:

$$\Delta Q_2' = (I-L)^{-1} \cdot \Delta D \qquad [2]$$

with
$\Delta Q_2'$ : demand-driven secondary shocks
$\Delta D$ : change in final demand due to higher prices.
$(I-L)^{-1}$: Leontief inverse

$$\Delta D = \Delta P \bullet E \qquad [3]$$

E : column vector of price elasticity
$\Delta P$ : column vector of price shocks
● : Hadomard product

Remember from equation [1] that $\%\Delta P/P$ = 'ISRIC'.

The secondary demand effects [2] are proportional to the initial supply-driven shock as measured by ISRIC [1]. Note that while $\Delta Q$ and ISRIC in equation [1] were price effects (Ghosh models), $\Delta Q_2'$ is a quantity effect (Leontief models). Nevertheless, price and quantity dimensions are not independent and the secondary demand effects —a drop in demand ($\Delta Q_2'$)— will, in turn, induce a downward correction in prices, thus reducing somewhat the initial supply-driven price shock.

In order to avoid this loop effect, Papadas and Dahl (1999) have suggested splitting the I-O matrix into exogenous and endogenous sectors, and have captured the backward sectoral impacts of supply-driven multipliers only on the non-exogenized sectors. When the production of sector *n* is altered exogenously, the backward effects are felt by the sectoral outputs (different from *n*) which are used as inputs by *n*[27].

The discussion on the relative merits of alternative approaches falls beyond the limited scope of this paper. For our present purpose, it is sufficient to keep in mind that the secondary demand impacts are proportional (through the price elasticities and the Leontief-inverse) to the initial supply-driven price effects as measured by ISRIC. As already mentioned, the simultaneous modelling of the structural interactions induced by changes in prices would ideally have to be realized using computable general-equilibrium models, something which falls outside the objectives of this paper.

- ***Application to the Asia-USA example.***

Demand shocks derived from the increases in output price presented in Table 7 are estimated using traditional Leontief model (final demand impulses), as described in equation [2]. As the price elasticity for most products tends to cluster around 1.0, a unitary elasticity is a commonly used rule of thumb. A unitary elasticity here means that the negative shock in quantity demanded is equal to the resulting increase in prices (IRSIC), itself higher than the initial 30% increase in unit costs of substitute intermediate inputs.

Results presented in Table A2.1 are based on the sectoral impacts on other countries resulting from an initial supply shock affecting all the manufacturing sectors of a given supplier country, as shown in Table 7. Secondary demand results may nevertheless differ somewhat, based on the relative strength of backward linkages in affected economies.

The summary results (South-East panel of Table A2.1) indicate that a disruption of the supply chain in China has potentially large recessive implications for the partner countries (in average over the four partners, the drop in demand resulting from the price hike could reach over 10% in manufacture). North-East panel indicates that all partners excepted USA would be affected, Malaysia being the most vulnerable. Disruptions originating in Japan also have important implications, especially for transport equipment. Thailand would be the most affected by a shock originating in Japan. A supply shock originating from the USA would affect proportionally more developing Asian countries than Japan.

[27] It should be noted that Papadas and Dahl believed that "there is no satisfactory way to account simultaneously for the impacts of primary backward and forward effects, and thus their secondary ones." This may be true in the quantity space, but we have demonstrated that it is possible to model sequentially both forward and backward effects by restricting forward supply-driven effects to the price space, and demand-driven backward effect to the quantity space. The link between both spaces is provided by the elasticity equation [3].

Table A2.1 Secondary demand shock in response to an initial 30% increase in the price of imported manufactured intermediate inputs, 2006 [a] (percent)

| | Imported from China to: | | | | | Imported from Japan to: | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | China | Japan | USA | Malaysia | Thailand | China | Japan | USA | Malaysia | Thailand |
| Agriculture | ... | -5.4 | -1.7 | -11.7 | -10.7 | -3.5 | ... | -0.8 | -3.5 | -8.3 |
| Mining | ... | -6.3 | -1.9 | -13.5 | -7.6 | -3.8 | ... | -0.9 | -8.0 | -4.8 |
| Textile and clothing | ... | -15.2 | -1.9 | -13.8 | -6.6 | -4.1 | ... | -0.6 | -5.1 | -4.8 |
| Electronics | ... | -9.1 | -3.0 | -13.5 | -17.7 | -5.0 | ... | -2.0 | -3.8 | -5.3 |
| Transport equipment | ... | -3.0 | -1.0 | -7.3 | -4.3 | -5.4 | ... | -1.7 | -8.6 | -17.7 |
| Other manufactures | ... | -6.7 | -2.0 | -23.0 | -11.9 | -6.2 | ... | -0.9 | -7.4 | -9.5 |
| Utilities | ... | -3.1 | -1.0 | -13.1 | -4.0 | -3.6 | ... | -0.4 | -3.8 | -3.5 |
| Construction | ... | -1.3 | -0.7 | -3.9 | -1.8 | -1.6 | ... | -0.3 | -2.2 | -2.3 |
| Trade, transport services | ... | -3.0 | -1.1 | -17.1 | -7.1 | -6.3 | ... | -0.6 | -5.8 | -4.9 |
| Other services | ... | -1.3 | -0.7 | -6.2 | -2.9 | -2.2 | ... | -0.2 | -1.9 | -2.6 |
| | Imported from USA to: | | | | | Imported from Malaysia to: | | | | |
| | China | Japan | USA | Malaysia | Thailand | China | Japan | USA | Malaysia | Thailand |
| Agriculture | -2.0 | -1.5 | ... | -2.0 | -3.4 | -0.7 | -0.3 | -0.1 | ... | -3.0 |
| Mining | -2.0 | -1.4 | ... | -2.3 | -1.1 | -0.7 | -0.3 | -0.1 | ... | -1.5 |
| Textile and clothing | -2.3 | -1.6 | ... | -5.5 | -4.4 | -0.7 | -0.3 | -0.2 | ... | -1.6 |
| Electronics | -3.7 | -4.2 | ... | -5.4 | -7.0 | -1.1 | -0.5 | -0.3 | ... | -0.7 |
| Transport equipment | -3.2 | -3.6 | ... | -2.3 | -3.6 | -0.8 | -0.3 | -0.1 | ... | -1.3 |
| Other manufactures | -4.0 | -2.0 | ... | -4.3 | -3.8 | -1.1 | -0.4 | -0.1 | ... | -2.4 |
| Utilities | -2.0 | -1.1 | ... | -2.9 | -0.9 | -0.7 | -0.2 | -0.1 | ... | -1.2 |
| Construction | -0.7 | -0.3 | ... | -1.1 | -0.4 | -0.3 | -0.1 | 0.0 | ... | -0.7 |
| Trade, transport services | -4.0 | -0.9 | ... | -5.3 | -2.0 | -1.1 | -0.2 | -0.1 | ... | -1.4 |
| Other services | -1.1 | -0.4 | ... | -1.4 | -0.5 | -0.4 | -0.1 | 0.0 | ... | -1.0 |
| | Imported from Thailand to: | | | | | **Summary :** average sectoral shocks originating from:[b] | | | | |
| | China | Japan | USA | Malaysia | Thailand | China | Japan | USA | Malaysia | Thailand |
| Agriculture | -0.3 | -0.4 | -0.1 | -1.3 | ... | -7.4 | -4.1 | -2.2 | -1.0 | -0.5 |
| Mining | -0.3 | -0.4 | -0.1 | -1.6 | ... | -7.3 | -4.4 | -1.7 | -0.6 | -0.6 |
| Textile and clothing | -0.4 | -0.5 | -0.3 | -2.0 | ... | -9.4 | -3.6 | -3.4 | -0.7 | -0.8 |
| Electronics | -0.5 | -0.3 | -0.2 | -0.7 | ... | -10.8 | -4.0 | -5.1 | -0.7 | -0.4 |
| Transport equipment | -0.4 | -0.6 | -0.1 | -1.3 | ... | -3.9 | -8.3 | -3.2 | -0.6 | -0.6 |
| Other manufactures | -0.6 | -0.5 | -0.1 | -2.3 | ... | -10.9 | -6.0 | -3.5 | -1.0 | -0.9 |
| Utilities | -0.3 | -0.2 | -0.1 | -1.3 | ... | -5.3 | -2.8 | -1.7 | -0.5 | -0.5 |
| Construction | -0.2 | -0.1 | 0.0 | -0.7 | ... | -1.9 | -1.6 | -0.6 | -0.3 | -0.3 |
| Trade, transport services | -0.6 | -0.2 | -0.1 | -1.4 | ... | -7.1 | -4.4 | -3.0 | -0.7 | -0.6 |
| Other services | -0.2 | -0.1 | 0.0 | -0.8 | ... | -2.8 | -1.7 | -0.9 | -0.4 | -0.3 |

*Notes:* a/ Assuming an uniform 1.0 price elasticity of demand; b/ simple average of sectoral effects to other partners.
*Source:* Authors' calculations.

**ANNEX 3. Simulating a disruptive supply shock in the Asian-US sub-region**

The simulation used in the paper is based on the possibility of (imperfect) substitution between domestic and imported inputs for all participants in the supply chain. Nevertheless, for a country at an earlier stage of industrialization, a shock originating from an industrial country might become disruptive if the domestic firm is totally dependent of the international productive network, or when the domestic manufacturing does not have the technological capacity to substitute the inputs, at any price.

The disruptive shock created by a brutal disruption of manufactured inputs imported from Japan and the US would probably stop entirely most of the firms relying on these inputs, and in particular, most of their export oriented manufacturing sectors. As discussed previously, the input-output framework defined by the Ghosh matrix is inappropriate to measure such disruptive shocks in the quantity space, because of the strict complementarities of inputs (corresponding to a null Armington elasticity of substitution between imported and domestic inputs).

Because of forward linkages, an economy based on strictly complementary production factors would progressively slow down to a complete stop as the supply constraints will progressively extend to all sectors. A more realistic scenario is one where the export oriented activities stop when the required inputs for processing are no more available.

For the most advanced industrial countries, while there is always the possibility of substituting domestically an intermediate input produced in a less developed country, the increase in production costs may be much higher than the standard 30% used in the simulation, due to, *inter alia*, the difference in the cost of factorial services, especially labour.

Our back-of-the-envelope calculation of the potential increase in sectoral production cost is based on a single international price for tradable goods and a pricing of non-traded factorial services based on the equivalence of purchasing power parity. The purchasing power parity ratio between the developed and developing countries is about 0.40; in other words, factorial services are 150% more expensive in the US and Japan than in the developing Asian countries (Table A3.1).

*TableA3.1 Ratio of PPP conversion factor to market exchange rate, 2005*

| Ratio of PPP conversion factor to market exchange rate, 2005 | Based on US dollar | Based on Japanese Yen |
|---|---|---|
| USA | 1.00 | 0.85 |
| Japan | 1.18 | 1.00 |
| China | 0.42 | 0.36 |
| Malaysia | 0.46 | 0.39 |
| Thailand | 0.40 | 0.34 |

*Source:* International Comparison Program: "New purchasing power parity estimates from the 2005 International Comparison Program", World Bank.

On the other hand, the direct share of domestic value added (the remuneration of factorial services) in the value of production in Japan and the USA was about 53% in 2006. Thus the expected increase in input prices, when shifting production from a typical developing Asian country supplier to a domestic (Japanese or US) supplier should be 80% (0.53 x 150%). This shock is applied simultaneously to the cost of all manufactured inputs previously imported from China, Malaysia and Thailand by Japan and the USA (Table A3.2).

*Table A3.2 Combined disruptive shock from the manufacturing sectors of Asian developing countries (percentage)*

| | Japan | USA |
|---|---|---|
| Agriculture | 3.2 | 1.8 |
| Mining | 1.6 | 1.0 |
| Textile and clothing | 4.6 | 2.8 |
| Electronics | 3.4 | 2.7 |
| Transport equipment | 3.1 | 2.1 |
| Other manufactures | 2.4 | 1.5 |
| Utilities (water, gas, elect.) | 1.3 | 1.0 |
| Construction | 3.1 | 1.5 |
| Trade and transport services | 1.0 | 0.8 |
| Other services | 1.1 | 1.0 |

*Note:* Expected increase in sectoral cost of production following a disruptive shock from China, Malaysia and Thailand manufacturing sectors.
*Sources:* Authors' calculations.

The induced rise in output prices is significant, especially in the sectors of textile, electronics and transport equipments, where the disruption of supply chains in the manufacturing sectors of the three developing Asian countries would lead to a 2% increase in the average price of sectoral outputs in the ex-importing countries. Japan is more affected the US in all sectors, especially for textile and clothing, construction and agriculture, showing her greater reliance on imported inputs and fragmented production.