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Mitigating fire sales with a central clearing counterparty☆

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ABSTRACT

Theoretically, one rationale for central clearing counterparties is the mitigation of inefficiencies associated with distressed asset sales. With novel archival data, I empirically study the first event in economic history during which a CCP successfully played this role: the global wool crisis of 1900. In the leading wool futures market in France, an inefficient equilibrium with fire sales and cascading defaults could be avoided due to price support provided by surviving CCP members. Cooperation to achieve price support–which is nowadays the main element of CCP auctions–could arise due to family relationships and cultural proximity between traders.

1. Introduction

Distressed asset sales, typically occurring during financial crises, are associated with costly market disruptions, such as deviations of prices away from fundamentals (Coval and Stafford, 2007), inefficient liquidations when margin constraints bind (Brunnermeier and Pedersen, 2009), predatory trading and short-selling (Brunnermeier and Pedersen, 2005), or ex ante liquidity hoarding (Acharya et al., 2011).

Because of these inefficiencies, an important question is whether markets can be designed to eliminate fire sales. Theory suggests that policymakers can improve efficiency by episodically restricting the ability of investors to freely transact, through either circuit breakers (Greenwald and Stein, 1991) or short-sale restrictions (Brunnermeier and Oehmke, 2014). Alternatively, policy can prevent fire sales by providing liquidity to constrained agents (Diamond and Rajan, 2012) or by supporting prices via asset purchases. More recently, Kuong (2021) suggested that central clearing counterparties (CCPs) can also be instrumental to mitigate fire sales.

In this paper, I empirically assess the relevance of this claim, and discuss which CCP features can be explained by the need to eliminate fire sales. That CCPs can play a role in preventing distressed asset sales is not obvious. Most of the literature on central clearing has modeled other functions of CCPs, notably the management of counterparty risk (Biais et al., 2016; Kuong and Maurin, 2023) and the facilitation of netting (Koeppl et al., 2012). While they explain key aspects of CCPs' structure, these models cannot explain one important feature of central clearing: when a member defaults, CCPs do not liquidate the defaulter's assets right away — a practice that could result in fire sales. Instead, they organize auctions between surviving members, and penalize members submitting low bids (so-called "juniorization"). I argue that the specific form taken by CCP auctions can be understood as a privately-designed mechanism to mitigate inefficiencies that would otherwise be caused by fire sales. To empirically assess whether this is the case, I study the first event in economic history during which CCPs came to play this role.

I start by setting up a theoretical framework, largely based on Kuong (2021). It is well understood that, in models with pecuniary externalities, asset sales can give rise to multiple equilibria. If agents expect low prices in the future, they may sell assets today, pushing down prices, possibly triggering further rounds of asset sales (e.g., if they are subject to margin constraints, as in Brunnermeier and Pedersen, 2009). This equilibrium is inefficient and Pareto-dominated by another one with high price expectations and no sales. Such fire sales ultimately result from a coordination failure.

The key insight from theory is that a CCP can eliminate the inefficient equilibrium by setting up a mechanism ensuring – is some scenarios such as the default if a member – that prices never fall below a certain threshold. Compared to the outright liquidation of defaulted positions, CCP auctions act as a mechanism to support prices. The economic effect is equivalent to a government-led price support (e.g., via asset purchases), but it is implemented privately, via the

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widespread practice of "juniorization": members submitting low bids are either fined or see their default fund contribution (i.e., the part of members' resources that is pooled across CCP participants) impaired first. Theoretically, Huang and Zhu (2021) confirm that juniorization amounts to a price support in CCP auctions.

Empirically, I study the first historical event during which a CCP successfully organized cooperation between investors to eliminate fire sales. This historical investigation brings two benefits. First, evidence that CCPs can eliminate fire sales has been only narrative so far. CCP auctions are rare and data is kept confidential to researchers. To my knowledge, not a single researcher has had access to CCP auction data. Instead, publicly available archival data can be collected on specific historical events. Second, while auctions with juniorization mechanisms are now part of the standard rulebook of CCPs, this was not always the case. When CCP auctions first appeared, traders had to coordinate to avoid a coordination failure — which may sound as a contradiction in terms. Understanding the conditions of emergence of CCP auctions sheds light on the mechanisms that helped overcoming this contracting problem.

The setup I study is the global wool crisis of 1900. I collect archive data from Roubaix–Tourcoing (France), which was then a major center of the industrial revolution ("the French Manchester") and one of the two largest markets for wool trading and transformation in Europe. It had an active futures market with a CCP. Following fears of a wool shortage in 1898–1899, wool prices had increased globally and local traders had accumulated large stocks. The drop in prices in 1900 induced a first wave of defaults. Traders from Roubaix–Tourcoing knew that liquidating these traders' wool positions would induce another drop in prices, which would trigger new margin calls followed by new defaults. To end this "liquidity spiral", the CCP took two sets of decisions: (i) it prevented predatory short-selling by changing margining rules, and (ii) after several trading houses defaulted, it did not liquidate positions in the open market but arranged settlements with surviving traders at above-market prices.

Both decisions by the CCP were unprecedented: the CCP came to play a novel role which was not part of its mandate. In spite of early criticisms by some trading houses, the set of decisions taken by the CCP was soon widely praised as a model of how harmful liquidity spirals can be avoided. I study how coordination could be achieved in the absence of any regulatory intervention, and find that two main factors were essential.

First, there were family ties between the main trading houses, and strong family values. This allowed traders to find informal arrangements based on non-contractible information, and arguably made free-riding more costly.

Second, we know from economic theory that free-riding is possible whenever market prices coexist with non-market prices (Jacklin, 1987). Interestingly, when it was negotiating liquidations at off-market prices, the CCP explicitly refused to register any transaction from traders that would conduct side trades. It also suspended the publication of prices. These decisions proved sufficient to prevent any failure of coordination.

I then collect two types of data, to show that the CCP was successful at avoiding inefficient fire sales. On the one hand, I study data from futures prices, in Roubaix–Tourcoing, and in two other wool markets in Europe, Antwerp and Le Havre. In Kolmogorov–Smirnov tests and in difference-in-differences regressions, I find no evidence of a stronger price drop in Roubaix–Tourcoing relative to other markets. This is even true after exploiting variation across futures' maturity, based on the idea that short-term futures are more subject than long-term futures to deviations from the law of one price (because arbitrage across markets takes time).

On the other hand, I show that the successful management of the crisis in the futures market shielded the broader economy from real effects. Specifically, I hand-collect city-level data on trade flows and estimate difference-in-differences models to show that the crisis had no material impact on real economic activity at the local level, relative to other localities importing and exporting wool. I also collect narrative evidence that a similar crisis, occurring five years later in Paris – a futures markets which, at the time, had no CCP – had much more disruptive effects. Overall, I conclude that the conditions under which the CCP could mitigate fire sales and its indirect effects are consistent with those expected from theory.

I finally highlight the relevance of my findings for current discussions on CCP design. A general message from the paper is that CCP auctions should not just be seen a technical element of CCPs' default waterfall (whose purpose would only be to protect the CCP itself), but a mechanism to avoid market-wide prices dislocation when other institutions default. I also stress a few implications for the occurrence of CCP auctions, as well as for the design of incentive mechanisms and initial margins.

Related literature

This paper is primarily related to the literature on asset fire sales. Assets can be sold below their fundamental value either because the highest potential bidders are constrained (Shleifer and Vishny, 1992), because of limited market participation (Allen and Gale, 1994), or because of slow-moving capital (Grossman and Miller, 1988). Fire sales of financial assets have been documented in several markets (Coval and Stafford, 2007; Ellul et al., 2011). Anticipating future illiquidity, investors can behave strategically, giving rise to inefficiencies ex ante: financial market runs (Bernardo and Welch, 2004; Kuong, 2021), predatory trading (Brunnermeier and Pedersen, 2005) or liquidity hoarding (Acharya et al., 2011). More generally, the inefficiency of private contracting in the presence of pecuniary externalities is studied by Lorenzoni (2008), Krishnamurthy (2010) and Acharya and Viswanathan (2011).

A related literature studies the policies that can eliminate inefficient fire sales, in particular the ones arising from coordination failures. A particularly relevant paper is by Kuong (2021), who shows that inefficient equilibria with fire sales can be eliminated by a CCP or by price support mechanisms, such as asset purchases. Another relevant contribution is by Biais et al. (2021), who show that, if agents can write contracts on fire sale events, these may not lead to inefficiencies. In this context, the role of public policy may only be to facilitate ex ante contracting.[1] Beyond CCPs, policies restricting asset trading during illiquidity spikes, such as circuit breakers (Greenwald and Stein, 1991) or short-selling bans (Brunnermeier and Oehmke, 2014), can also be beneficial.

Also connected is a growing literature, surveyed by Menkveld and Vuillemey (2021), devoted to central clearing. This literature almost exclusively focuses on the role of CCPs as institutions insulating investors against counterparty risk (Biais et al., 2016), acting as delegated monitors of risk (Kuong and Maurin, 2023) and facilitating netting and settlement (Koeppl et al., 2012). Empirically, the literature shows that the establishment of CCPs has been associated with a reduction in counterparty risk (Loon and Zhong, 2014; Bernstein et al., 2019) and with real effects (Vuillemey, 2020).[2] This paper is the first, to my knowledge, to study the role of CCPs as institutions mitigating coordination failures associated with distressed asset sales. In doing so, my goal is not to claim that avoiding fire sales is the dominant motive for establishing CCPs. Instead, I claim that some features of CCPs that remain unexplained by standard theories – notably auctions with juniorization – can be understood as mechanisms to avoid fire sales.

[1] A number of models in which fire sales are inefficient, such as Gromb and Vayanos (2002) or Lorenzoni (2008), incorporate forms of market incompleteness that prevent ex ante contracting.

[2] Part of the literature studies the amount of collateral needed for CCPs to adequately provide insulation against counterparty risk (Duffie and Zhu, 2011; Duffie et al., 2015; Menkveld, 2017; Cruz Lopez et al., 2017). Bignon and Vuillemey (2020) study CCP defaults.

2. Theoretical background

In this section, I rely on the existing theoretical literature to provide an explanation about the mechanisms that can lead CCPs to mitigate fire sales. This theoretical background helps guiding empirical tests.

In a number of models, fire sales arise from coordination failures. A canonical example is Diamond and Dybvig (1983), in which strategic complementarities between depositors' decisions to run induces a bank to liquidate long-term assets at a low price. This insight has been extended in a number of directions to explain fragility and asset liquidations in other markets. In this respect, the theory that is most relevant to my setup is by Kuong (2021). As opposed to Diamond and Dybvig (1983), he models a setup in which debt is collateralized — which eliminates incentives to run arising from the "first come, first served" feature of deposits. However, in his setup, collateral does not eliminate multiple equilibria. If agents expect low asset (collateral) prices in the future, they will take actions that lead to more assets being sold preemptively: "Thus, the anticipation of fire sales *causes* fire sales" (Kuong, 2021, p. 2912). This equilibrium is Pareto-dominated by another one in which agents expect higher prices. While the collateral constraints in Kuong (2021) are endogenous, similar multiple equilibria arise in models in which collateral (or leverage) constraints are exogenous, such as Bernardo and Welch (2004), Brunnermeier and Pedersen (2009) or Krishnamurthy (2010).

Another advantage of the theory by Kuong (2021) is that he studies mechanisms that can eliminate the inefficient equilibrium with fire sales. One such policy is asset price guarantees, such as selected government or central bank asset purchases. Intuitively, if agents expect that asset prices will never fall below a certain threshold, they will no longer have incentives to sell preemptively. Another one is to set up a CCP which, in this model, should coordinate the fixation of margins. Based on these insights, it is possible to expand theoretical insights about the role of CCPs. In Kuong (2021), the value of CCPs comes from the fact that they are centralized agents that can standardized contract terms. But it is also possible to think of CCPs as a private price support mechanism — much like asset price guarantees that public authorities may offer. Indeed, upon the default of a member, CCPs often do not liquidate positions in the open market, but organize auctions in which they penalize low bids. This leads to high auction prices, as demonstrated by Huang and Zhu (2021). When joining a CCP, members pre-commit to pay high auction prices in case a member's position needs to be liquidated. As such, CCPs can be understood as a price support mechanism that can eliminate inefficient equilibria with fire sales.

This theoretical argument about CCPs raises two final concerns. The main one is related to the potential for free-riding. Indeed, agents benefit from central clearing by eliminating costly fire sales in some states of the world, but this comes at the cost of a commitment to submit high bids during default events. In this context, an opportunistic agent who chooses to opt out of the CCP would benefit from the elimination of fire sales, but would not have to pay high prices in CCP auctions. If all agents behave opportunistically, the mechanism breaks down. Such free-riding is akin to the one modeled by Jacklin (1987) in the context of the model by Diamond and Dybvig (1983). However, CCPs are in an ideal position to eliminate free riding, precisely because they are centralized institutions. In a number of markets, trading outside CCPs is impossible or very costly. In addition, to the extent CCPs provide extra benefits, beyond the mitigation of fire sales (such as netting or counterparty risk insulation), trading outside CCPs also prevents enjoying these benefits. This further raises the cost of free-riding.

The second question is about the type of fire sales that CCPs can eliminate. In the above argument, a key point is that, upon the default of a CCP member, other members are credibly able to purchase the defaulted position at a high price. This requires the shock that triggered the initial default to be sufficiently idiosyncratic. In the case of systematic shocks, by which many agents are simultaneously in distress, CCPs may not be able to credibly avoid fire sales and the associated inefficiencies. In sum, CCPs may be especially important to avoid second-round defaults or "liquidity spirals" that would otherwise occur following idiosyncratic defaults.

3. Historical background and data

I now provide empirical evidence of a CCP's involvement to mitigate fire sales. Historically, this role of CCPs first appeared in Roubaix–Tourcoing's wool futures market (France) in 1900.

3.1. The wool market of Roubaix–Tourcoing

Throughout the 19th century, Roubaix–Tourcoing (the "French Manchester") was a major center of the industrial revolution in Europe, and the main place for wool trading, warehousing and transformation in France (representing about two-thirds of the domestic activity).[3] All main European wool trading houses had offices in either of these two neighboring cities, and 70% of the local workforce was in the textile industry.

Wool trade gave rise to large inventories and thus to significant price risk for dealers. Indeed, following shearing, dealers imported the yearly wool output within a few weeks (in large part from Australia). They warehoused this output and catered to the demand by industrial firms during the subsequent year (Raffalovich, 1901). To hedge the value of inventories, a futures market and a CCP (called *Caisse de Liquidation et de Garantie*, henceforth *CLG*) had been created in 1888 (Mussault, 1909).[4] The functioning of the CLG was similar in most respects to that of modern CCPs. After novation, the CCP bears all counterparty risk, and manages it using initial and variation margins (see Appendix B.1 for details). Whenever a trader defaults on a margin call, the CCP immediately liquidates this traders' position. Importantly, when it was created, the CLG did not incorporate any mechanism to liquidate positions at above-market prices. Such mechanisms emerged during the wool crisis of 1900.

3.2. The 1900 wool crisis

The crisis of 1900 results from a significant increase in wool prices, followed by a sharp drop, as seen in Panel A of Fig. 1. Due to fears of a global shortage, starting in 1897–1898, dealers piled up wool stocks, bidding up world prices (see Appendix B.2). Starting in January 1900, prices gradually fell due to reassuring news about production. By September 1900, the nearest-term future prices had dropped by 46% (from 6.775 to 3.650 FRF/kilogram). During these few months, a syndicate of traders from Roubaix–Tourcoing attempted to contain the fall in prices by boosting demand. This upward price pressure was not immediately arbitraged away, and explains some of the price differences observed with the other main European wool market in Antwerp (see Panel A of Fig. 1). With short lags, however, arbitrage trading took place: wool flowed from other European countries to Roubaix–Tourcoing (Delcambre, 1907). The large accumulation of unhedged inventories by members of this syndicate – amid falling global prices – is the main reason why a crisis hit Roubaix–Tourcoing significantly more than other European wool markets (Antwerp, Leipzig, etc.).

Severe turmoil started in August 1900, due to the suspension of margin payments by a number of large trading houses. Within a few days, 18 trading houses suspended payments and a few of them entered

[3] Together with the UK, France was one of the two largest markets for wool trade worldwide (Daviet, 1987). The UK were most important for the transit of wool, whereas France was better known for its transformation.

[4] The first derivatives CCP was created in 1882 in Le Havre's coffee futures market to insulate traders against counterparty risk (Vuillemey, 2020). Following its success, a wave of new CCP creation occurred in Europe in the late 1880s and early 1890s (Depitre, 1907).

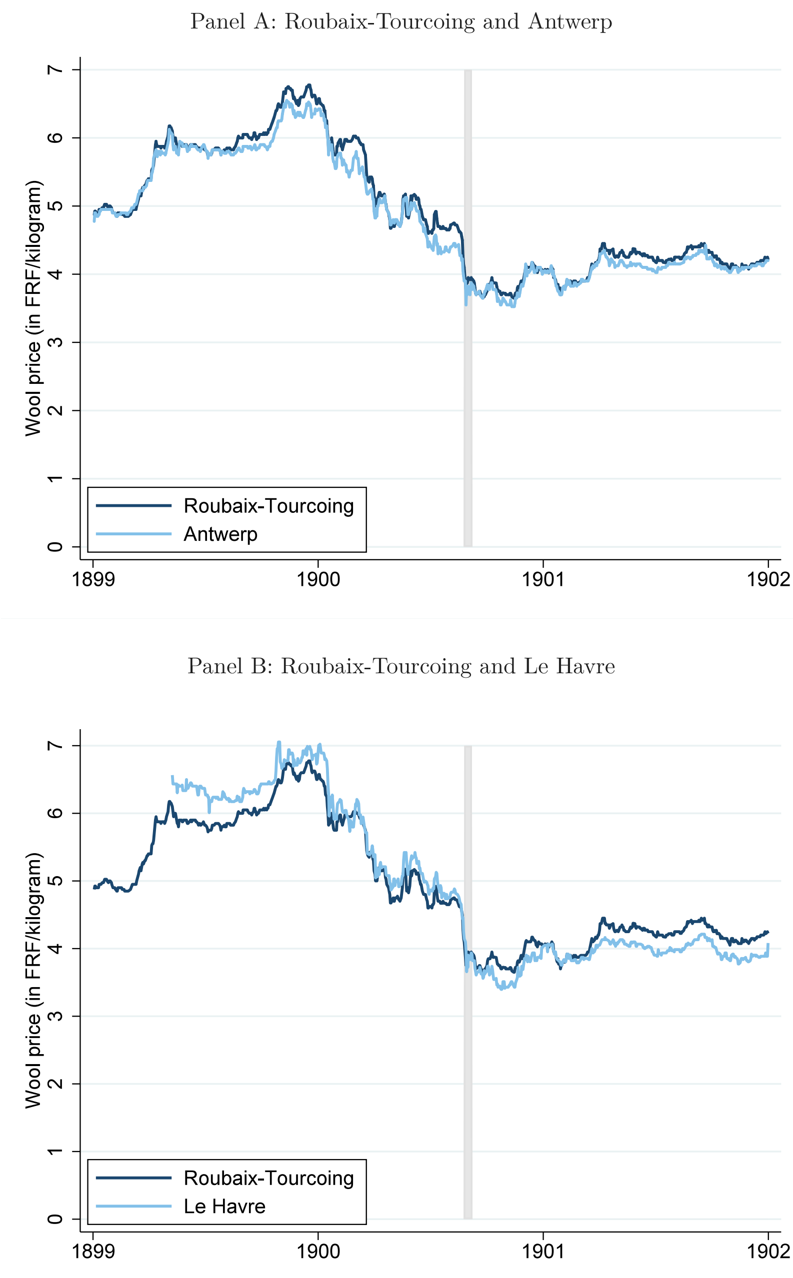

Fig. 1. Wool prices across markets.
This figure plots the daily price of the nearest-term future price in Roubaix–Tourcoing and Antwerp (Panel A) and in Roubaix–Tourcoing and Le Havre (Panel B) from January 1899 to December 1901. Data in Le Havre starts only on the 8th of May 1999, due to a change in the type of futures traded. To be comparable on the same scale, data in Le Havre is normalized to be equal to the data in Roubaix–Tourcoing on the first trading day of year 1901. The shaded area corresponds to the peak of the 1900 wool crisis, from August 25th to September 7th.

insolvency, while most were illiquid.[5] This wave of defaults should have triggered massive liquidations of either future contracts or physical wool, which would have further depressed prices. Interestingly, the crisis was understood by contemporaries as a "liquidity spiral", in the sense of Brunnermeier and Pedersen (2009): an initial drop in prices leads to margin calls, which force traders to liquidate positions, thereby inducing prices to drop further (see Appendix B.3 for evidence). Such liquidity spirals are akin to the Pareto-dominated equilibria discussed in Section 2. In this context, the event of interest is that the CCP managed to eliminate fire sales by organizing coordination between surviving traders. The crisis was nonetheless perceived as extremely severe, and sparked a long-lasting parliamentary debate on banning futures markets in France (Mussault, 1909).

3.3. Data

To study these events, I use a number of archive sources, further described in Appendix A. The main source of quantitative data is the *Bulletin des Laines*, a newspaper published daily in Roubaix–Tourcoing

[5] See *Journal de Roubaix*, dated September 2nd, 1900. Other sources give slightly different numbers (between 14 and 20). The difficulty to assess the number of payment suspensions comes from the fact that several trading houses were illiquid but not insolvent.

that compiles information about the local, national and international wool markets. From this newspaper, I retrieve daily future prices at all traded maturities, for the markets of Roubaix–Tourcoing, Antwerp and Le Havre. During the 1900 crisis, the *Bulletin des Laines* additionally devoted many articles to describe the CCPs' decisions, and to analyze the crisis more broadly. To reconstruct the history of the crisis, I also consult other newspapers, in particular the daily *Journal de Roubaix*, and rely on accounts by contemporaries, primarily Pupin (1900), Raffalovich (1901), Delcambre (1907) and Mussault (1909). To study the real effects of the 1900 crisis, I finally hand-collect imports and exports data at the city-commodity-year level from the *Tableau général du commerce*, that is, French customs' data.

4. Empirical evidence

I now show how the CCP's decisions ended the "liquidity spiral" and thus mitigated the inefficiencies associated with fire sales.

4.1. Decisions to mitigate fire sales

The end the liquidity spiral, the CCP took two sets of decisions. First of all, it took a series of decisions to mitigate predatory short-selling, that is, short sales that aim to push prices down and force constrained investors to sell assets at depressed prices. The CLG increased initial margins in several steps, first from 1000 FRF to 2000 FRF, then to 3000 FRF per contract.[6] Starting on August 28th, the CLG decided to considerably increase initial margins specifically on short positions — to 10,000 FRF per contract.[7] The CLG additionally announced that any operation that would not be settled with physical delivery would face a financial penalty (250 FRF per contract). This further discouraged speculators from engaging in predatory trading. While not exactly akin to a short-selling ban (which the CLG could not legally impose), these decisions made it extremely costly for agents to take any naked short position on wool. It is striking that the CCP could privately achieve this outcome; indeed, in models where short-selling bans are the efficient response to predatory trading, they are typically imposed by a regulator (Brunnermeier and Oehmke, 2014). The use of margins to avoid deviations of prices away from fundamentals was a novelty.

Second, after several trading houses defaulted, the CLG did not liquidate these traders' positions in the open market. Instead, the CCP agreed with surviving trading houses to sell positions on a bilateral basis at prices above the market price. Delcambre (1907, p. 166) writes that "instead of throwing defaulted positions in the open market, the CLG sold them amicably. They were bought at a single price by houses which, having sold futures in the past, agreed to close their positions". Even though the details of the multilateral agreement do not seem to have survived, the ability of the CCP to implement such a deal to avoid fire sales was a contractual novelty. There is no evidence that similar arrangements ever existed in previous CCPs.

It is remarkable that both short-selling restrictions and off-market settlement could be implemented privately to eliminate potential coordination failures. While consistent with the model by Kuong (2021), the ability to privately mitigate fire sale externalities was not part of the CLG's initial mandate. In particular, neither the margining rules imposed by the CCP nor the settlement of defaulted positions via off-market sales were consistent with the CLG's rulebook. Consequently, when they were taken, both measures were harshly criticized by some market participants, both in Roubaix–Tourcoing and in other markets.[8] However, soon after the CLG was successful at containing the liquidity spiral, criticisms vanished and these decisions were generally praised (Delcambre, 1907; Depitre, 1907). This is consistent with the idea that traders quickly recognized that the CLG had acted in the best interest of the marketplace, not in the specific interest of one side of the market. In this context, it is essential to understand how the CCP could implement a value-improving arrangement that was not part of its mandate.

4.2. Achieving coordination

Two main factors explain the ability of the CCP to achieve coordination between surviving members. The first one is the existence of close family ties between the main trading houses in Roubaix–Tourcoing, together with strong family values. The role of family values in Roubaix–Tourcoing's wool industry, as well as strong religious (catholic) values, have been documented most notably by Landes (1976). Furthermore, the practice of endogamy – that is, marriages between the main local families in the textile industry – was strict (Daumas, 2004, p. 241 to 243). Businessmen from the main trading houses (Motte, Desurmont, Tiberghien, Masurel, etc.) were linked through a complex structure of cousinship. These close ties between local wool traders provided two distinct benefits in order to achieve coordination. First, informal family relationships can be a substitute for formal legal arrangements (Burkart et al., 2003). As such, outcomes that could otherwise be implemented only by a regulator (social planner) could be made possible without regulation: family relationships expand the set of feasible outcomes by allowing for informal arrangements based on non-contractible information. Second, family ties make it more costly for an individual to deviate from the socially optimal behavior and thus to make coordination break down. Indeed, if family values are strong, free-riding on family members is associated with a high reputational cost.

Second, even strong and valued family relationships do not ensure that coordination failures can be avoided. Indeed, as shown by Jacklin (1987) in the context of the model by Diamond and Dybvig (1983), market and non-market prices cannot coexist whenever agents can freely trade in the open market. In the specific case of wool crisis, the concern is that surviving traders individually buy wool at a depressed market price while other traders buy it at above-market prices from the CCP. Theoretically, if such side trades are possible (or, in other words, if an open market for wool exists in parallel with the CCP's sale), then coordination is likely to break down. It is remarkable that the CCP took two decisions specifically addressing Jacklin (1987)'s critique. First of all, the CLG declared that it would refuse to register any transaction from a trader that would conduct side trades.[9] That is, traders had to clear either all or none of their transactions with the CCP. This made it virtually impossible to conduct side trades. Indeed, in a period of elevated counterparty risk, traders were reluctant to leave futures transactions uncleared.[10] Second, to make it even more difficult to conduct side trades, the CLG decided to suspend the publication of prices during

[6] Decision taken on August 24th, see *Bulletin des laines* from August 27th, 1900.

[7] See *Bulletin des laines* from August 29th, 1900.

[8] For example, the *Journal de Roubaix* on September 7th, 1900, reproduced the following testimony from a wool trader in Le Havre: "All we hear and read from Roubaix–Tourcoing, all the weird and illegal decisions taken by the CLG, [...], demonstrate that the principles of future markets were never understood there. The CLG is everything, does everything, governs everyone. It elaborates technical rules that should be written by others, it quadruples margin requirements for some parties, it acts as a tribunal imposing fines, it chooses which traders to accept. The CCP there is a monster that constantly threatens traders, a school teacher constantly with a stick in the hand".

[9] See *Bulletin des laines* from August 27th, 1900.

[10] As in the case of Le Havre's coffee market (Vuillemey, 2020), anecdotal evidence suggests that, soon after the creation of the CCP, virtually all trades were centrally cleared.

Table 1
Kolmogorov–Smirnov tests with wool prices.

Window	Before the crisis				After the crisis			
	Mean price		KS-stat.	p-val.	Mean price		KS-stat.	p-val.
	Roub.-Tour.	Antwerp			Roub.-Tour.	Antwerp		
30 days	4.619	4.316	0.900***	(0.000)	3.800	3.754	0.300	(0.134)
100 days	4.787	4.622	0.435***	(0.000)	3.854	3.784	0.253***	(0.004)
200 days	5.322	5.143	0.213***	(0.000)	3.948	3.889	0.143**	(0.037)

This table presents the results from Kolmogorov–Smirnov tests assessing whether the distributions of the nearest-term wool future price in Roubaix–Tourcoing and in Antwerp are similar. The test is performed separately for the periods before and after the 1900 crisis, and for three time windows: 30 days, 100 days and 200 days before and after the crisis. These time periods are defined relative to August 25th, 1900. The mean prices, the Kolmogorov–Smirnov statistic (KS-stat.) and the p-value for the tests are reported. *, ** and *** refer respectively to statistical significance at the 10%, 5% and 1% levels.

the time period needed to reach an agreement (Delcambre, 1907, p. 166). Therefore, the only price that was known to market participants (apart from prices in Antwerp, where no forced sales were taking place) was the price at which the CCP was settling defaulted positions. As such, it is remarkable that the decisions taken by the CCP implemented a private solution to Jacklin (1987)'s problem.

4.3. Empirical evidence from prices

Next, I provide quantitative evidence that the CCP was successful at avoiding fire sales, in the sense that we observe no sustained depression of prices in Roubaix–Tourcoing after the crisis. To see this, I run two sets of tests that compare futures prices in Roubaix–Tourcoing and in Antwerp around the crisis. Antwerp is the most natural benchmark, for at least two reasons: futures traded in Antwerp are written on a type of wool that is similar to the one traded in Roubaix–Tourcoing (worsted wool), and the futures market is liquid and deep. The other two main wool markets in Europe are less suitable as benchmarks: the market is Leipzig closed before the crisis of 1900, so that no data is available; the market in Le Havre is for a distinct grade of wool (raw wool). Thus, if we expect the law of one price to hold (almost) exactly, it should be between Roubaix–Tourcoing and Antwerp.

Theoretically, it is not obvious that we should observe any deviation from the law of one price between Roubaix–Tourcoing and Antwerp, even if there are fire sales only in Roubaix–Tourcoing. Indeed, if arbitrage is efficient enough, any price difference between the two markets will almost immediately be traded upon and disappear. For my tests, I rely on the fact that arbitrage between the two markets is "slow-moving" (Duffie, 2010). Specifically, trading in wool futures is almost exclusively done by physical traders and dealers.[11] Arbitrage thus often requires physical wool to move across markets — which takes time and comes at a cost.[12] For this reason, arbitrage opportunities are harder to exploit at short maturities than at longer maturities. This fact is confirmed by studying the standard deviation of price differences between Roubaix–Tourcoing and Antwerp: it is larger at the 1-month maturity than at the 6-month maturity (0.107 versus 0.070). Beyond this, short-term and long-term futures are comparable in many respects: initial margin requirements are similar for all maturities, the volatility of 1-month and 6-month futures is almost identical (standard deviations of respectively 0.900 and 0.891 over the 1899–1901 period), and both are traded frequently (i.e., it is not the case that the low volatility of long-term futures can be attributed to the absence of trades).[13]

To summarize, if we expect the law of one price to fail, it should fail primarily for nearest-term futures. This is why, in my baseline tests, I focus only in these futures. Next, I will study explicitly the price difference between nearest-term and 6-month futures in a difference-in-differences setting.

In my first set of tests, I compare the distribution of prices on nearest-term future in Roubaix–Tourcoing and in Antwerp, both before and after the crisis. To begin with, Fig. 2 plots the cumulative distribution function of prices in these two markets, separately before and after the crisis, for three time windows: 30 days, 100 days and 200 days. We clearly see that the largest price divergence between prices in these two markets occurs before the crisis, with higher prices observed in Roubaix–Tourcoing. After August 1900, the two distributions are almost indistinguishable. The fact that distributions are most different before the crisis is confirmed by estimating Kolmogorov–Smirnov tests, that is, tests for whether two distributions are identical. The results, in Table 1, show much lower p-values pre-crisis, confirming that distributions are most different in this period.

A potential interpretation of these findings could be that significant differences in price levels before the crisis that close afterwards are evidence of fire sales, since price levels change on a sustained basis. However, this interpretation is not supported by the data. Indeed, as Fig. 2 shows, the differences in distributions are most striking just before the crisis (top panel) and are less marked over longer horizons (100 or 200 days before). Visual inspection of Panel A of Fig. 1 also shows that prices in Roubaix–Tourcoing and Antwerp are not on a different level on a sustained period after the crisis. Instead, it is when the crisis approaches that price differences widen. This statistical evidence is consistent with narrative accounts that a syndicate of buyers was pushing prices up via massive purchases in Roubaix–Tourcoing before the crisis. All in all, these patterns are inconsistent with fire sales: after August 1900, prices in Roubaix–Tourcoing and Antwerp are remarkably similar, as they were long before the crisis (e.g., through most of 1899).

The absence of discernable fire sale dynamics is also confirmed in Panel B of Fig. 1, which plots prices in Roubaix–Tourcoing and in another wool market, Le Havre (also in France). Here, the law of one price holds less precisely, because the type of wool traded in Le Havre is distinct from that traded in Roubaix–Tourcoing (raw wool, as opposed to worsted wool). But the fact that prices do not drop significantly

[11] In various archives and in newspaper discussions of the 1900 crisis, I find no names of financial institutions involved in the wool market. Furthermore, at the time, the main source to assess the financial condition of banks are inspection reports of the Banque de France's local subsidiaries. Reading these reports for the years 1900 and 1901, I find no evidence of large bank exposure to the wool futures market.

[12] Unfortunately, there does not seem to be any detailed archive data recording which trades (or shares of trades) are physically or cash settled.

[13] Data on the volume traded at each maturity are reported in the *Bulletin des laines* but is not always readable from the microfilms of the National library in Paris. A simple way to assess whether there are large differences in trading volume across maturities is to measure the frequency of days with zero-returns. This frequency is similar for 1-month and 6-month futures (38.51% and 36.77% respectively). One limitation of this measure is that zero returns can be realized even when there is non-zero trading volume (due to a fairly large tick size).

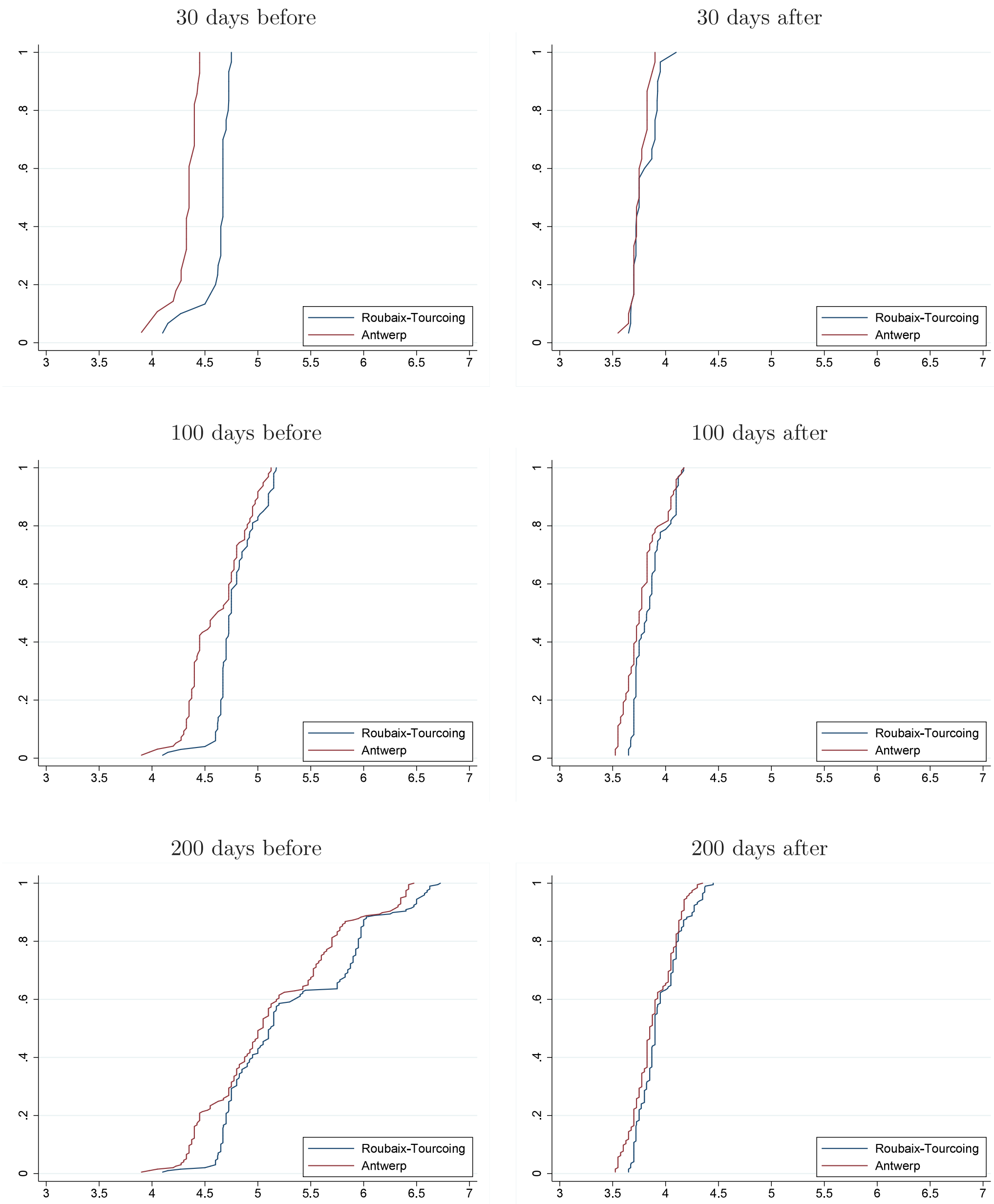

Fig. 2. Distribution of prices before and after the 1900 crisis.
This figure plots the cumulative distribution functions of the nearest-term wool future price in Roubaix–Tourcoing and Antwerp over three time windows: 30 days, 100 days and 200 days before and after the crisis. These time periods are defined relative to August 25th, 1900.

more in Roubaix–Tourcoing is nonetheless confirmed. If anything, the opposite is observed.

In my second set of tests, I exploit explicitly – in a difference-in-difference regression – the fact that deviations from the law of one price are more likely to arise for short-term than for longer-term futures. Specifically, I define

$$\Delta P_{m,t}^{RoubaixTourcoing-Antwerp} = \left| P_{m,t}^{RoubaixTourcoing} - P_{m,t}^{Antwerp} \right|, \quad (1)$$

as the absolute price difference between Roubaix–Tourcoing and Antwerp for contracts with maturity m at date t. I then compare contracts for which $m = 1$ month with contracts for which $m = 6$ months. I then estimate

$$\Delta P_{m,t}^{RoubaixTourcoing-Antwerp} = \alpha + \beta \cdot Post_t \cdot Treated_m + \gamma \cdot Treated_m + \mu \cdot Post_t + \epsilon_{m,t}, \quad (2)$$

where $Treated_m$ is a dummy variable equal to 1 when $m = 1$ (that is, the shortest futures, which are theoretically more subject to fire sales) and where $Post_t$ is a dummy variable equal to 1 starting on August 25th, 1900. If there are fire-sales at the shortest-maturities (i.e., the ones that are the most difficult to arbitrage), then we expect $\beta > 0$, that is, the absolute price difference should widen specifically for short maturities after the crisis.

In Panel A of Table 2, Eq. (2) is estimated on five time windows of 20, 30, 50, 100 and 200 trading days around the crisis, with robust standard errors. Across all specifications, I obtain a robust finding: the estimated coefficient β is negative and significant, not positive. To interpret this sign, β needs to be compared to γ, the coefficient on $Treated_m$ during the pre-crisis period: this coefficient is positive and significant, confirming the above finding that the largest deviations from the law of one price for short-term futures occurred before, not after, the crisis. Given this fact, we also observe that the magnitudes of β and γ are roughly similar, leading to the following conclusion: the negative sign β post-crisis simply corresponds to a correction of

Table 2
Investigating prices across maturities.

Panel A: Between 1-month and 6-month ahead maturities					
	Diff. prices	Diff. prices	Diff. prices	Diff. prices	Diff. prices
Treated*Post	−0.086***	−0.088***	−0.111***	−0.065***	−0.070***
	(0.026)	(0.020)	(0.017)	(0.017)	(0.012)
Treated	0.088***	0.086***	0.096***	0.049***	0.060***
	(0.017)	(0.013)	(0.012)	(0.015)	(0.011)
Post	−0.120***	−0.142***	−0.092***	−0.035***	−0.064***
	(0.016)	(0.013)	(0.012)	(0.010)	(0.007)
Days before/after	20	30	50	100	200
Robust std. error	Yes	Yes	Yes	Yes	Yes
Adj. R2	0.690	0.771	0.642	0.172	0.290
Obs.	75	113	193	386	768

Panel B: Between current month and 6-month ahead maturities					
	Diff. prices	Diff. prices	Diff. prices	Diff. prices	Diff. prices
Treated*Post	−0.098***	−0.095***	−0.113***	−0.073***	−0.064***
	(0.024)	(0.020)	(0.017)	(0.017)	(0.013)
Treated	0.077***	0.081***	0.097***	0.054***	0.058***
	(0.017)	(0.014)	(0.013)	(0.016)	(0.011)
Post	−0.120***	−0.142***	−0.092***	−0.035***	−0.064***
	(0.016)	(0.013)	(0.012)	(0.010)	(0.007)
Days before/after	20	30	50	100	200
Robust std. error	Yes	Yes	Yes	Yes	Yes
Adj. R2	0.752	0.799	0.651	0.192	0.277
Obs.	69	99	175	351	694

This table displays the results from the estimation of Eq. (2). In both panels, the dependent variable is the difference between future prices in Roubaix–Tourcoing and in Antwerp, at maturities of either 6 months and 1 month (Panel A) or 6 month and the current month (Panel B). The treated maturity is the shortest one. The model is estimated on windows of either 20, 30, 50, 100 and 200 trading days around the start of the wool crisis on August 25th, 1900 (respectively in columns 1 to 5). Robust standard errors are in parentheses. *, ** and *** refer respectively to statistical significance at the 10%, 5% and 1% levels.

some mispricing that occurred before the crisis (with $\gamma > 0$). This again confirms the findings from the Kolmogorov–Smirnov tests, but now in a difference-in-differences setting. Finally, I confirm these findings in Panel B of Table 2, in which I focus on current-month futures as opposed to next-month futures.[14]

4.4. The absence of real effects: Evidence from trade flows

Another way to assess whether the CLG was successful at eliminating the inefficiencies that outright sales of defaulting members' positions may have caused, is to study whether the crisis had real effects. To test whether this is the case, I rely on data on local trade flows from the French customs.

Theoretically, if fire sales of wool contracts occur, we could expect a transmission from the futures market to local trade flows. As discussed above, the vast majority of participants in the exchange were wool traders and dealers, actively involved in the import, storage and export of physical wool. Large losses or a sudden drop in the ability to hedge, in the presence of financing constraints, could induce them to cut their activities in the market for physical wool. Empirically, in the context of another commodity market, a sizeable impact of the ability hedge on trade flows has been demonstrated (Vuillemey, 2020). Focusing on local trade flows also brings two other benefits. Relative to other real outcomes, such as production or employment, they are consistently measured, at a commodity-city level, over a long sample period. Finally, it is well-documented that trade flows are two to three times more volatile than real outcomes such as GDP (see, for example, Houthakker and Magee, 1969; Ahn et al., 2011). Therefore, if the 1900 crisis had significant real effects, they should be reflected in trade flows.

To test whether this is the case, I hand-collect imports and exports over the 1896–1905 period for 14 textile commodities and for the 24 largest customs in France, which include Roubaix and Tourcoing separately.[15] This corresponds to 13,440 observations in total. Descriptive statistics on textile trade flows for the main customs are provided in Table 3. I use these data to estimate a variety of difference-in-differences models, comparing wool trade flows with flows in other textiles.

Difference-in-differences using total trade flows

I start by estimating a difference-in-differences model based on total trade flows, that is, imports or exports of all goods combined, expressed in volume. Specifically, I compare the volume of total imports or exports for Roubaix and Tourcoing (or other neighboring customs that could cater to these cities) to the volume of trade in other French cities around the crisis of 1900. Focusing on imports and exports of all goods relies on the idea that the 1900 crisis could have affected not just the local wool industry, but the local economic activity more broadly. This hypothesis is reasonable, given that local activity in Roubaix–Tourcoing was heavily concentrated in the textile industry (up to 70% of the local workforce).

Specifically, I define $Post_t$ to be equal to one after 1900, and $TrCity_c$ a dummy equal to one for cities potentially affected by the 1900 wool crisis, including Roubaix and Tourcoing. I estimate

$$Trade_{ct} = \beta_1 \cdot Post_t \cdot TrCity_c + \beta_2 \cdot Post_t + \beta_3 \cdot TrCity_c + \epsilon_{ct}, \tag{3}$$

where $Trade_{ct}$ is either the share of imports or exports of city c within total French imports or exports in year t, or the log volume of trade in city c in year t. The treated cities include naturally Roubaix and Tourcoing. However, the baseline regressions also consider the neighboring city of Lille (12 km away) and the neighboring harbor of Dunkerque (65 km away) as treated. Indeed, while Roubaix, Tourcoing and Lille are distant from the sea, Dunkerque was the main harbor through which wool and other goods were entering or exiting the local

[14] There are fewer data points for this test, since current-month futures often stop being traded a few days before being settled and delivered.

[15] The list of sampled cities is given in Appendix A.

Table 3
Share of imports and exports by customs — 1896 to 1905.

	All goods	Raw wool	Woolen textiles	Raw cotton	Cotton textiles	Raw silk	Silk textiles	Diverse threads
Panel A: Share of imports								
Bordeaux	0.078	0.066	0.019	0.002	0.101	0.000	0.000	0.009
Cette	0.033	0.012	0.001	0.001	0.000	0.000	0.000	0.080
Dunkerque	0.098	0.550	0.007	0.115	0.020	0.000	0.000	0.089
Jeumont	0.135	0.003	0.000	0.000	0.001	0.001	0.000	0.008
Le Havre	0.100	0.035	0.066	0.763	0.167	0.008	0.352	0.004
Lille	0.002	0.000	0.003	0.001	0.003	0.000	0.001	0.054
Marseille	0.173	0.147	0.181	0.066	0.438	0.965	0.112	0.058
Nantes	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.002
Roubaix	0.001	0.003	0.005	0.003	0.000	0.001	0.000	0.026
Rouen	0.098	0.003	0.009	0.006	0.007	0.000	0.000	0.012
Saint-Nazaire	0.058	0.000	0.011	0.000	0.011	0.000	0.001	0.000
Tourcoing	0.010	0.079	0.007	0.013	0.001	0.002	0.000	0.058
Panel B: Share of exports								
Bordeaux	0.130	0.073	0.024	0.000	0.061	0.000	0.003	0.025
Cette	0.027	0.001	0.001	0.000	0.001	0.000	0.000	0.038
Dunkerque	0.079	0.041	0.006	0.003	0.018	0.000	0.000	0.174
Jeumont	0.039	0.030	0.002	0.000	0.005	0.004	0.002	0.004
Le Havre	0.109	0.043	0.172	0.158	0.359	0.128	0.431	0.083
Lille	0.005	0.000	0.001	0.044	0.001	0.000	0.000	0.072
Marseille	0.326	0.102	0.137	0.145	0.397	0.499	0.106	0.112
Nantes	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.006
Roubaix	0.002	0.062	0.101	0.029	0.004	0.003	0.000	0.023
Rouen	0.036	0.002	0.001	0.020	0.029	0.000	0.000	0.021
Saint-Nazaire	0.022	0.001	0.020	0.000	0.016	0.000	0.004	0
Tourcoing	0.020	0.447	0.021	0.046	0.003	0.010	0.002	0.193

This table reports the share of total French imports and exports for 12 customs. I report shares for raw wool and woolen textiles (treated commodities), for five other goods in the control group, and for imports of all goods combined (measured in volume). The shares are averaged over the period from 1896 to 1905.

market (see Table 3).[16] For each of these four cities, Fig. 3 shows preliminary evidence that neither the share of imports nor the share of exports, as a percentage of total French imports or exports, seem to have been going down systematically.

The estimates from Eq. (3) are displayed in Table 4 for imports and in Table 5 for exports. The baseline estimation, including Dunkerque and Lille as treated cities, shows no statistically significant effect on the crisis on local trade flows (Panel A of both tables), regardless of whether they are measured in shares of French trade (column 1) or in log volume (column 4). This holds true for both imports and exports. Then, remaining columns show that the absence of negative effect of the crisis on trade flows is robust to including only Roubaix and Tourcoing as treated cities (columns 2 and 5), and to excluding imports and exports that move in and out of warehouses (columns 3 and 6).[17]

A natural question is whether the difference-in-differences estimates of Panel A hide short-term drops in trade flows that get reverted later. To address this concern, I re-estimate Eq. (3) after interacting $TrCity_c$ with five dummy variables taking a value of one for each year from 1901 to 1905. The results, in Panel B of Tables 4 and 5, show no impact of the 1900 crisis on the share of trade flows for treated cities, regardless of the specification (columns 1 to 3). When imports and exports are measured in log volume (columns 4 to 6), the estimates show a decrease in trade activity in 1901–1902 (and 1903 for exports). However, the estimates are never statistically significant. I conclude that the 1900 crisis did not depress the general economic activity in Roubaix–Tourcoing even in the years that immediately followed the crisis (see Figs. 4 and 5).

Triple differences estimation at the city-good level

While I observe no decline in total trade activity, a question is whether, in the cross-section of industries, the wool industry was particularly affected by the 1900 crisis. Finding no effect specifically on wool activity would suggest that the CLG was particularly successful at containing fire sales. To assess whether this is the case, I conduct a triple difference-in-differences estimation, by exploiting three sources of variation, (i) before and after 1900, (ii) within trade flows in wool, variation between treated and other cities, and (iii) within treated cities, variation between wool and other textiles. Exploiting all three sources of variation enables ruling out confounding explanations relying either on commodity-specific or on city-specific demand and supply shocks. The estimated equation is

$$\begin{aligned} Trade_{cgt} = {} & TreatedCity_c \cdot \sum_{s=1901}^{1905} \beta_{1,s} \cdot \mathbb{1}_{\{t=s\}} + \cdot TreatedGood_g \cdot \sum_{s=1901}^{1905} \beta_{2,s} \cdot \mathbb{1}_{\{t=s\}} \\ & + TreatedCity_c \cdot TreatedGood_g \cdot \sum_{s=1901}^{1905} \beta_{3,s} \cdot \mathbb{1}_{\{t=s\}} \\ & + \mu_t + \mu_{cg} + \epsilon_{cgt}, \end{aligned} \quad (4)$$

where $\mathbb{1}_{\{t=s\}}$ is an indicator variable that takes a value of one when $t = s$. As before, treated cities in the baseline specification are Roubaix, Tourcoing, Lille and Dunkerque, while the treated good is raw wool. Control goods include other textiles.[18]

[16] The customs data do not record the starting point or the final destination of trade flows, but the point at while they legally cross the borders, that is, where duties are paid or where they are stored in duty-free warehouses.

[17] I rely on a distinction in customs data between *general* and *special* trade. When goods are imported from abroad, either a duty is paid and the good can be consumed locally, or it can be stored in duty-free warehouses and be re-exported in the future. General imports include the sum of both components, while special imports include only imports for consumption. Similarly, when goods are exported abroad, either they come from domestic production, or they come from abroad and were warehoused domestically. General exports include the sum of both components, while special exports include only exports from domestic production.

[18] Specifically, they are hemp, raw cotton, cotton textiles, diverse threads, raw linen, linen textiles, raw furs, diverse furs, raw silk, silk textiles, silk cocoons. Depending on the specification, woolen textiles are either in the treatment or in the control group.

Fig. 3. Share of total French trade — Imports and exports.
This figure plots the share of total imports/exports of all goods (measured in volume) over total French imports/exports for four harbors potentially affected by the 1900 crisis: Roubaix, Tourcoing, Dunkerque and Lille. Data is at a yearly frequency over the period 1896–1905. The vertical gray line indicates the 1900 crisis.

The estimates for the coefficients of interest, $\beta_{3,s}$, are displayed in Table 6, in Panels A and B respectively for imports and exports. First of all, whenever the dependent variable is the share of either imports or exports relative to total French imports or exports (columns 1 to 4), we observe no statistically significant drop in trade flows. This is true regardless of the specification: when only Roubaix and Tourcoing are considered treated (column 2), when focusing on special trade flows (as defined in footnote , column 3), and when including woolen textiles as treated goods. The evidence is broadly consistent, albeit mixed, when measuring imports and exports by their log volume (columns 5 to 8). In the baseline specification (column 5), imports drop significantly (at the 10% level), while exports do not. The significance of the drop in imports disappears when only Roubaix and Tourcoing are considered treated (column 6), or when woolen textiles are considered treated (column 8). Relatedly, the drop in exports is never statistically significant, with one exception in 1905, casting doubt that it can be attributed to the 1900 crisis directly. Overall, all results in this section are consistent with the view that the CCP's actions to mitigate fire sales were successful at avoiding contagion to real economic activity.

4.5. A narrative counterfactual: The Paris sugar crisis of 1905

Ideally, another way to causally establish the impact of the CCP's decision on the elimination of fire sales would be to compare the same crisis across two markets, one with a CCP (Roubaix–Tourcoing) and one without. Unfortunately, this counterfactual does not exist in our case.

Another event can nonetheless be used for comparison — and, at the time, was often compared to the wool crisis in Roubaix–Tourcoing. This event is the crisis of 1905 in the Paris sugar futures market, in which there was no central clearing. Obviously, the comparison of these two events can only be narrative, and cannot be used to establish strict causal evidence. Nonetheless, contemporaries, including the French parliament, repeatedly compared the two crises in order to praise the decisions taken by the CLG in Roubaix–Tourcoing, and to argue in favor of mandatory central clearing. Here, I simply bring some narrative evidence from the main contemporaries, including Dunan (1907), Depitre (1907), Delcambre (1907) and the Ministère du commerce et de l'industrie (1911). A more detailed analysis of this crisis is left for future work.

Beyond the absence of a CCP, the two events are fairly similar: sudden rises in the price of a commodity due to fears of a shortage, followed by a sharp drop (Dunan, 1907, p. 32–38). In August and September 1905, several major trading houses failed, and had to liquidate positions. Interestingly, in the absence of a CCP, Dunan (1907, p. 54–55) cites an attempt by traders to coordinate in order to delay some of the sales and mitigate its impact on sugar prices. However, the attempt was a failure, seemingly because of free-riding by some traders. Ultimately, the assets sales amount to a coordination failure: what had been made possible by the CLG in Roubaix–Tourcoing could not be implemented in Paris in the absence of a CCP.

There is also strong evidence that the 1905 crisis had real effects beyond the futures market. For example, Dunan (1907, p. 151–152) writes: "What did we see? Brokers who could not meet their commitments due to the failure of their clients; sugar producers, making losses and hesitating to reopen their factories; farmers facing a major drop in sugar beet prices: a whole cascade of defaults that ultimately affected agriculture". In analyzing this crisis, Delcambre (1907) makes an explicit comparison between these failures and the absence of real

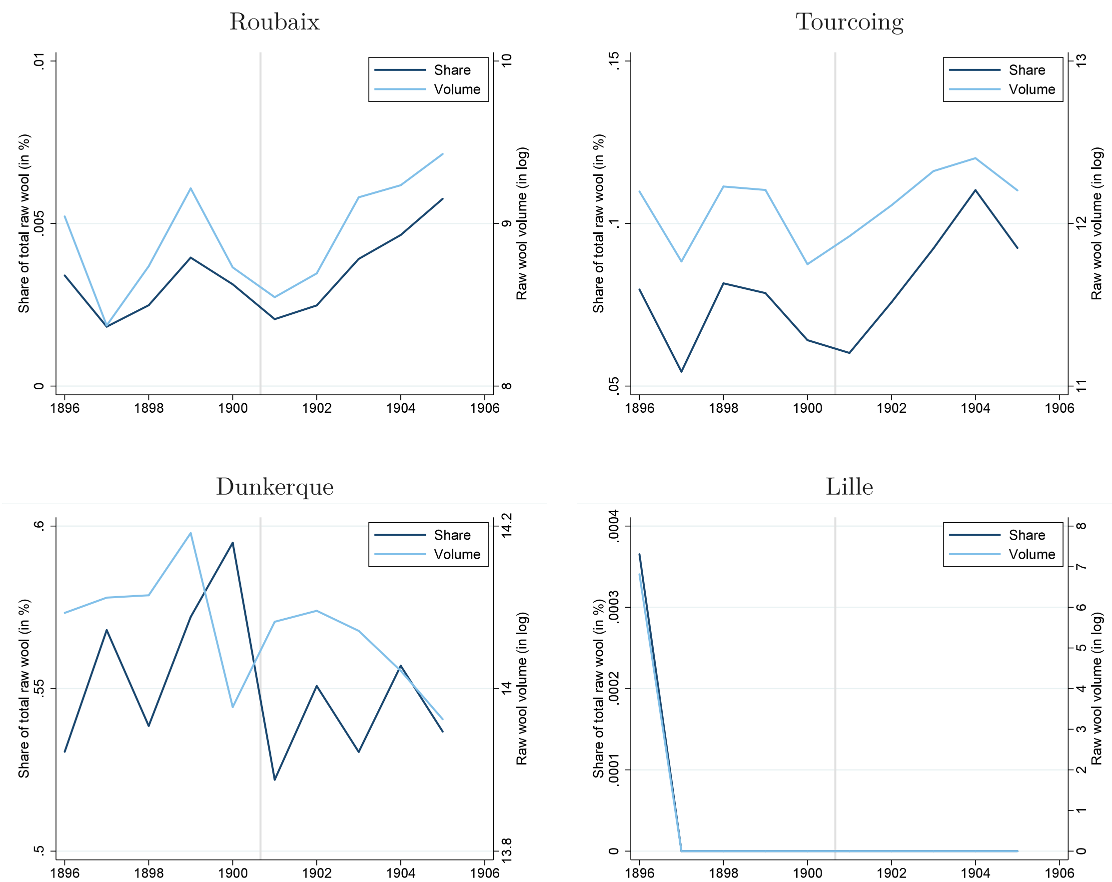

Fig. 4. Imports of raw wool.
This figure plots imports of raw wool for four harbors potentially affected by the 1900 crisis: Roubaix, Tourcoing, Dunkerque and Lille. It plots both the share of raw wool imports for a city over total French raw wool imports (left axis, solid line), and the logarithm of the volume of raw wool imports for each city (right axis, dotted line). Data is at a yearly frequency over the period 1896–1905. The vertical gray line indicates the 1900 crisis.

effects in Roubaix–Tourcoing. The striking comparison even gave rise to a debate on mandatory central clearing, for which a parliamentary report was written (Ministère du commerce et de l'industrie, 1911), even though it did not lead to a legal decision.

5. Implications for CCP design

I finally discuss the implications of my analysis for the design of CCPs.

5.1. Mitigating fire sales in contemporary CCPs

While coordination among surviving CCP members was made possible in 1900 because of family relationships and a common cultural background, these informal ties have now mostly disappeared and have been replaced by formal ex ante contracting. This is another example of a frequently observed dynamics in economic history, whereby institutions that are born informally, embedded in personal relationships, subsequently turn into formal institutions and impersonal mechanisms (Weber, 1981).

Today, when joining a CCP, members explicitly accept a set of rules that will apply in case a member's portfolio needs to be liquidated. The exact nature of these rules varies across CCPs, but they all share common features: CCP auctions are organized and combined with mechanisms to incentivize high bids (Huang and Zhu, 2021), thus mitigating potential fire sale discounts.[19]

Incentivization most commonly takes the form of juniorization of default fund contributions for non-bidders or for low bidders. To be precise, upon default of a member, the CCP is left with an open position, as it commits to make good on the defaulter's positions vis-à-vis its original counterparty. This open position is a source of potential losses for the CCP, if market prices adversely move before the liquidation is over. These losses are allocated according to a "default waterfall" (Duffie, 2015): the first part of the loss is absorbed by the defaulter's contributed funds, and then borne by a default fund, i.e., mutualized resources contributed by all members.[20] In the absence of incentive mechanisms in auctions, default fund contributions by all members

[19] Even in the absence of incentive mechanisms, or if these mechanisms do not bind, a CCP could still reduce fire sales discounts compared to a situation of uncoordinated liquidations, by eliminating an adverse selection problem. Indeed, when uncoordinated liquidations occur, a buyer cannot distinguish whether sales are motivated by default-induced liquidations or by negative information about assets. This information asymmetry commands a price discount. Instead, a CCP never trades based on private information, so that price discounts arising from adverse selection should disappear whenever the CCP is a counterparty. I abstract from this mechanism throughout the paper.

[20] Before the default fund is used, a tranche of CCP equity may first be impaired.

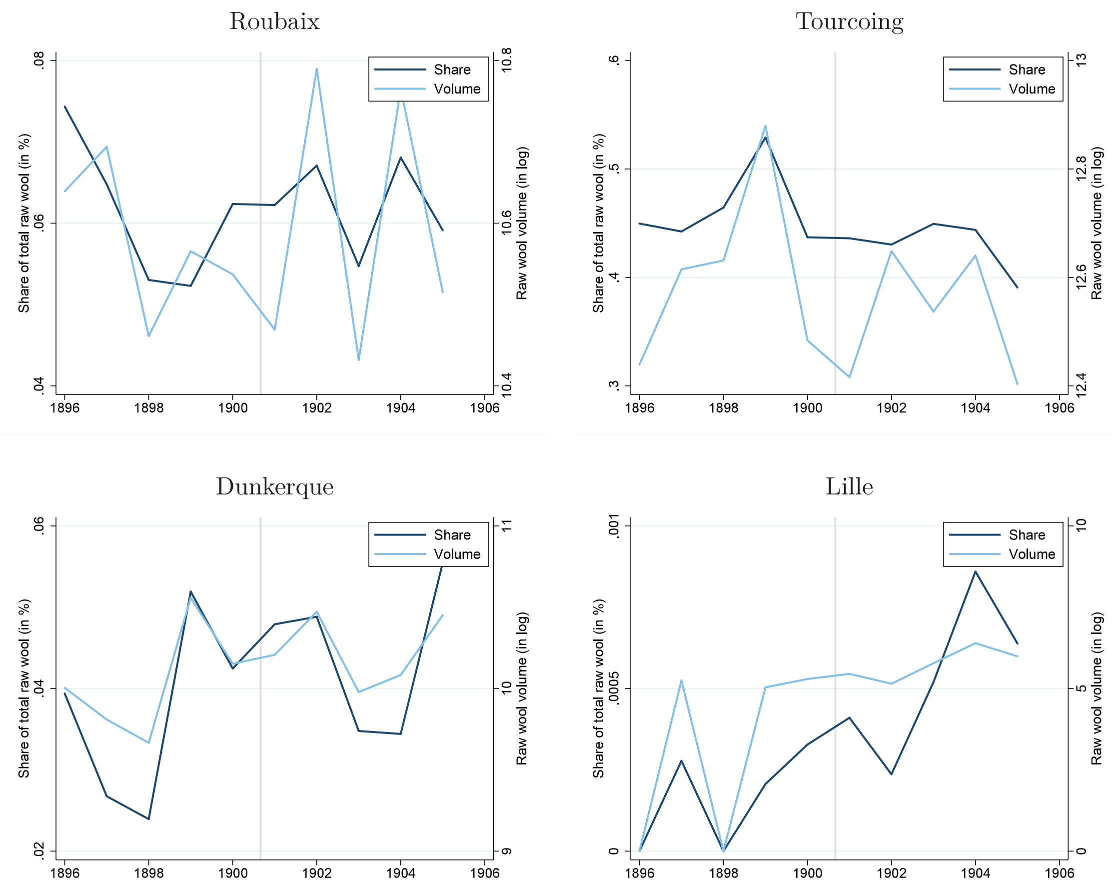

Fig. 5. Exports of raw wool.
This figure plots exports of raw wool for four harbors potentially affected by the 1900 crisis: Roubaix, Tourcoing, Dunkerque and Lille. It plots both the share of raw wool exports for a city over total French raw wool exports (left axis, solid line), and the logarithm of the volume of raw wool exports for each city (right axis, dotted line). Data is at a yearly frequency over the period 1896–1905. The vertical gray line indicates the 1900 crisis.

would be written down proportionally. With incentive mechanisms, members submitting low bids will see their default fund contribution being used before that of members submitting high bids.[21] Additionally, a few CCPs implement fines for non-bidders, particularly for members with low default fund contributions. Regardless of the exact design, the need to provide incentives for high bids is also recognized by regulatory authorities (BIS, 2012; CPMI-IOSCO, 2020).

Beyond incentivization mechanisms, an important feature of present-day CCP auctions are mechanisms to manage the dissemination of information that could be used for traders to free-ride or trade against the CCP. During the events in Roubaix–Tourcoing, as discussed above, the CCP suspended the publication of prices to make it harder for market participants to conduct side trades. While this solution is generally not possible today, in part because many CCPs are distinct from trading venues (notably in OTC markets), CCPs remain extremely careful about information management around default auctions, as discussed by CPMI-IOSCO (2020). The key issue for a CCP is to reveal some information to market participants in order to allow them to bid, but not too much information — which could give them incentives to trade against the CCP. Information management is conducted using multiple instruments: by selecting which participants to invite in the auction, whether the defaulted position is sold during a single auction or via multiple sub-auctions (different members can then be invited to different sub-auctions), by establishing confidentiality or non-disclosure agreements with bidding participants, by establishing specific governance rules related to information sharing, etc. This set of rules is critical for CCPs to avoid free-riding as in Jacklin (1987).

A few CCP auctions have been organized in recent years, the most notable ones being those following the defaults of Lehman Brothers in 2008 and of Einar Aas vis-à-vis Nasdaq Clearing AB in 2018 (Bell and Holden, 2018). In the absence of data available to researchers, it is hard to assess the extent to which these auctions helped mitigating asset fire sales. Nonetheless, in the case of Lehman Brothers, narrative evidence from Norman (2011), as well as legal evidence from Summe (2012) and Lubben (2017), suggest that large derivative positions could be liquidated with significantly fewer market disruptions than other (uncleared) parts of Lehman Brothers' portfolio.

5.2. Issues in CCP and auction design

While auctions to liquidate positions at above-market prices are common in CCPs, they are typically not seen as mechanisms to mitigate fire sales. Instead, auctions are often only understood as loss-allocation mechanisms reducing the likelihood of CCP default. The main policy implication from my analysis is that auctions with forced participation can be valuable even when the CCP is away from distress, in order to eliminate fire sales. Once this role is recognized, new light can be shed on several issues.

[21] Low bids can be defined either with respect to a predefined band, or relative to winning bids. Furthermore, the exact process of juniorization varies across CCPs. Some CCPs define categories of bidders and use default fund contributions on a pro-rata basis within each category. Other CCPs establish a reverse ladder so that default fund contributions are used sequentially from the worst bidder to the best.

Table 4
Difference-in-differences estimation — Total imports.

Panel A: Baseline estimation						
	Share	Share	Share	Log. vol.	Log. vol.	Log. vol.
Treated*Post	−0.002	0.000	0.001	−0.054	0.017	−0.026
	(0.016)	(0.021)	(0.015)	(0.479)	(0.627)	(0.448)
Treated	−0.016	−0.040***	−0.018*	−1.442***	−2.332***	−1.515***
	(0.011)	(0.015)	(0.011)	(0.339)	(0.443)	(0.317)
Post	0.000	−0.000	−0.000	0.101	0.091	0.080
	(0.007)	(0.006)	(0.006)	(0.196)	(0.181)	(0.183)
Treated: Dunkerque	Yes	No	Yes	Yes	No	Yes
Treated: Lille	Yes	No	Yes	Yes	No	Yes
Trade type	Gen.	Gen.	Spe.	Gen.	Gen.	Spe.
Adj. R2	0.006	0.045	0.009	0.127	0.179	0.155
Obs.	240	240	240	240	240	240

Panel B: With year dummies						
	Share	Share	Share	Log. vol.	Log. vol.	Log. vol.
Treated*1901	−0.003	0.000	0.002	−0.125	−0.032	−0.033
	(0.026)	(0.036)	(0.025)	(0.790)	(1.064)	(0.738)
Treated*1902	−0.003	0.002	0.001	−0.080	0.088	−0.008
	(0.026)	(0.036)	(0.025)	(0.790)	(1.064)	(0.738)
Treated*1903	−0.002	0.001	0.002	0.003	0.106	0.028
	(0.026)	(0.036)	(0.025)	(0.790)	(1.064)	(0.738)
Treated*1904	−0.003	−0.001	0.000	−0.098	−0.079	−0.115
	(0.026)	(0.036)	(0.025)	(0.790)	(1.064)	(0.738)
Treated*1905	−0.001	−0.000	0.003	0.032	0.001	−0.004
	(0.026)	(0.036)	(0.025)	(0.790)	(1.064)	(0.738)
Treated: Dunkerque	Yes	No	Yes	Yes	No	Yes
Treated: Lille	Yes	No	Yes	Yes	No	Yes
Trade type	Gen.	Gen.	Spe.	Gen.	Gen.	Spe.
Adj. R2	−0.011	0.028	−0.008	0.112	0.165	0.140
Obs.	240	240	240	240	240	240

This table displays the results from the estimation of Eq. (3). I focus on total imports of all goods (measured in volume). In both panels, the dependent variable is either the share of total imports of city c within total French imports in year t (columns 1 to 3), or the logarithm of the volume of imports in city c in year t (columns 4 to 6). Treated cities include either only Roubaix and Tourcoing (columns 2 and 5) or Roubaix, Tourcoing, Dunkerque and Lille (columns 1, 3, 4 and 6). In columns 3 and 6, I focus on special trade rather than on general trade, that is, on imports for which a tax is paid and that serve domestic production/consumption. Panel B estimates Eq. (3) after interacting the $TrCity_c$ coefficient with post-treatment year dummies, rather than with a single $Post_t$ dummy. The model is estimated using the full sample of 24 customs cities, at a yearly frequency over the period 1896–1905. Standard errors are in parentheses. *, ** and *** refer respectively to statistical significance at the 10%, 5% and 1% levels.

Currently, auctions are decided by CCPs when they fear that outright liquidations may put the CCP's resources at high risk. Based on my analysis, this may imply that CCP auctions do not take place as frequently as they should. For example, in case the liquidation of a defaulted member's position is disruptive for the market (by creating fire sales) but not for the CCP (because it has sufficient resources), running an auction could be socially optimal, but the CCP may decide otherwise. Whether an auction will be run depends on the CCP's governance: presently, CCP managers are deciding whether a defaulted position is liquidated outright or via an auction. The agency conflict between what could be socially optimal and what is optimal for the CCP may paradoxically be worse for CCPs with large resources (including members' pre-funded resources). To mitigate the underlying conflict, a cooperative governance, in which members have a say on whether auctions should be held, is worth considering.

The same logic can help us assess incentive mechanisms in CCP auctions. At present, these mechanisms bind only when the CCP's default fund is at risk, that is, when contributions of low-bidding surviving members are subject to juniorization (Huang and Zhu, 2021). Given that inefficient fire sales can occur regardless of whether CCP default funds are at risk, incentive mechanisms could be more widespread. This structure would have one additional benefit relative to the current design. Indeed, in CCPs where incentive mechanisms are purely based on default fund juniorization, surviving members have incentives to under-bid – rather than over-bid – when the default fund is not at risk. By doing so, they appropriate the residual resources from the defaulted member (its initial margin and own default fund contribution), and reduce the recovery value for the defaulted investor's creditors.[22] This is a form of predatory trading that is bounded above by the defaulter's resources at the CCP; it amplifies fire sale problems and associated inefficiencies. Better-designed incentive mechanisms should avoid these distortions. That said, how to optimally design auctions and associated incentive mechanisms remains a question for future research. So far, it has mostly been studied by Huang and Zhu (2021).

6. Conclusion

Fire sales are among the most severe market inefficiencies associated with financial crises. Because fire sales typically result from coordination failures between investors, it is often assumed that policy intervention is needed to mitigate them. In this paper, I study historical evidence from the 1900 global wool crisis and show that, in the leading wool market in France, a CCP could mitigate fire sales in the absence of any government intervention, by organizing the liquidation of defaulted positions at above-market prices. Coordination was facilitated by family relationships and a common cultural background across CCP members. Nowadays, CCP auctions with juniorization mechanisms fulfill the same role.

This study leaves a number of questions open. First, a basic question is whether institutions other that CCPs have historically served to mitigate fire sales. Second, regarding CCPs, it remains unclear how exactly they should be designed to most efficiently eliminate fire sales.

[22] Underpriced asset sales from CCPs to surviving members occur. One example is the sale of Lehman Brothers' position with CME (Salmon, 2010).

Table 5
Difference-in-differences estimation — Total exports.

Panel A: Baseline estimation						
	Share	Share	Share	Log. vol.	Log. vol.	Log. vol.
Treated*Post	0.005	0.002	0.004	−0.031	−0.014	−0.155
	(0.023)	(0.031)	(0.020)	(0.418)	(0.556)	(0.419)
Treated	−0.021	−0.034	−0.014	−0.667**	−1.168***	−0.598**
	(0.017)	(0.022)	(0.014)	(0.296)	(0.393)	(0.296)
Post	−0.001	−0.000	−0.001	0.180	0.176	0.191
	(0.010)	(0.009)	(0.008)	(0.171)	(0.160)	(0.171)
Treated: Dunkerque	Yes	No	Yes	Yes	No	Yes
Treated: Lille	Yes	No	Yes	Yes	No	Yes
Trade type	Gen.	Gen.	Spe.	Gen.	Gen.	Spe.
Adj. R2	−0.002	0.006	−0.007	0.036	0.063	0.035
Obs.	240	240	240	240	240	240

Panel B: With year dummies						
	Share	Share	Share	Log. vol.	Log. vol.	Log. vol.
Treated*1901	0.005	−0.001	0.007	−0.245	−0.283	−0.210
	(0.039)	(0.053)	(0.032)	(0.688)	(0.943)	(0.689)
Treated*1902	0.004	0.002	−0.000	−0.137	−0.060	−0.521
	(0.039)	(0.053)	(0.032)	(0.688)	(0.943)	(0.689)
Treated*1903	0.001	0.001	0.002	−0.212	−0.180	−0.190
	(0.039)	(0.053)	(0.032)	(0.688)	(0.943)	(0.689)
Treated*1904	0.006	0.004	0.006	0.113	0.183	0.004
	(0.039)	(0.053)	(0.032)	(0.688)	(0.943)	(0.689)
Treated*1905	0.008	0.005	0.007	0.328	0.271	0.139
	(0.039)	(0.053)	(0.032)	(0.688)	(0.943)	(0.689)
Treated: Dunkerque	Yes	No	Yes	Yes	No	Yes
Treated: Lille	Yes	No	Yes	Yes	No	Yes
Trade type	Gen.	Gen.	Spe.	Gen.	Gen.	Spe.
Adj. R2	−0.019	−0.011	−0.024	0.022	0.049	0.021
Obs.	240	240	240	240	240	240

This table displays the results from the estimation of Eq. (3). I focus on total exports of all goods (measured in volume). In both panels, the dependent variable is either the share of total exports of city c within total French exports in year t (columns 1 to 3), or the logarithm of the volume of exports of city c in year t (columns 4 to 6). Treated cities include either only Roubaix and Tourcoing (columns 2 and 5) or Roubaix, Tourcoing, Dunkerque and Lille (columns 1, 3, 4 and 6). In columns 3 and 6, I focus on special trade rather than on general trade, that is, on exports of goods which come from domestic production. Panel B estimates Eq. (3) after interacting the $TrCity_c$ coefficient with post-treatment year dummies, rather than with a single $Post_t$ dummy. The model is estimated using the full sample of 24 customs cities, at a yearly frequency over the period 1896–1905. Standard errors are in parentheses. *, ** and *** refer respectively to statistical significance at the 10%, 5% and 1% levels.

Table 6
Triple difference-in-differences estimation — Imports and exports.

Panel A: Imports								
	Share	Share	Share	Share	Log. vol.	Log. vol.	Log. vol.	Log. vol.
TrCity*TrGood*1901	−0.013	−0.002	−0.023	−0.005	−1.081	−0.618	−1.122	−0.538
	(0.025)	(0.034)	(0.023)	(0.019)	(0.985)	(1.338)	(0.921)	(0.728)
TrCity*TrGood*1902	−0.003	0.004	−0.004	−0.001	−1.805*	−0.697	−1.460	−0.731
	(0.025)	(0.034)	(0.023)	(0.019)	(0.985)	(1.338)	(0.921)	(0.728)
TrCity*TrGood*1903	−0.005	0.012	−0.007	−0.002	−1.790*	−0.916	−1.516*	−0.501
	(0.025)	(0.034)	(0.023)	(0.019)	(0.985)	(1.338)	(0.921)	(0.728)
TrCity*TrGood*1904	0.006	0.021	0.006	0.008	−1.919*	−0.769	−1.676*	−0.174
	(0.025)	(0.034)	(0.023)	(0.019)	(0.985)	(1.338)	(0.921)	(0.728)
TrCity*TrGood*1905	−0.007	0.011	−0.005	−0.000	−1.926*	−1.074	−1.612*	−0.032
	(0.025)	(0.034)	(0.023)	(0.019)	(0.985)	(1.338)	(0.921)	(0.728)
Treated: Dunkerque	Yes	No	Yes	Yes	Yes	No	Yes	Yes
Treated: Lille	Yes	No	Yes	Yes	Yes	No	Yes	Yes
Treated: Textile	No	No	No	Yes	No	No	No	Yes
Trade type	Gen.	Gen.	Spe.	Gen.	Gen.	Gen.	Spe.	Gen.
Adj. R2	.898	.898	.92	.898	.864	.862	.872	.863
Obs.	3120	3120	3120	3120	3120	3120	3120	3120

(*continued on next page*)

Two relevant issues are the design of margins and of auctions in case of investor defaults. Third, a broader question relates to the respective roles of contracts and of regulation (or public intervention more broadly) to mitigate fire sales. Overall, while fire sales are now well-documented, research must go on to study how they can be best eliminated or reduced.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jfi.2023.101045.

Table 6 (*continued*).

Panel B: Exports								
	Share	Share	Share	Share	Log. vol.	Log. vol.	Log. vol.	Log. vol.
TrCity*TrGood*1901	0.002	−0.000	−0.013	0.009	0.454	−0.189	0.436	0.442
	(0.027)	(0.036)	(0.028)	(0.020)	(0.985)	(1.329)	(0.959)	(0.729)
TrCity*TrGood*1902	0.000	−0.002	−0.016	0.006	0.042	−0.296	0.068	−0.056
	(0.027)	(0.036)	(0.028)	(0.020)	(0.985)	(1.329)	(0.959)	(0.729)
TrCity*TrGood*1903	−0.009	−0.011	−0.019	−0.004	−0.691	−1.017	−0.641	−0.546
	(0.027)	(0.036)	(0.028)	(0.020)	(0.985)	(1.329)	(0.959)	(0.729)
TrCity*TrGood*1904	−0.003	−0.006	−0.019	0.004	−1.237	−1.834	−1.218	−0.472
	(0.027)	(0.036)	(0.028)	(0.020)	(0.985)	(1.329)	(0.959)	(0.729)
TrCity*TrGood*1905	−0.023	−0.054	−0.024	−0.013	−1.346	−2.191*	−1.189	−0.636
	(0.027)	(0.036)	(0.028)	(0.020)	(0.985)	(1.329)	(0.959)	(0.729)
Treated: Dunkerque	Yes	No	Yes	Yes	Yes	No	Yes	Yes
Treated: Lille	Yes	No	Yes	Yes	Yes	No	Yes	Yes
Treated: Textile	No	No	No	Yes	No	No	No	Yes
Trade type	Gen.	Gen.	Spe.	Gen.	Gen.	Gen.	Spe.	Gen.
Adj. R2	.87	.87	.859	.87	.865	.865	.866	.865
Obs.	3048	3048	3048	3048	3120	3120	3120	3120

This table displays the results from the estimation of Eq. (4). Panel A is for imports and Panel B for exports. In both panels, the dependent variable is either the share of total imports/exports of city c within total French imports/exports in year t (columns 1 to 3), or the logarithm of the volume of imports/exports of city c in year t (columns 4 to 6). Treated cities include either only Roubaix and Tourcoing (columns 2 and 5) or Roubaix, Tourcoing, Dunkerque and Lille (columns 1, 3, 4 and 6). In columns 3 and 6, I focus on special trade rather than on general trade (see footnote for details). The model is estimated using the full sample of 24 customs cities and 13 different goods, at a yearly frequency over the period 1896–1905. Standard errors are in parentheses. *, ** and *** refer respectively to statistical significance at the 10%, 5% and 1% levels.

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