Liquidity-saving mechanisms in trade credit networks: Optimising corporate liquidity

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Trade credit, or the delayed payment for intermediate goods[2], has been reported as an important source of short-term external finance for many non-financial firms. The value of trade payables is comparable with that of outstanding corporate bonds and is about one-third of non-financial firms' outstanding bank loans (Boissay, et al., 2020). In the United States, trade receivables represented approximately 8% of the assets of corporate balance sheets in 2022 (Federal Reserve System, 2023).

During financial crises, as bank credit weakens, trade credit becomes a substitute source of liquidity (see Baños-Caballero, et al., 2023). According to the literature, firms able to access trade credit are better positioned to withstand financial crises. For instance, a study of over 200,000 European firms found that an increase in the availability of trade credit to a firm led to a significant decrease in the likelihood of distress (McGuinness, et al., 2018). Therefore, there is a potential benefit in supporting trade credit throughout the entire economic cycle, particularly during financial downturns.

By extending a short-term loan to buyers, sellers of goods and services provide liquidity, facilitate the purchase of supplies by other firms, encourage long-term customer relationships, and increase demand. As firms recursively borrow from their suppliers and lend to their customers through the supply chain, trade credit networks foster economic activity. Accordingly, trade credit has been reported to be a key element in enabling economic activity and ensuring financial stability.

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[1] The views expressed in this paper are the author's own and do not necessarily represent the views of the Saudi Central Bank (SAMA).

[2] Under this broad definition, *trade credit* refers to *accounts payable* (i.e., money borrowed by customers in the supply chain) and *accounts receivable* (i.e., money lent by suppliers in the supply chain) in which the lending non-financial firms finance the receivables with their own resources. In *trade finance*, trade credit is used to facilitate international trade (see, Boissay, et al., 2020).

However, this positive feedback loop created by trade credit networks also works in the opposite direction, with the potential to create instability in the economy. For instance, if some firms do not pay on time, others may find it difficult to pay on time, and a cascading effect of higher payment terms may ensue; furthermore, when firms cannot pay, the cascading effect may be worse. That is, in adverse scenarios, the trade credit channel that runs parallel to input-output linkages could negatively affect the liquidity and the solvency of firms, and, in turn, economic activity and stability (see Costello, 2020).

This type of network and feedback effect is well-known in interbank markets. When banks provide liquidity to each other in the money market, the inability of a single bank to pay on time may threaten the safe and efficient functioning of the payment system and, eventually, the solvency of the financial system. Large-value payment systems have long acknowledged that interbank liquidity is a network problem that is better tackled by implementing intraday Liquidity-Saving Mechanisms (LSMs), i.e., a suite of algorithms designed to compress liquidity requirements to facilitate smoother flows of liquidity. By introducing LSMs into real-time gross settlement systems, large-value payment systems have mitigated liquidity and counterparty risk.

We suggest a similar approach to mitigate liquidity and counterparty risks in trade credit networks. By introducing a new Financial Market Infrastructure (FMI) that runs LSMs in trade credit networks, we can reduce the outstanding exposures among firms, reduce the payment terms, and mitigate potential risks arising from undesirable network and feedback loop effects. This way, by implementing LSMs, risks and potential amplification effects from trade credit exposures are mitigated while their potential contribution to firms' growth, supply chain resilience, and economic activity is preserved. Besides, as this implementation of LSMs requires observing the trade credit network, new data for monitoring and policy-making is available for central banks and financial authorities.

Back to the Bazaar: Trade Credit Clearing's Ancient Roots

The importance of addressing liquidity challenges in early forms of trade credit dates back to the European mediaeval clearing fairs of the 12th century. As described in Boerner and Hatfield (2010), those fairs enabled a decentralised multilateral clearing algorithm to offset non-tradeable obligations among merchants, as follows:

1. Merchants reveal their debtors and creditors;
2. They find reciprocal clearings; those positions cancel out directly;
3. They find clearing cycles; in cycles, where merchant A owes B, B owes C, and C owes A, the common amount is called out;
4. They find clearing chains; in chains, A owes B and B owes C, B clears its positions and new debt from A to C is created accordingly;
5. Repeat until a time limit is reached or no more clearing opportunities exist;

6. The remaining debt should be settled, by paying in cash or by issuing a new debt.

This multilateral clearing algorithm — a mediaeval precursor of what would today be recognised as an LSM — enabled liquidity risk mitigation by finding archetypes of payment flows (i.e., reciprocal obligations, cycles, and chains), and enabling cashless payments and solving problems of money shortage.[3]

Today, trade credit clearing is rare[4] but the risks in trade credit persist. As reported in the 2023 European Payment Report (Intrum, 2023), across Europe, six in ten businesses are more worried than ever before about their customers' ability to pay. In the UK, six in ten businesses expect late payments to increase in the next 12 months. As trade credit among firms results in a chain of corporate short-term financing, the recent economic headwinds of high inflation and high interest rates have resulted in decreased demand and sales, and a network effect of increasing payment terms. In this vein, not only has it been reported that 90% of UK businesses have been asked to accept longer payment terms than they are comfortable with, but also 70% are finding it harder to pay their own suppliers on time.

In the US, a report showed that in the first quarter of 2023, only 49% of accounts receivable in the non-residential construction sector are paying current, whereas about 27% are over 90 days delayed (see Dun & Bradstreet, 2023). Also, an Allianz Research (2023) report on the global state of global trade credit found that 50% of firms in the US and the UK are expecting export payment terms to be extended, whereas about 40% of firms expect that there will be an increase in export non-payment risk in 2023.

Any effort or mechanism that can reduce the exposure to the late or non-payment of trade payables is likely to deliver a positive impact on the economy by mitigating their negative direct and indirect effects (i.e., negative externalities) on the economy. At a macro level, it would facilitate deleveraging and derisking the supply chain and mitigating the cascading impact on commercial banks through loan delinquency and default. At a micro level, it would ensure firms have working capital to invest in their business, pay their suppliers, and employ labour, thus, having a positive impact on the growth of firms and the economy. Hence, it stands to reason that solutions that make trade credit safer and more efficient could deliver significant first and second-order benefits to the economy.

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[3] Some complications have been omitted for brevity–but will be addressed in a forthcoming section. For instance, in the clearing chain, C may find itself exposed to a bad debtor when B is cleared from the cycle. Also, the order of the algorithm affects its outcome and the benefits for the participants. Clearing fairs had regulations to address these issues.

[4] See the case of Slovenia, reported in Fleischman, et al. (2020), and Republika Srpska, reported in Božić & Zrnc (2023).

Solving Cycles and Chains in Modern Trade Credit Networks

Trade credit relationships within an economy can be conceived as a complex system of contractual obligations (i.e., IOUs) between entities, whether individuals, firms, or the government. This system dynamically changes and evolves over time as new obligations are issued and existing ones are settled.

Such a system is better portrayed as a network or graph, where firms are nodes and obligations are vertices that link the nodes together. When visualised, the same archetypes of payment flows solved in European mediaeval clearing fairs may emerge, i.e., reciprocal obligations, cycles, and chains. Each one of them has different characteristics from both a risk and liquidity perspective.

Reciprocal payment flows

A bilateral or reciprocal relationship occurs when two firms hold obligations issued by each other; it is a cycle between two nodes. For example, a utility company could provide waste management services to the firm that supplies its accounting services or the government would receive tax payments from firms that also supply its goods and services.

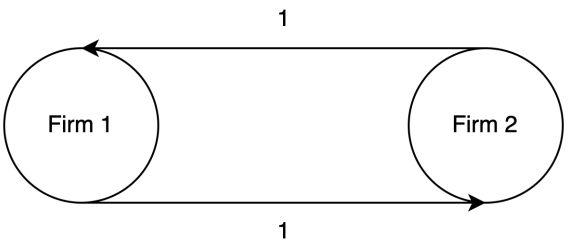

Diagram 1. Reciprocal payment flows.

The solution to reciprocal relationships is **bilateral netting**. If both obligations have the same value, they would cancel out and be removed from the trade credit network; if they don't, a single obligation results from the net of both obligations. In either case, after clearing the loop, the total outstanding and the number of obligations will be lower.

Chain payment flows

There will be chains when multiple firms each have obligations to a successive firm in the chain. In this case, unless they receive payment from the preceding firm in the

chain, they may not have enough liquidity to make payment - particularly when distressed. For example, in the chain below, Firm 2 may not be able to pay Firm 3 unless Firm 1 makes its payment.

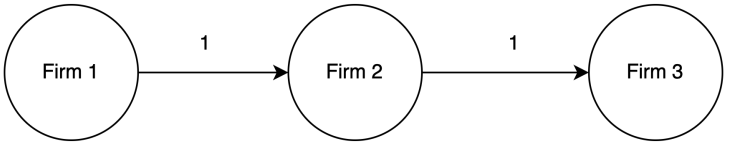

Diagram 2. Chain payment flows.

In this case, the solution may be based on enforcing the right sequence, i.e., **resequencing**, when Firm 1 pays Firm 2, and, then, Firm 2 pays Firm 3. However, an alternative solution is **multilateral offsetting** or **netting**. If both obligations, from Firm 1 to Firm 2 and Firm 2 to Firm 3 have the same values, Firm 2 could be removed from the chain, and a single obligation from Firm 1 to Firm 3 results. If they don't have the same values, Firm 2 may not be removed but two individual (i.e., non-successive) obligations between the firms will result. In either case, after clearing the chain, the total outstanding will be lower and the succession of obligations could be avoided.

Cyclical payment flows

There will be cyclical structures when multiple firms have obligations that form a loop of varying lengths. Diagram 3 shows a loop between three firms: Firm 1 may not pay Firm 3 unless it receives payment from Firm 2, and Firm 2 may not pay Firm 1 unless it receives payment from Firm 3. This can represent a gridlock situation where the failure or delay of any of the three firms to pay their counterparty would mean that none of the firms could meet their obligations without acquiring external liquidity or using existing balances.

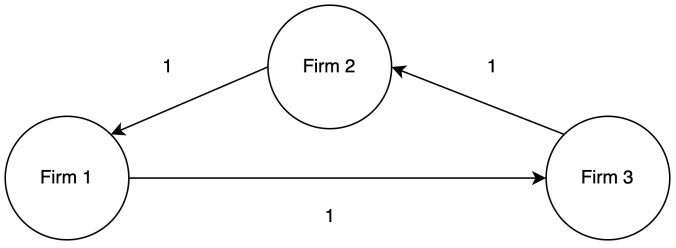

Diagram 3. Cyclical payment flows.

In this case, the solution is **netting**. If all obligations have the same values, they would cancel out, and the entire cycle can be settled simultaneously and removed from the trade credit network; otherwise, if obligations do not have the same values, the total outstanding will be lower and the cycle of obligations could be avoided.

These different archetypes of payment flows or network structures could be integrated such that there will be multiple cycles and chains. For instance, in Diagram 4, Firm 2 cannot pay Firm 3 its obligation of two units unless it receives payment from both Firm 1 and Firm 4.

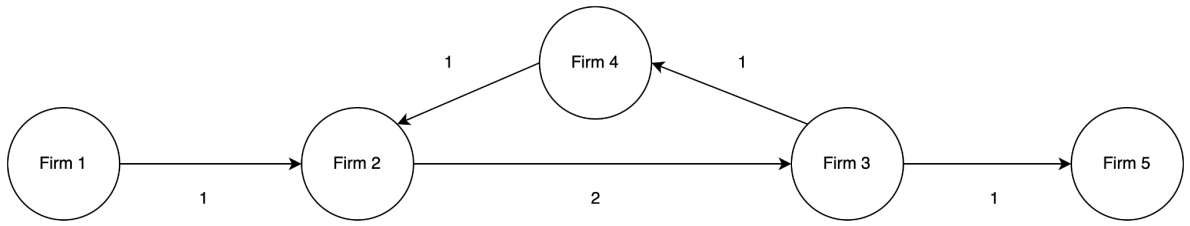

Diagram 4. Integrated payment flows. Source: Fleischman, et al. (2020)

In this case, we can see that an optimal sequence is for Firm 1 to pay Firm 2, Firm 4 to pay Firm 2, Firm 2 to pay Firm 3, Firm 3 to pay Firm 4, and Firm 3 to pay Firm 5. That is, a **resequencing of the payments** could solve this integrated case of cycles and chains. Nevertheless, there are other options. For example, the cycle between Firm 2, Firm 3, and Firm 4 could be netted. As the cycle has no equal values, an obligation to pay 1 unit from Firm 2 to Firm 3 would remain, which would result in a chain of payments from Firm 1 to Firm 2, Firm 2 to Firm 3, and Firm 3 to Firm 5; again, this is an archetype of payment flow that could be solved by enforcing the right sequence.

Case Study: The Trade Credit Network in the Huangdao Zone, China

To demonstrate the effectiveness of our LSM approach in addressing the problem of trade credit liquidity optimization, we applied LSM algorithms to trade credit data from Huangdao Zone, Shandon Province, China, sourced from Cui (2021). This data[5] corresponds to 8,704 obligations between firms and provides a significantly large enough dataset to further examine the usefulness of the proposed algorithms to enhance liquidity management.

[5] https://figshare.com/articles/dataset/data_txt/14547432 [Retrieved on 10th October 2023]

Using FNA's network visualisation solutions, the left panel of Figure 1 depicts the trade credit graph. It shows the interconnected nature of trade credit networks. There are a myriad of connections and connective patterns, each one representing a direct risk between firms and an indirect risk to the overall financial stability of the system. Further, although banks are not included in the network, they could be affected by the relationships with firms in the network—who may be their depositors or borrowers.

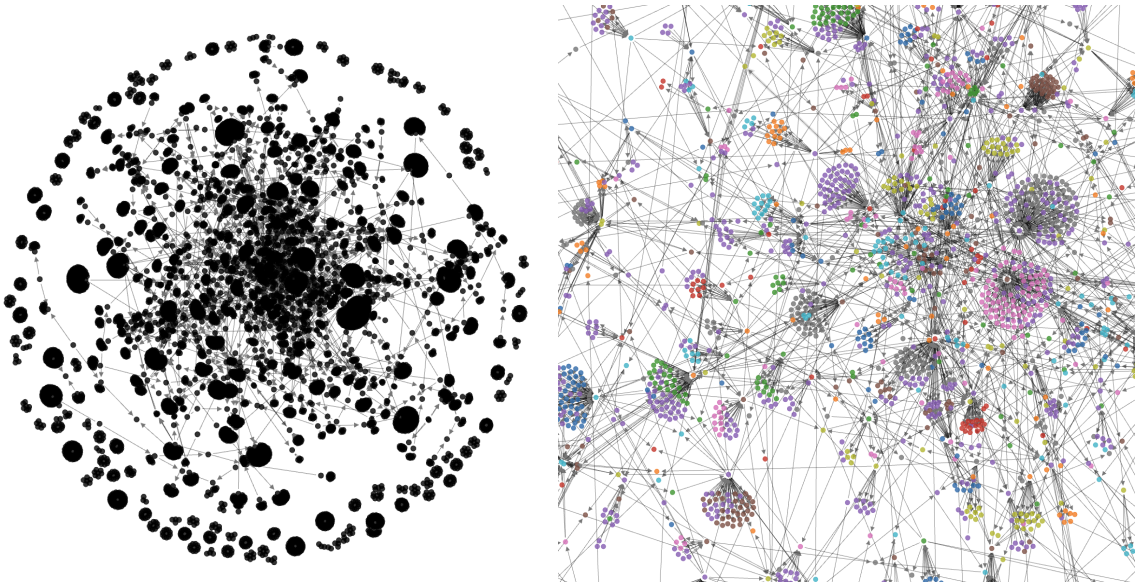

Figure 1. Sample Trade Credit Network. Left, entire graph; right, zoom. Source: Cui (2021), with FNA network visualisation solutions.

The right panel of Figure 1 displays a zoom on a section of the network. It shows there are communities within trade credit networks, where delay or failure to pay may propagate rapidly within the community. However, at the same time, those communities remain intensively interconnected with the rest of the network, with the potential to generate system-wide contagion.

As mentioned, payments can be **sequenced** in a way that helps each participant maintain sufficient liquidity in order to meet the incoming obligations at the right point in time. Also, by means of **bilateral** and **multilateral netting**, cyclical structures can be netted out of the graph so as to remove the gridlock or deadlock situations[6]. Applied together or independently, these approaches can yield significant liquidity savings and mitigate the risks related to liquidity flows in trade credit networks[7].

[6] Gridlocks are situations where the inability of all obligations to be settled is not due to inadequate liquidity but rather due to the inability to settle at the same time. Deadlocks refer to the settlement that is prevented by a lack of liquidity in the system.

[7] There are factoring and other financial solutions that could be applied to solve this problem too. Nevertheless, those solutions require access to a specialised financial product that may not be available or that firms do not want to access to.

In the case of the trade credit data from the Huangdao Zone, if these obligations were processed in a conventional manner, it would have required CNY 1.61 billion to settle. However, by using LSMs a set of payment orders was created that, whilst fulfilling all obligations, would have required only CNY 1.09 billion CNY to settle. This is a 32% liquidity saving, significant in relative terms—and potentially significant in absolute terms if extrapolated across a region or an economy.

We achieved these liquidity savings by optimally sequencing the payments, i.e., resequencing. Interestingly, we achieved identical liquidity savings by multilateral netting, with only CNY 1.09 billion to settle, about 32%. However, both solutions to the trade credit network differ fundamentally.

Both solutions, multilateral netting and resequencing, require a central agent that observes the trade credit network and finds the solution. Nonetheless, multilateral netting could result in new bilateral obligations between firms that had no relationships before; this could be problematic as firms could find themselves exposed to counterparty risks or customer relationships they are not willing to take. The central agent could interpose itself between firms with no prior relationship to avoid this issue, but this would result in the novation of obligations, turning the central agent into a central counterparty—with the legal and financial demands this entails. As part of the solution, the central agent could require providing liquidity to some firms—directly or indirectly.

The multilateral netting solution has been implemented in at least two cases, Slovenia and the Republika Srpska[8]. In both cases, firms submit invoices to a central clearing system that offsets obligations among firms. In Slovenia (see Fleischman, et al., 2020 and Fleischman & Dini, 2021), a special case of multilateral netting with external liquidity sources that avoids creating new relations among firms has been able to clear obligations representing about 1.9% and 0.5% of GDP in 2012 and 2019, respectively. In the case of Republika Srpska, Božić & Zrnc (2023) report that it had successfully reduced the debt component of GDP by some 8% between 2015 and 2019. However, as highlighted by Fleischman et al. (2020) when discussing the Slovenian case, preserving the pre-independence centralised system of tax collection and social contributions allowed for keeping a tight grip on firms' reporting—a feature that could be unique to Slovenia and a few other countries.

On the other hand, resequencing does not result in new obligations between otherwise unrelated firms. The central agent observes the trade credit network, finds the solution, and instructs firms to pay according to the optimal sequence that has been calculated. It is a solution based on coordinating the sequence of existing payments - without the need to create unwanted exposures, introduce external liquidity sources or interpose a central counterparty that novates obligations between firms. A solution based on resequencing would be less demanding for the institution performing the central agent role and the legal and financial changes to implement it would be minimal. Furthermore, the resequencing solution could be developed in a

[8] One of the two entities that constitute Bosnia and Herzegovina.

decentralised manner, without a central agent but a consortium of firms running the solution.

A New Financial Market Infrastructure: Achieving the Potential of LSMs in Trade Credit Networks

To mitigate the coordination challenges and deliver economic benefits at scale, we propose introducing a new form of Financial Market Infrastructure (FMI) focused on extending the benefits of LSMs from large-value payment systems to trade credit networks. This FMI could take the form of either a centralised or decentralised platform operated by either the private or public sector, in which a sufficient cohort of firms submits their respective payment obligations along with data on the due date, priority, acceptance of partial settlement, etc. In order to prevent fraud, the counterparty may be required to also accept the obligation; alternatively, participants could report account payables and receivables to run a matching routine. This would occur in a privacy-preserving manner and may, for example, leverage some of the advances being made in zero-knowledge cryptography[9] to maximise the privacy of the data.

The platform would determine the optimum sequencing of payments and/or multilateral netting to ensure that the liquidity required to settle the system of obligations is minimal whilst adhering to the constraints set by the participants on each transaction; no external sources of liquidity would be required. The frequency of execution (e.g., daily, weekly, monthly) could be technically determined after testing and iterating or could be set to be dynamic, e.g., based on the total outstanding receivables, by value or number.

This FMI could reduce the outstanding exposures among firms, decrease the payment terms, and mitigate potential risks arising from undesirable feedback loop effects in trade credit networks. By implementing LSMs, risks and potential amplification effects from trade credit exposures are mitigated while their potential contribution to firms' growth, supply chain resilience, and economic activity is preserved.

Further, the introduction of LSMs to trade credit networks not only strengthens the supply chain but also helps to reduce the contagion effects from the real sector to the banking sector through balance sheet exposures. All in all, the economy as a whole is better off after introducing an FMI that runs LSMs in trade credit networks: there is a potential positive impact on economic growth that is accompanied by a decisive contribution to financial stability as contagion effects within and from the supply chain are mitigated.

[9] Zero-knowledge refers to a branch of cryptographic algorithms that allow one party to prove to another party a fact (such as an obligation) without disclosing any details of that fact other than the cryptographic proof of its veracity.

Coda: A New Source of Information for Decision Making

Beyond the potential positive impact on economic growth and financial stability, introducing this FMI could shed some light on the otherwise obscure supply chain. By gathering the data from trade credit, this new FMI would allow unparalleled visibility into the supply chains—a critical part of the economy from which it is often very difficult to get insights.

This would enable central banks to monitor liquidity and activity in the corporate sector and measure the effects of monetary policy on the real economy. From a financial stability viewpoint, this new data would enable central banks to monitor risk build-up in the corporate sector — in the form of delays and failures to pay among firms — and to stress-test the economy based on corporate shocks and cascading effects.

Governments may also find value in being able to better monitor trade credit. This could translate into a better understanding of tax flows (such as those related to value-added tax or goods and services taxes) and also strengthen their ability to detect certain forms of money laundering. Likewise, government agencies (e.g., the Ministry of Industry) may find it useful to monitor trade credit to enhance input-output analysis.

Also, commercial banks could enhance corporate credit risk modelling and scoring if the trade credit data becomes available. As it currently stands, part of the reason for trade credit is the information asymmetry inherent in the supply chains that make it difficult for banks to truly assess lending risk. However, by having visibility into the upstream and downstream obligations of a firm, banks can better assess the risk of default and also simulate different failure scenarios, such as the risk of cascading failures or concentration risks.

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