### International capital flows and development: financial openness matters

#### Summary of Working Paper No. 472 Dennis Reinhardt, Luca Antonio Ricci and Thierry Tressel

This paper revisits the Lucas paradox by quantifying empirically the relevance of a specific set of policies — restrictions on international capital flows — in shaping the patterns of capital movements at various stages of economic development. The determinants of the direction of capital flows, and their relation to economic development, constitute an important topic in open economy macroeconomics. The study is particularly relevant at the present time, since the size and direction of capital flows have been central to the recent debate on global imbalances and will remain relevant in the aftermath of the global financial crisis. Indeed, it remains unclear, empirically, whether (and which) policies can result in capital flowing 'uphill'.

Our starting point is the classic paper in which Robert Lucas remarked that too little capital flows from rich to poor countries, relative to that predicted by the standard neoclassical model ('Lucas' paradox'). According to neoclassical theory, when countries have access to similar technologies and produce similar goods, new investment and therefore international net capital inflows — should take place more extensively in countries with lower stocks of capital per capita and therefore a higher marginal product of capital.

A large theoretical and empirical literature has provided solutions to the 'Lucas paradox', by extending the basic neoclassical model to encompass additional factors. A first group of factors include differences in technologies, factors of production, and government policies. A second group relates to the role of institutions and capital market imperfections, encompassing the quality of enforcement of private contracts, asymmetric information and moral hazard, risks of expropriation, and sovereign default.

In this paper, we step back and show that the 'failure' of the neoclassical model to predict international capital flows can also be explained by a violation of one of the model's key underlying assumptions ie that capital can flow freely across countries. Specifically, we find that the prediction of the standard neoclassical theory holds only when taking into account the degree of capital account openness, conditional on a set of fundamentals. Among countries with an open capital account, richer countries tend to experience net capital outflows, while poorer countries tend to experience net capital inflows. In contrast, in countries with a closed capital account, there appears to be no systematic relationship between the level of economic development and net capital flows. The results imply that capital account restrictions must have been effective in constraining capital flows when they were in place: rich countries liberalising their capital account should experience net capital outflows and poor countries net capital inflows.

In contrast to the recent literature that has sometimes emphasised long-term determinants of cross-sectional differences in capital flows, we focus mainly on the impact of capital account liberalisation on capital flows over time. At the time Robert Lucas was writing his paper, many developing countries still had significant capital account restrictions in place. Since then, however, countries across all income groups have progressively liberalised capital movements. High-income countries with restrictions in place initiated the process in the 1980s and, by the early 2000s, capital was flowing freely between advanced economies. Emerging markets followed the same process of liberalisation, but with a lag. Many restrictions were removed in the early 1990s, sometimes to prepare for entry to the OECD (as was the case for Korea and Mexico), or under the auspices of the International Monetary Fund. Liberalisation of capital movements started at a later stage in lower-income countries, mostly in the second half of the 1990s (some moderate restrictions are still in place). We show that this liberalisation process was associated with significant changes in the patterns of capital flows across countries at different income levels.

Our findings have important policy implications. Policies related to the capital account create externalities in the international monetary system by sustaining large current account imbalances. Our results suggest that liberalising the capital account would significantly reduce these distortions and allow capital to flow into the fast-growing emerging market surplus countries. The paper has no implications for the recent reintroduction of capital controls for potential prudential concerns, but studies the removal of pervasive capital controls.

Our paper also offers useful empirical implications: because of a global trend towards capital account liberalisation, and as more data become available over time, empirical studies will be less and less likely to detect the Lucas paradox for the average country.

## The pitfalls of speed-limit interest rate rules at the zero lower bound

#### Summary of Working Paper No. 473 Charles Brendon, Matthias Paustian and Tony Yates

This paper looks at how well 'speed-limit' rules for setting central bank interest rates do at stabilising the economy when we consider the possibility that from time to time interest rates may get trapped at their natural floor of zero (the 'zero bound'). A more common approach taken by researchers is to study interest rate setting procedures such as Taylor rules, where the interest rate is (for example) raised if inflation exceeds target, or the output gap is positive. A speed-limit rule, by contrast, is a rule where it is decided how far to raise rates based not on the level, but the rate of change of some concept like the output gap. Interest in speed-limit rules stemmed from two lines of thought, both of which ignored the zero bound as a factor for policy (largely because at the time this work was done rates were so far above the zero bound that it was considered highly unlikely they would ever get there). One was that speed-limit rules seemed to provide a way to insulate central banks from policy errors that occurred through mis-measurement of key concepts like the output gap (the difference between actual and potential output); it was easier to measure the rate of change than the level. Another was that speed-limit rules were shown to be a way for central banks to implement what the academic literature has termed 'optimal commitment policies'. These are policies that stabilise inflation and the output gap (or whatever society cares about) as well as possible, and by using the power of inflation expectations to anchor inflation, through making commitments not to simply think afresh as each period and each new shock to the economy comes along.

Our paper provides a cautionary note to those contemplating speed-limit rules, to weigh against these benefits. We find that there is a chance that rates could end up pinned at the zero bound through self-fulfilling expectations of low inflation, even if there were no fundamental shocks depressing the economy. Normally, in models of rational expectations like ours, if rates followed a Taylor rule with interest rates sufficiently responsive to inflation, and the zero bound were not in play, self-fulfilling recessions would be ruled out. Anyone who contemplated the possibility of future low inflation would recognise that this would itself drive inflation down (through the Phillips curve, the relationship determining inflation which includes a large role for expectations). That alone would prompt a sharp cut in rates, and one that would not be reversed until the output gap that was opened up by the lower inflation was closed. However, under a speed-limit rule, and faced with the zero bound, agents in the economy would correctly surmise that things will be different. First, rates cannot fall so far to begin with to counter the fall in inflation. And second, agents would forecast that after the initial fall in inflation and opening up of the output gap, the central bank would tighten more quickly. This is because it would be concerned to make sure the output gap does not close too quickly (given its concern for the 'speed limit'). This means people forecast tighter policy tomorrow, which validates the initial forecast of low inflation. Inflation and the output gap fall, and interest rates are pushed to the zero bound, simply because agents in the economy believe it will. This problem of self-fulfilling attacks at the zero bound also afflicts policy rules that involve terms in the rate of change in house prices, in a New Keynesian model modified to include housing.

# Not all capital waves are alike: a sector-level examination of surges in FDI inflows

#### Summary of Working Paper No. 474 Dennis Reinhardt and Salvatore Dell'Erba

After the global financial crisis capital flows started pouring back into emerging markets. This phenomenon is not new: capital flows often come in waves and have a strong cyclical component, as an extensive literature has documented. Capital inflows can bring many benefits such as compensating for limited domestic savings, increasing the extent of risk-sharing, and contributing to the development of financial markets. There is, however, a wide literature documenting the risks associated with the cyclical nature of capital inflows, showing that they can contribute to amplifying economic cycles, fuel credit booms, appreciate the real exchange rate, and can be subject to sudden reversals.

The perceived wisdom is that there is a pecking order among capital flows, with foreign direct investment (FDI) perceived as 'good' as it promotes growth in the receiving countries, while portfolio investment (PI) is seen as 'bad' as it is more volatile and can lead to excessive business-cycle fluctuations. While the theoretical literature shows the superiority of FDI over PI in a world of asymmetric information, the evidence from the empirical literature is mixed. Evidence from the latest financial crisis shows that large FDI flows in the financial sector appear to be related to greater macroeconomic instability in the receiving countries, suggesting that there exists heterogeneity across flows at the sectoral level, which is an aspect so far neglected in the literature.

Motivated by this evidence, this paper examines episodes of large gross capital inflows (which we will call surges) from a sectoral perspective. Specifically, we focus on surges in gross FDI at the sectoral level for emerging market economies during the period 1994–2009, employing a new data set for gross sector-level FDI inflows. The paper focuses on FDI because it has been the most important source of foreign capital for many emerging economies since the beginning of the 1990s.

We make three contributions. First, we show that while FDI surges occur across all sectors, only surges in FDI in the financial sector are accompanied by a boom-bust cycle in GDP growth. A possible explanation for this may be the expansion of credit in foreign currency that typically accompanies these flows, which might amplify the transmission of external shocks under the presence of collateral constraints.

Second, we document substantial sectoral heterogeneity in the explanatory power of the various global, contagion, and domestic factors identified by the literature as important determinants of capital flows. Global factors, chiefly global growth, have a particularly strong and positive impact on the emergence of FDI surges in the financial sector. We also find that contagion plays a stronger role in surges in the financial than non-financial sectors: countries are more likely to experience a surge in financial sector FDI (but not in the other sectors) if countries in the same region have experienced a recent surge in financial FDI.

Third, we document a role for policies related to the capital account. Restrictions on instruments that may constitute alternative sources of funding for subsidiaries of foreign banks (such as bonds) tend to increase the likelihood of FDI surges. We also find some tentative evidence that regulations restricting lending and borrowing in foreign currencies reduce the probability of surges in financial sector FDI. These findings may have implications for the design of future prudential regulation policies.

## Policy multipliers under an interest rate peg of deterministic versus stochastic duration

#### Summary of Working Paper No. 475 Charles T Carlstrom, Timothy S Fuerst and Matthias Paustian

By how much does economic activity increase when government spending goes up a little bit? This is the marginal fiscal multiplier. In normal times, this multiplier is typically smaller than one as private demand is partially crowded out by public demand. This occurs partly because government spending raises inflation, to which central banks react by raising nominal interest rates. However, it is well known that the multiplier can be larger than one when interest rates are temporarily fixed at some level, for example at the zero lower bound. The lower bound simply means that interest rates cannot become negative as people always have the option to hold cash, which earns a zero rate of return. Intuitively, this larger multiplier occurs because with fixed interest rates there is no crowding out of private demand. In fact, there is crowding in, because higher expected inflation lowers real interest rates which stimulate private demand.

This paper revisits the size of the fiscal multiplier under these special circumstances. It contrasts the usual assumption of an uncertain (stochastic) exit date from the fiscal expansion with a certain (deterministic) exit. We show that the simple modelling choice of a stochastic exit implies that the fiscal multiplier is substantially larger than that under a deterministic exit of equal mean duration. This result is surprising as the expected fiscal stimulus is the same in both cases. The explanation essentially follows from a mathematical relationship known as Jensen's inequality. When we take simple averages of two points on a straight line, the average lies halfway between them on the line. But if the line is curved, then that average will lie above or below the line (depending on whether it is curved outwards or inwards, known as convex or concave respectively). In our case, the deterministic exit fiscal multiplier is a convex function of the duration of the stimulus at constant interest rates. The fiscal multiplier under a stochastic exit averages the deterministic multipliers across all possible durations. It then follows from convexity and Jensen's inequality that this mean multiplier is larger than the multiplier evaluated at the mean duration. Overall, our findings suggest that the precise magnitude of the

fiscal multiplier is very sensitive to seemingly minor modelling assumptions, which should lead to caution in the interpretation of results from similar models.

Fiscal multipliers are typically computed in linear approximations to non-linear models, because it is easier to solve and understand economic mechanisms in linear models. But it is well known that linear approximations can be inaccurate. We therefore check whether our key results also hold in a non-linear model. Although we find that stochastic exit multipliers are again bigger than the corresponding deterministic exit multipliers, the difference is much less pronounced. This is because the errors from the linear approximation are much larger in the stochastic exit model than in the deterministic exit model.

We note that our analysis assumes that the exit from the interest rate peg is exogenous. It is unaffected by choices of firms, households and the government. In particular, it is assumed to be invariant to the size of the increase in government spending. The results are therefore best interpreted as the marginal multiplier for very small changes in spending. In practice when monetary policy is constrained by the zero lower bound, large increases in spending would generally make the exit from the bound more likely as they increase inflation. The average multiplier in this very different scenario is typically smaller than the marginal multiplier we consider in this paper.

Finally, this paper and much of the related literature has assumed that there is no other monetary policy tool that could be used to stabilise inflation when interest rates are constant at the zero lower bound. In practice, central banks have used a range of tools to further loosen monetary policy. Since these tools are likely to have significant effects on the economy, it is probable that fiscal multipliers would be lower than those presented here. For that, and a host of other reasons not examined in this paper, the multipliers analysed here should not be interpreted as the authors' best estimate of the fiscal multiplier for any specific country.

## Oil shocks and the UK economy: the changing nature of shocks and impact over time

#### Summary of Working Paper No. 476 Stephen Millard and Tamarah Shakir

This paper examines the impact of oil price movements on the UK economy, exploring how the impact of these movements may have changed over time. Ever since the dramatic oil price spikes of the 1970s, and the global recessions that ran alongside, policymakers have paid close attention to fluctuations in globally traded oil prices and worried about the potential impact on economic growth and domestic price inflation. Recent years have once again seen large fluctuation in oil prices, with prices rising from \$15 a barrel in 1998 to nearly \$140 a barrel in 2008. This rise and the volatility in both the oil price and economic performance since have reopened the debate about how, and by how much, oil shocks affect economies and how monetary policy ought to respond.

Over the past 30 years a wide range of studies have attempted to examine the impact of oil prices on the macroeconomy. Many of these studies have found that oil price movements appear to have large impacts on the economy, much larger than the share of oil in costs would imply. But alongside this headline finding, many of the same studies also find that oil price movements appear to have had a smaller impact on activity and inflation since the mid-1980s. A number of alternative explanations have been put forward to explain why the impact of oil price movements may have become smaller over time. These explanations include falls in the share of oil in the economy, more flexible labour markets, and a better or more credible policy response, together with changes in the oil market itself.

The majority of studies of the relationship between oil prices and output and inflation have focused on the United States. But, we might expect the United Kingdom to be different as it is an economy that has transitioned from net oil importer in the 1970s to net exporter in the 1980s and early 1990s and returned to be a net importer again in the mid-2000s. So, in this paper we consider the impact of oil movements on the UK economy.

We aim to answer two questions. First, how does the effect of oil price movements on the UK economy depend on the nature of the underlying shock, ie what caused the movement in oil prices in the first place? In particular, we identify three types of underlying source for oil price movements: oil supply shocks which raise oil prices and reduce oil output and world output more generally — world demand shocks — which raise oil prices at the same time as world output is going up — and oil-specific demand shocks (essentially a residual) — which raise oil prices and output while reducing world output. Second, how have these effects changed over time? We do this by using a time-varying parameter structural vector autoregression (TVP-SVAR) approach to estimate these effects. A VAR is a set of equations which are each driven by lags of all the variables in the system and by error terms, modelling the dynamics of all the variables together in response to shocks. What makes it structural is that the assumptions listed above allow us to decompose (or 'identify') the fundamental shocks that together combine to make the equation errors, so that we can trace out the impact on the variables we look at from particular types of event. The time-varying aspect allows us to see how these effects might have changed over time by not restricting the estimated effects to be constant (unlike in normal SVARs).

We find that the source of the underlying shock to oil prices does matter for the response of the UK economy. Oil supply shocks lead to larger falls in output and increases in prices than world demand shocks, with the effects becoming much smaller from the mid-1980s onwards. World demand shocks are associated with a rise in output but had little effect on inflation prior to 2006, since when they have been associated with a rise in inflation. Oil-specific demand shocks have a much smaller effect on inflation than oil supply shocks, though their effect on UK output is now similar. As a small economy, all innovations in the oil price are generally considered as exogenous to UK economic activity. That may tend to suggest that the exact source of the exogenous oil shock is of little relevance for policymakers. However, the findings in this paper suggest that even if the shock is still exogenous understanding its causes is important, as the ultimate impact for the United Kingdom is likely to be different.

We also found that the impact of different types of oil shocks on UK activity and prices has varied over time. In line with many other studies we found a fall in the impact of oil supply shocks on UK output and inflation from the mid-1980s onwards. But more unusually, we also found evidence that the impact of oil supply and demand shocks has increased since the mid-2000s. This timing coincided with the United Kingdom's transition from a net exporter to a net importer of oil. And this suggests that it may be useful to explore which channels may have been most affected, for example, the extent to which the exchange rate may have appreciated in response to oil price shocks while the United Kingdom was a net exporter, cushioning the effects on inflation of oil price rises on the rest of the economy.

# Non-uniform wage-staggering: European evidence and monetary policy implications

#### Summary of Working Paper No. 477 Michel Juillard, Hervé Le Bihan and Stephen Millard

Actual patterns of wage-setting are a key determinant of how economic shocks affect employment, unemployment and inflation. These patterns include the extent to which wages are indexed to past or future expected wage or price inflation, the extent to which they respond to movements in other costs, the extent to which wages are set differently for newly employed workers as opposed to existing members of staff, how often wages are renegotiated, whether this renegotiation occurs at regular intervals and whether wages are renegotiated at the same time for the bulk of workers in an economy or wage negotiations are evenly spread out over the year. Recent research by the Eurosystem's Wage Dynamics Network has generated much microeconomic and survey evidence on all of these issues, as well as looked at the macroeconomic implications of this evidence. Some particular findings from the cross-country survey carried out by researchers within this network were that there is substantial heterogeneity in wage-setting institutions across European countries, that wages are typically adjusted once a year, less frequently than prices, and that wage-setting is staggered and synchronised, with a large proportion of wages reset in January.

In this paper, we first document recent evidence on the degree of synchronisation among wage-setters in the euro area as a whole and in some individual euro-area countries. We then construct a simple model of the euro area to investigate the macroeconomic and monetary policy consequences of these patterns of wage-staggering. We construct a model in which, each quarter, a group of workers and employers set their wages for four quarters, but the proportion of workers doing this varies across quarters. With this model, we can study the case of full synchronisation of wage changes in a single quarter, or any particular breakdown of the probability of wage change across quarters that may match the actual bargaining pattern. We embed this set-up in a standard dynamic stochastic general equilibrium model of the euro area. We find that, when wage-staggering is uneven, then inflation and output are less persistent, both in general and, more specifically, in the way that they respond to monetary policy changes, than under an even wage-staggering scheme. Furthermore, inflation responds by more, and more rapidly, to a given interest rate change if the central bank makes this change in the quarter when most workers are renegotiating their wages, ie in quarter four, than in any other quarter. However, when calibrating the model with the micro data recently produced by the Wage Dynamics Network, which feature a significant degree of uneven staggering, we find that the quantitative outcome is close to that resulting from an even staggering scheme. And we find that this result is robust to using a US calibration for the degree of wage synchronisation, to alternative ways of modelling when wages are reset, and to reasonable variations in the degree of price stickiness: the quantitative difference between the effects of a monetary policy shock in Q4 and other quarters remained small.

Armed with these results, we then consider the consequence of non-synchronised wage-setting for optimal monetary policy. In particular we investigate whether the policy rule should vary from quarter to quarter as a result of seasonality in the wage-setting process. We find that the model has the potential to generate an optimal policy rule that varies considerably across quarters, especially in cases that get close to flexible prices and full synchronisation of wage changes. But, again, we find that under our baseline microeconomic calibration, in spite of some visible unevenness in wage-setting, there is little difference across quarters in the optimal policy response.

### Capital over the business cycle: renting versus ownership

#### Summary of Working Paper No. 478 Peter N Gal and Gabor Pinter

How does the ownership of capital affect the aggregate behaviour of the economy? Does it matter whether firms own or rent production capital such as machinery and equipment, offices and structures? These questions have been somewhat ignored by macroeconomists, mainly because in a frictionless world the question of capital ownership becomes irrelevant as firms are indifferent between renting and owning. But in the presence of credit constraints the issue of leasing versus buying may become relevant for firms' investment decisions. The motivation of our paper is to show that the presence of credit constraints makes the question of renting versus owning relevant when attempting to understand the business cycle as well.

The empirical part of the paper reports three sets of evidence on the role of renting. First, we use US firm-level data to show that more financially constrained firms tend to rely more on renting, as indicated by their higher share of renting among capital expenditures. Second, we establish that renting is countercyclical, and we link it to cyclical changes in credit standards. Finally, using cross-country aggregate data, we show that countries with a larger rental sector experience a smaller output loss after financial crises.

The theoretical part of the paper develops a general equilibrium model, where firms' decisions to purchase capital are subject to credit constraints. In contrast, firms' decisions to rent capital are assumed to be unconstrained. The model is used to explain both the observed countercyclicality of rentals and why the presence of rentals mitigates crises. While a stylised model, it is able to match some key dimensions of the US economy. The intuition behind the countercyclicality of renting is that in a crisis, when the real interest rate falls, the cost of renting (the rental fee) falls by the same magnitude as the real interest rate. By contrast, the cost of owning is reduced by falling interest rates only proportionally to the share that owning is credit financed. This asymmetric impact of the falling real interest rate on the cost of investment choices means that capital renting becomes relatively cheaper, and firms naturally substitute owned capital with rented capital.

Regarding the mitigating impact of renting, in the face of financial distress, the possibility of renting may serve as an extra margin of adjustment for both savers and borrowers. This extra margin serves the purpose of allocating the extra savings that cannot be absorbed by parts of the economy where credit conditions tighten and the capital accumulation process is impeded. This consideration involves not only the choices faced by producing firms, but also the potential suppliers of funds and rented capital.

Without the presence of rentals, equilibrium in the market of loanable funds is restored by further falls in the interest rate, which reduces savers' wealth and slows down economic recovery. With the presence of rentals, some of the extra savings in the economy are absorbed by capital investment which is then rented out for production purposes. Hence the downward pressure on interest rates is mitigated, the wealth of savers is protected and the economic recovery is faster. This general equilibrium mechanism is one of the key theoretical insights of the paper.

The implication is that well-developed rental and leasing markets may effectively offset the impact of malfunctioning credit markets.

### Financial factors and the international transmission mechanism

#### Summary of Working Paper No. 479 Abigail Haddow and Mariya Mileva

Two striking features of the Great Recession of 2008–09 are the speed and synchronicity of the collapse in world output and trade in the wake of the sub-prime crisis. These observations provide compelling evidence that spillovers of shocks across national boundaries can be large. But standard macroeconomic models are unable to account for such strong linkages in real activity across countries. There is also little consensus in previous work on the impact that financial market shocks have on real activity and how they might spill over from one country to another. The aim of this paper is therefore to investigate theoretically the impact that financial frictions have on the transmission of shocks across countries and to investigate if incorporating financial factors into an open economy model could help these models to account for the large and synchronised declines in cross-country real activity, often observed following financial crises, not only the recent one. It also analyses how the nature of financial market shocks affect the way that shocks spill over to real activity.

To investigate the impact of financial factors on the transmission of shocks across countries we build a two-country model, with sticky prices and financial frictions. Our analysis is twofold. First we build a shadow version of the model without financial frictions that is used in conjunction with the baseline friction model to analyse how financial frictions affect the way that shocks propagate across countries. Then we introduce two financial market shocks that affect the premium which borrowers pay on their loans, the credit spread, to study how the source of the shock to this credit spread affects its impact on real activity. We introduce a risk shock and financial wealth shock that are calibrated to match the increase in credit spreads seen in the United States over the recent financial crisis period. These are used to consider whether the model's predicted movements in macroeconomic variables are similar to the rapid cross-country declines in output and trade seen over the recent recession period.

Using this modelling framework, we find that the international spillovers of shocks are driven by movements in the real exchange rate and terms of trade. Both the real exchange rate and terms of trade determine the responses of real international economic variables to shocks, such as exports and imports. Under certain conditions, we find that introducing financial frictions can magnify movements in these international relative prices and therefore the spillovers of shocks to real international economic variables. The source of the shock to the credit spread also matters. Results suggest that credit spread increases of equivalent size, but driven by different shocks, have different consequences for output and inflation in the Home and Foreign economy.

Our model can generate synchronised declines in output across the two economies, similar to that seen after financial crises such as the Great Recession, but the international spillovers following all shocks are relatively small. In addition, there is little evidence that financial variables across countries tend to move together in this model, even in response to shocks which are financial in nature. To generate spillovers more in line with the 2007-10 period the model requires a coincident widening of the credit spread across the two economies. This could be interpreted in two ways. On one hand, a richer framework that incorporates direct international linkages between financial sectors is needed to analyse how financial shocks spillover to activity across economies. On the other hand, our results could be consistent with the view that the global reach of the recent Great Recession is due to a common international shock rather than a contagious spread of a country-specific event.

### Central counterparties and the topology of clearing networks

#### Summary of Working Paper No. 480 Marco Galbiati and Kimmo Soramäki

The 2008–09 financial crisis prompted reforms in important parts of the financial infrastructure. Central counterparties (CCPs) are playing a major role in this reform, especially for over-the-counter (OTC) derivatives. Notably, the G20 leaders agreed in Pittsburgh in September 2009 that 'All standardised over-the-counter derivative contracts should be traded on exchanges or electronic trading platforms, where appropriate, and be cleared through central counterparties end-2012 at the latest'. Since 2009, a substantial amount of progress has been made in defining new standards and implementing infrastructure reforms.

The main function of CCPs is to novate contracts between trading parties, becoming the 'seller to every buyer, and buyer to every seller'. By so doing, CCPs concentrate counterparty credit risk on themselves, sitting at the vertex of what can be seen as clearing networks.

In the simplest, theoretical case, a clearing network comprises the CCP at the vertex and, directly linked to this, a number of general clearing members (GCMs). Almost invariably though, the clearing network is more articulated, as some GCMs may in turn work as clearing agents for other entities (be these banks or market participants in general), and so forth in a sequence of tiers.

What are the consequences of such stratification? More generally: how does the *topology* of a clearing network affect the systemic risk-reduction role of central clearing? This paper develops a stylised model to look into this question.

The topology of a clearing network will have an effect both on credit exposures and market participants' liquidity needs as

margin calls are issued by the CCP in order to manage its exposures, and possibly also by GCMs when clearing for second-tier entities.

To analyse these issues we proceed as follows. First, we lay out a stylised but general model of central clearing. Then, we look at how *initial* bilateral *exposures* are transformed by the network into centrally *cleared exposures*, which in turn generate *liquidity demands*. The model allows exposures and liquidity demands for any network topology to be computed. We can look at the effects on exposures and liquidity demands arising in different topologies.

The model is highly simplified, flattening out fine but important detail of how, for example, exposures may be netted across the network, or how margins may be computed. Moreover, the model takes initial bilateral exposures as exogenous random variables, mechanically turning them into cleared exposures without including any behavioural component.

However, because of its simplicity, this work sheds some light on the properties of clearing networks. Its results give insights into the effects of tiering and concentration<sup>(1)</sup> on the systemic risk-reduction role of central clearing. Tiering appears to increase some key risks faced by the CCP. For example, it increases the likelihood of large exposures, and makes them more unpredictable. CCP exposures are on average smaller in concentrated systems, while extreme exposures become less frequent. The effects on margin needs are, interestingly, non-monotonic but, unfortunately, less clear-cut as they crucially depend on details of the margining methodology; in particular, on whether 're-hypothecation' is allowed or not.

 <sup>&#</sup>x27;Concentration' here refers to the way second-tier members are distributed across GCMs.