

Securities settlement fails network and optimal buy-in strategies

Pedro Gurrola-Perez (BoE)

Jieshuang He (The Chinese University of Hong Kong, Shenzhen)

Gary Harper (BoE)

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- Settlement failure may have consequences for the parties directly involved and for the system as a whole (negative externalities).
- Chains of fails, for example, could lead to gridlock situations and large volume of fails can affect the liquidity and smooth functioning of financial markets.

A typical example:

- Firm B, as part of a short-selling strategy, borrows a security from dealer A.
- To keep a matched book, the dealer A then borrows the security from another participant C.
- If, at the time of giving back the security, B fails to give it back to the dealer A, then the dealer will fail to return the security to C (a “daisy chain” of fails).

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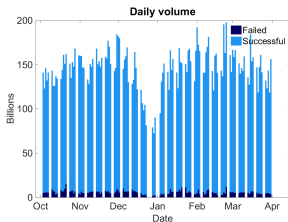
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- Literature on settlement fails has mostly focused on the US markets (Evans et al., 2009; Fleming and Garbade, 2002, 2005) and on exploring the determinants of settlement fails.
- More recent studies have also investigated the EU markets (Corradin et al., 2017) and have considered the systemic nature of settlement fails (e.g. Iyer and Macchiavelli (2017), including modelling the impact of the default of a major settlement participant (Devriese and Mitchell, 2005).
- However, to the best of our knowledge, there are no studies on the network characteristics of settlement fails or on determining the efficiency of buy-in regimes.
- Because of the differences in regulation and market practices, studies may not be easily comparable across borders, as there is potential for a wide variation of behaviour and structures between jurisdictions.

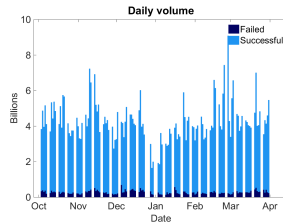
- Gilt markets: They rely on market makers who are obliged to sell at the price they quote regardless of inventory. This can lead to fails if they do not borrow to manage their short positions. The market is not anonymous: participants may prefer to avoid enforcing buying in against each other as it might damage trading relationships or in the hope to receive a quid pro quo on their own strategic fails (Boni, 2006).
- FTSE 100: There are no market makers. Most trading is done through order books and is anonymous.

Table : Summary statistics of equity and gilts fails from 3 October 2016 to 31 March 2017 (127 business days). Fails are accounted on a daily basis and include fails that have been outstanding up to 5 days. FR_t is the daily fail ratio.

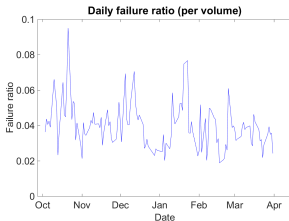
	Gilts				FTSE 100			
	Min	Max	Mean	s.d.	Min	Max	Mean	s.d.
Number of transactions ('000s)	6.03	14.2	10.8		21.3	33.4	28.6	
Successful								
Value (£bn)	92.6	261.05	186.03	27.79	6.16	37.9	13.2	4.83
Volume (bn)	70.54	189.65	140.64	21.14	1.46	8.84	4.01	1.08
Failed								
Value (£bn)	2.26	18.74	7.58	2.71	0.83	4.19	1.73	0.53
Volume (bn)	1.82	15.38	5.86	2.17	0.15	0.70	0.29	0.098
FR_t	0.019	0.095	0.040	0.013	0.026	0.165	0.069	0.023



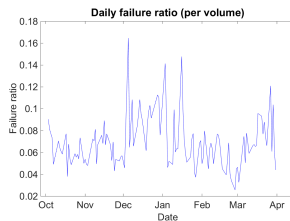
(a) Gilts



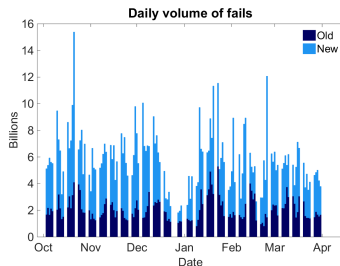
(b) FTSE 100



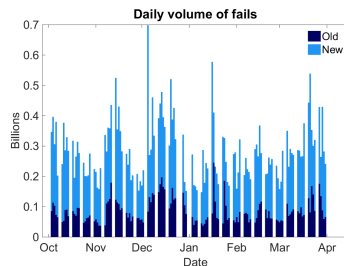
(c) Gilts



(d) FTSE 100

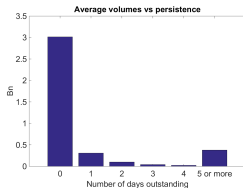


(e) Gilts

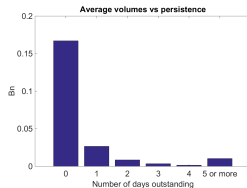


(f) FTSE 100

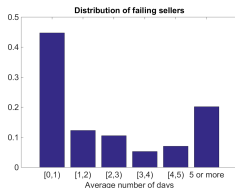
Figure : Daily volume of fails, distinguishing between new and old fails. For gilts, the average daily volume of new fails is 3.74bn and the average ratio of old fails with respect to the total number fails is 38%. For FTSE 100, the average volume of new fails is 0.2 bn and the average ratio of old vs total fails is 31%. The vertical gaps between the bars correspond to weekends and bank holidays.



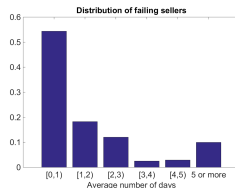
(a) Gilts



(b) FTSE 100



(c) Gilts



(d) FTSE 100

Figure : (a) and (b) show how volumes are distributed according to the business days between the intended settlement day and the day in which the trade was finally settled (or canceled). Graphs (c) and (d) show the distribution of failing sellers according to the average number of days their failed trades have remained outstanding before being settled or canceled. For each seller, this average is obtained by considering the average across ISINs and across all days in the period .

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In general, fails are attributed to one (or more) of the following reasons:

- *Operational problems:* e.g. Poor communications between the seller's front and back office fails and the back office. Technological disruptions can also impede settlement.

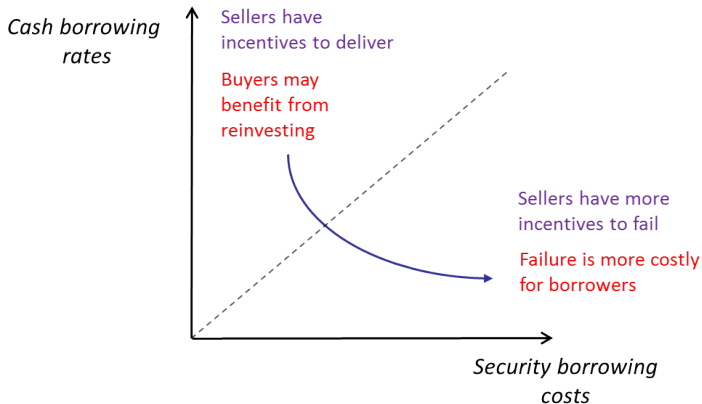
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 - *Cascades of fails:* a market participant was relying on receiving the same securities it was supposed to onward deliver ("daisy chains").
 - *Supply/demand imbalances:* For example, short sellers may be unable to cover the position ahead of the intended settlement date, because of high demand of a particular security (in our case, both Gilts and FTSE are very liquid markets)

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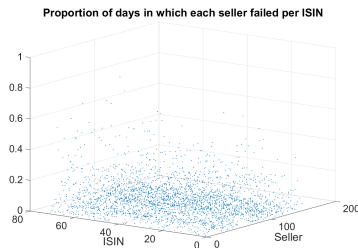
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- *Strategic behaviour:* The seller may deliberately fail if borrowing costs are high or if it can profit from using the security in another trade.

Incentives to fail

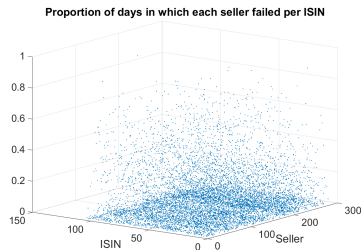


When borrowing costs are high, short sellers may choose not to deliver.

$f(X, i) =$ proportion of days in which the participant X failed to deliver the security i

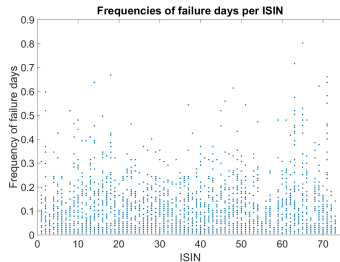


(a) Gilts

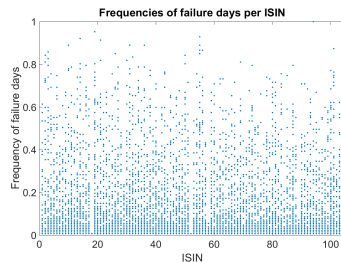


(b) FTSE 100

Figure : Each dot indicates the proportion of days in which seller X failed to deliver security defined by ISIN i .

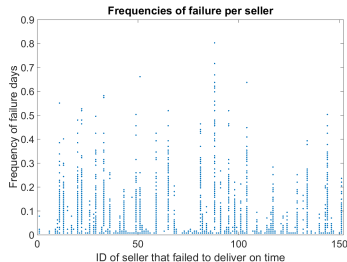


(a) Gilts

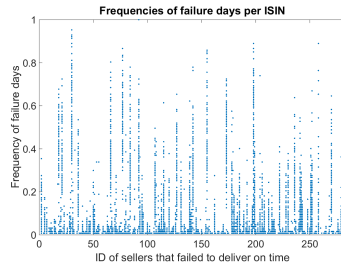


(b) FTSE 100

Figure : Homogeneity across ISINs. How often each ISIN was failed to settle by a selling counterparty

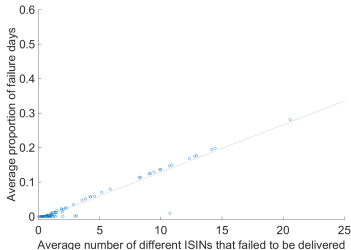


(a) Gilts

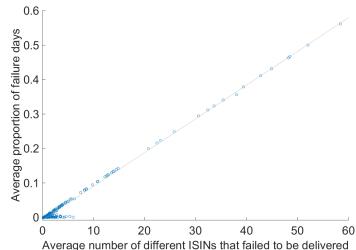


(b) FTSE 100

Figure : Heterogeneity across participants. How often each failing market participant failed to deliver a security.

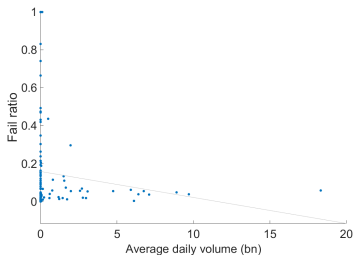


(a) Gilt

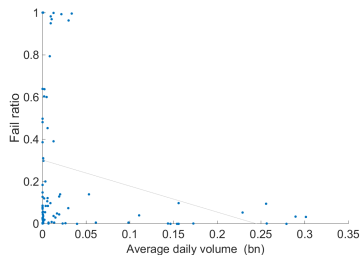


(b) FTSE 100

Figure : Relation between the average percentage of daily fails for each participant, against the variety of ISINs the participant has failed to settle.



(a) Gilts



(b) FTSE 100

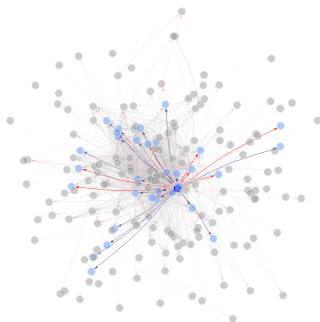
Figure : Relation between the total volume of trading for each failing seller, against the seller's fail ratio.

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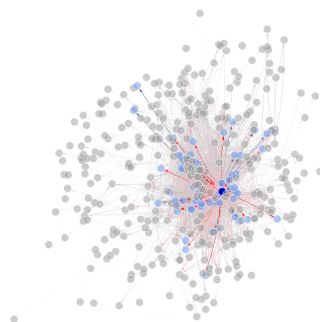
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Table : Summary statistics of transactions on a single day.

	Gilts	FTSE 100
Number of transactions	10,988	67,562
Number of ISINs traded	72	98
Number of sellers	86	239
Number of buyers	89	243
Total volume of securities traded (bn)	131	4.95
Total value of securities traded (£bn)	175	21.23

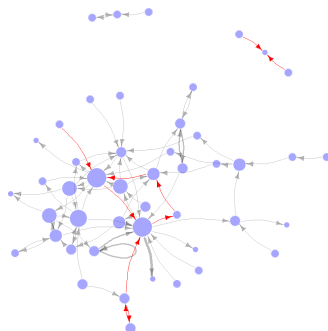


(a) Gilts

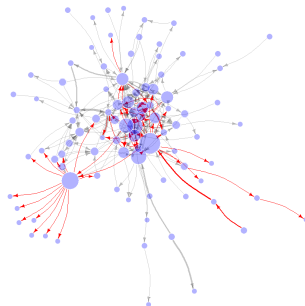


(b) FTSE 100

Figure : Security settlement network of all ISINs on a random day. Trading counterparties are represented by gray nodes. Gray linkages represent successful settlement, while pink linkages represent settlement fails. Overlaps of linkages between nodes are showed as darker color edges. We highlight the seller that failed the most variety of ISINs with dark blue node, as well as its counterparties with light blue nodes. Dark blue linkages represent successful settlement, while red linkages represent fails.



(a) Gilts



(b) FTSE 100

ISIN with the largest contribution to total fails. The node size is proportional to its outdegree. Link widths are proportional to transaction volume of the contracts between counterparties. Gray links represent successful settlement, while red ones are fails. A loop from a node to itself is the transaction between different accounts held by the same participant.

Figure : Day 1

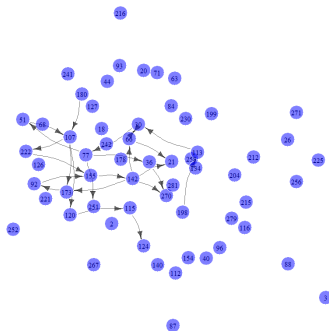


Figure : Day 2

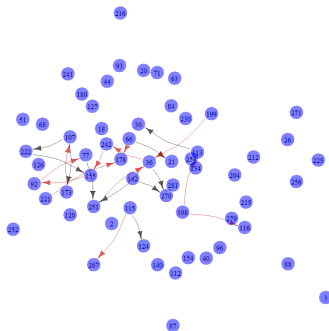


Figure : Day 3

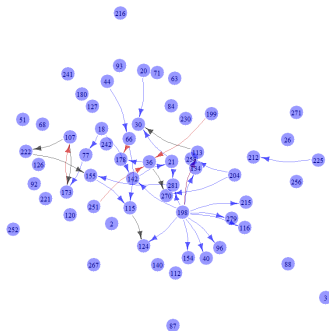


Figure : Day 4

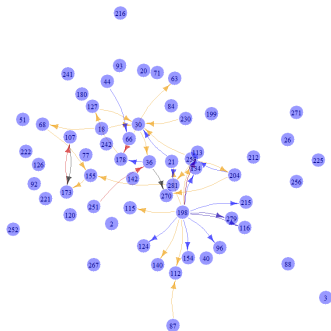


Figure : Day 5

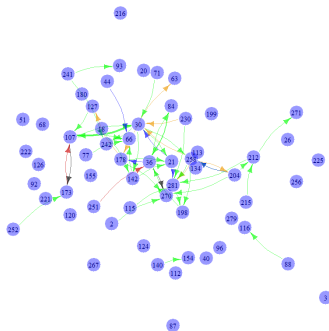


Figure : Day 6

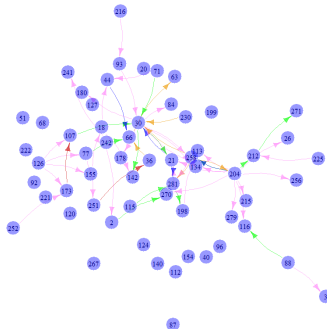


Figure : An illustration of failure network dynamics of one particular ISIN

- We define fails due to **cascade effects** as those fails which coincide with the participant not receiving the same ISIN from its debit counterparties.
- In this context, one could ask how often an ISIN is involved in a fail due to cascade effect (which relates to the connectedness of the settlement network for each layer of individual ISIN), or how often a participant fails in the presence of cascade of fails.
- Because fails can last for several days, the network effects can propagate through time.
- For example, there may be trades which come due between two counterparties while their last trade is still unsettled for the same security.

For each date t , let $\mathcal{S}_t(X)$ be the set of all participants that failed to deliver the ISIN X on day t in a new transaction (that is, as a fail with zero days outstanding). For each participant $i \in \mathcal{S}_t(X)$, we compute the net obligation due to i from previous days as the difference

$$D_{-j}^{\text{old}}(X, t) = D_{\bullet, j}^{\text{old}}(X, t) - D_{j, \bullet}^{\text{old}}(X, t), \quad (1)$$

where $D_{\bullet,i}^{\text{old}}(X, t)$ is the total volume of fails due to i which have been one or more days outstanding at time t and $D_{i,\bullet}^{\text{old}}(X, t)$ is the corresponding total volume of old fails due from i .

Then, the net obligation due from participant i after separating the fails due to cascade effects is

$$D_i^{nc}(X, t) = \max(D_i^{new}(X, t) - C_i(X, t), 0) \quad (4)$$

Subtracting the net obligation from the total gross new fails due from i gives us the new fails due to cascade effect by i on day t ;

$$D_i^c(X, t) = D_i^{new}(X, t) - D_i^{nc}(X, t) \quad (5)$$

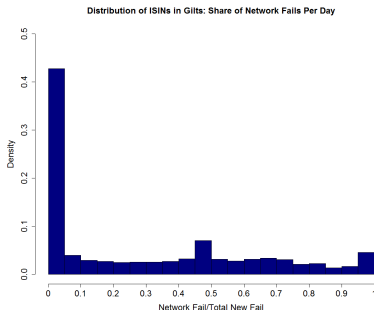
Let $\mathcal{X}$ be the set of ISINs. To measure the impact of cascade effects on new fails of a seller i , we can estimate for each seller i the ratio of cascades of fails across ISINs relative to the total number of new fails

$$FR^c(i) = \frac{\sum_t \sum_{X \in \mathcal{X}} D_i^c(X, t)}{\sum_t \sum_{X \in \mathcal{X}} D_i^{new}(X, t)} \quad (6)$$

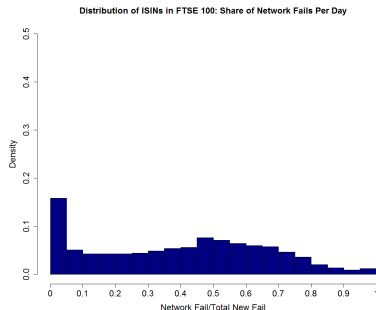
Similarly, the ISIN's fail ratio across set of sellers $\mathcal{S}$

$$FR^c(X) = \frac{\sum_t \sum_{i \in \mathcal{I}} D_i^c(X, t)}{\sum_t \sum_{i \in \mathcal{I}} D_i^{new}(X, t)}. \quad (7)$$

Identifying fails due to cascade effects



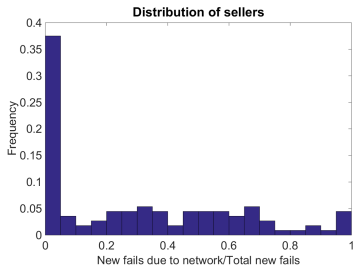
(a) Gilts



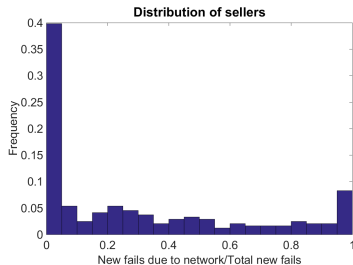
(b) FTSE 100

The distribution of ISINs suggests that, while both in gilts and equities cascade effects play a role, the network densities for ISINs in FTSE 100 are higher. These differences could be driven by the different market structures and the different type of participants.

Identifying fails due to cascade effects



(c) Gilts



(d) FTSE 100

Share of network fails out of total new fails. In both markets, about 40% of all the sellers are not affected by cascades of fails. Whether their fails contribute or not to cascades of fails will depend on their out-degree in the settlement network.

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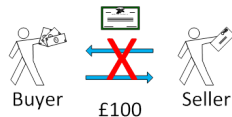
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- The implementation details varies across settlement systems and jurisdictions,
- In general, the principle behind it is to restore the economic position the counterparties would have been in had the original transaction settled.
- It usually takes the form of a contractual right by which, in the event that the seller fails to deliver the securities on the agreed settlement date, the buyer can enforce delivery of the securities to replace the original transaction.

Original trade



The seller is
"bought-in"



Figure : An illustration of the buy-in mechanism. After the seller fails to deliver the securities, the buyer can instruct a third party to source the security (or it can proceed through an auction process). Any difference in the market price is paid by the seller.

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- Because of these constraints, it would be desirable to identify buy-in strategies that could have maximal impact in resolving a settlement fail chain and at a minimal cost.
- Given the potential complexity of a network of fails, designing an efficient buy-in strategy may not be straightforward.
- For example, when a network of fails has resulted in closed chains of fails it may be difficult to determine which participants need to be bought in and by which amounts, in a way that the outcome is consistent across all the nodes in the network and the curing effect of the buy-in is maximized.

We identify three types of participants:

- A) Participants who are only buyers of securities, therefore do not need to be bought-in.
- B) Participants who are pure sellers and therefore must be bought-in for sure.
- C) Participants who are both buyers and sellers. Whether they need to be bought-in and by how much will depend on how much they will receive from other nodes once the buy-in process is initiated and how much they have to deliver to other nodes.

- To identify a way to complete the buy-in process with the minimum participants being bought-in, we can adapt the framework developed by Eisenberg and Noe (2001) (E-N hereafter) by interpreting their external operating cash-flows as securities that are borrowed or bought from the market.

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- One important difference is that, while E-N focuses on the network of payment liabilities that will mature at some future date, in our case we are looking at the nominal settlement obligations that remain when settlement has already failed to happen. In other words, we focus on the time when a buy-in process will be defined.

For any given ISIN X , we represent the network structure of fails at time t_0 by an $n \times n$ liabilities matrix $D = D(X)$, where n is the number of participants involved in the network and the matrix element D_{ij} is the volume due from participant i to j .

In other words, i needs to deliver D_{ij} units of securities to j . As usual, we assume $D_{ij} \geq 0$ for $i \neq j$ (all claims are non-negative), and $D_{ii} = 0$ (no node has claims against itself).

The sum $D_i = \sum_{j=1}^n D_{ij}(X)$ represents the total obligation of i to all other nodes in the network, and $D = (D_1, \dots, D_n)$ is the associated vector (*total obligations vector*).

- A *buy-in* vector as a vector $b = (b_1, \dots, b_n)$, where $b_i \geq 0$ represents the number of securities that will be bought-in against node i ; that is, the amount of securities that participant i needs to borrow or buy to fulfill some or all of the obligations that it has towards other nodes.
- These securities are exogenous to the network and we can interpret them as being lent by the market (which could also be represented as an external node with edges pointed to the nodes in the network).

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This implies that p^* is a clearing vector if and only if it satisfies the following set of non-linear equations:

$$p_i^* = \min\{D_i, \sum_{j=1}^n \pi_{ij} p_j + b_i\}, \quad \forall i = 1, \dots, n. \quad (9)$$

A direct application of E-N framework in this context implies that, under mild regularity conditions, given a system (D, b) , a settlement vector $p = p(b)$ exists and it is unique.

$$x \leq y \iff x_i \leq y_i, \quad \text{for all } 1 \leq i \leq n.$$

The question we ask is how to characterize the minimal buy-in vector $\bar{b}$ that guarantees full payments and, when the full buy-in is not possible, how to proceed to achieve the most efficient settlement at a lower cost.

Theorem

In a static security settlement fails network assume that, after a buy-in process is defined, all participants will pass on the security they receive according to their obligations, and all counterparties have the same priority to receive the security. Then, for any security X ,

- a) *The minimal buy-in vector needed to fulfill all settlement obligations is $\bar{b} = \max(D_i - \sum_{j=1}^n D_{ji}, 0)$.*
- b) *Given any buy-in vector b' , there is a buy-in vector b , such that $p(b) = p(b')$ and for which the minimum set of participants that need to be externally bought-in is composed of the participants with strictly positive net obligations. Moreover, $\sum_i b_i \leq \sum_i b'_i$.*

Assume that, at time t_0 , we observe the security settlement network for any given ISIN X . By definition, if all settlement obligations in the system are met in full then, $p^* = D$ which, according to equation 9, implies that $b_i \geq D_i - \sum_{j=1}^n \pi_{ij} p_j$ (node i has enough securities to cover its obligations to all j and $\sum_{j=1}^n \pi_{ij} p_j = \sum_{j=1}^i D_{ji}$ (all obligations to i are paid in full), for all i). This implies that the minimal buy-in vector is defined as

$$\bar{b}_i = \begin{cases} 0 & \text{if } \sum_{j=1}^n D_{ji} \geq D_i, \\ D_i - \sum_{j=1}^n D_{ji} & \text{otherwise.} \end{cases}$$

In particular, the external buy-in needed for each participant is the netted obligation it owes to other counterparties when the netted quantity is strictly positive, which proves the first point. $\square$

Proof.

To prove (b) we define a buy in process b as follows

$$b_i = \begin{cases} 0 & \text{if } \bar{b}_i = 0 \\ \min(b'_i, \bar{b}_i) & \text{otherwise.} \end{cases} \quad (10)$$

Clearly, $0 < b \leq \bar{b}$. On the other hand, if p' is the clearing vector associated to b' , we need to show that it is also the clearing vector associated to b . To see that this is the case, we observe that, if $b'_i < \bar{b}_i$ then, by equation 10, we have that $p_i = p'_i$. On the other hand, if $b'_i \geq \bar{b}_i$, then equation 9 implies that $D_i \leq \sum_{j=1}^n \pi_{ij} p_j + b'_i$ and therefore $p_i = D_i = p'_i$. $\square$

In summary,

- An optimal buy-in strategy always exists where only the nodes with positive net obligation positions are bought in. This holds even if there are constraints in the amount of securities to be bought or borrowed and the optimal buy-in vector $\bar{b}$ cannot be achieved.
- It is worth noting that by assuming that all participants will pass on the security they receive according to their obligations, we are effectively assuming that, once the buy-in is initiated, there is no strategic behaviour.

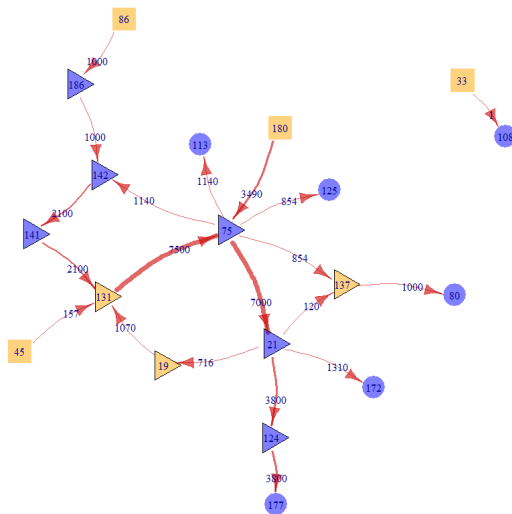


Figure : Buy-in process of a gilt ISIN. Numbers on the directed edges represent the obligation volume (in 10,000s) between two counterparties. The width of edges are proportional to obligation volumes. Three types of participants: (1) circle nodes are the pure buyers of the ISIN; (2) the square nodes are the pure sellers of the ISIN; and (3) the triangle nodes are the ones who both buy and sell the security. Orange nodes are the minimum set of participants needed to be bought-in.

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- One of the assumptions of the model is that securities will be passed to the buyers on a pro-rata basis. In reality, settlement systems may have different rules to prioritize settlement.
- For example, the settlement system may allocate securities giving preference to older trades, or instead allocate them so that the maximum number of trades is settled.
- The results of Elsinger (2011) show that we can relax the condition of equal priority in Proposition 4.1 to capture these more general situations where securities are settled using some prioritization mechanism.
- Also, we've assumed that there is no change of security demand of each participant during the buy-in process.

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Conclusions

- Empirical data suggest that supply/demand imbalances or strategic behaviour are not main drivers of settlement fails in the UK gilts and FTSE 100 markets. Instead, the results suggest fails are mostly due to operational frictions.
- The network of fails is more connected in the case of FTSE100. In particular, cascade effects are more pervasive in FTSE100 than in gilt markets. While for gilts more than 40% of fails are almost only attributable to the seller and not to cascade effects, this number drops to 16% in the case of FTSE 100.
- To fulfill the settlement obligations, the minimum set of participants needed to be externally bought-in is composed of the participants with strictly positive netted obligations in the failure network of a traded security.

Thank you!

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