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Liquidity connectedness and output synchronisation

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ABSTRACT

The paper examines the transmission of liquidity shocks across a panel of countries and explores the power of liquidity spillovers in generating output synchronisation. Using the information on stocks, we generate aggregate stock liquidity indices in 24 countries. From the error variance decomposition, we find that countries transmit liquidity shocks across each other, and the European countries have higher cross-variance shares. We find that the transmission of liquidity shocks across economies yields a divergence in output. A standard deviation increase in liquidity connectedness lowers the co-movement in output. Thus, liquidity transfers have economic implications.

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1. Introduction

In recent years, the apparent interplay between economic crisis and the liquidity of financial assets has remained an important topic. In the United States, changes in the real economy since the Second World War have been coinciding with changes in the liquidity of the US stock market (NÆS et al., 2011). After the 2008 financial crisis, the role of market liquidity in the business cycle has become an important research question. Its importance is heightened in the global financial system as a market-wide liquidity shock affects the global economy.[1] Liquidity management has become the priority of most regulators of monetary and economic stability. In the research arena, attention has been drawn to studying commonality and the determinants of liquidity as multiple unrelated markets become affected and need to be supported during a crisis.

This study focuses on stock liquidity spillovers. We generate aggregate stock market liquidity indices in 24 countries: Australia, Belgium, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Malaysia, Mexico, Netherlands, Norway, Philippines, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, United Kingdom, and United States. The data cover the period from 1990 to 2018. The study aims to analyse the interconnectedness between stock markets through spillovers in liquidity across the globe.

Our study is unique in generating pairwise liquidity connectedness across countries. Its contribution is essential given that liquidity commonality is priced into financial markets (see Acharya and Pedersen, 2005; Lee, 2011). The transmission of liquidity shocks from one market to another has attracted research interest. For instance, Chordia et al. (2004) found

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[1] The roles of liquidity for households and firms have been studied by Dogra and Gorbachev (2016) and Acconcia and Cantabene (2018), respectively. Meanwhile, Gambetti and Musso (2017) examine the role played by loan supply shocks over the business cycle in the euro area, United Kingdom, and United States.

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covariation in volatility and liquidity between Treasury bonds and the stock market. Thus, liquidity shocks are reflected in financial asset behaviour.

In this study, rather than focusing on liquidity, we examine its connectedness. We contribute to the market microstructure literature by computing pairwise liquidity transmissions across markets. We add to knowledge on liquidity shocks and extend several empirical studies that have shown time variation and commonality in liquidity (see Chordia et al., 2000, 2008; Hasbrouck and Seppi, 2001; Huberman and Halka, 2001). Our approach allows the identification of countries that transmit liquidity and those that are recipients of liquidity spillovers.

We extend previous studies by relating liquidity spillovers to output synchronisation. Our study is unique in analysing pairwise liquidity spillovers from country *i* to country *j* against output synchronisation between country *i* and country *j*. Thus, we add a new perspective to existing studies on the relationship between liquidity and the business cycle.

Our contribution is broadly twofold: measurement of time-varying liquidity spillovers, and analysis of their association with synchronisation in output or the business cycle across economies. Few studies have examined the relationship between liquidity and real economic activities across countries. Thus, our study is a major departure from existing studies since we identify both the transmitters and recipients of liquidity shocks across countries.

The pairwise liquidity spillovers provide a better avenue to analyse the correlation between any two country pairs. Rather than focusing on liquidity, we will examine how liquidity spillovers are reflected in global output convergence. Our dynamic connectedness approach offers an essential extension to the literature given that financial integration has allowed funds to flow across borders. Thus, our contribution will enrich knowledge of international financial integration.

The rest of the study is organised as follows. First, it presents the relevance of liquidity connectedness to the real economy. Then the approach to measuring liquidity and output synchronisation is presented. This is followed by details on the data and methodological procedure. Next, the computed liquidity spillovers are discussed and the results on the relationship between these spillovers and output synchronisation are presented. The final section concludes.

2. Liquidity shocks and the Macroeconomy

Since the global financial crisis, the mechanisms through which liquidity shocks are reflected in macroeconomic outcomes have been explored in the macroeconomic literature (see Jermann and Quadrini, 2012; Kiyotaki and Moore, 2012). Both funding liquidity shocks and stock liquidity shocks reflect in macroeconomic outcomes. As explained by Brunnermeier and Pedersen (2009), the reinforcing mechanism between funding liquidity and market liquidity during times of financial stress generates liquidity spirals, and its impact on the economy can be envisaged as fluctuations in asset returns affect the macroeconomy.

The liquidity shock hypothesis, as described in Kiyotaki and Moore (2012), explains how a sudden drop in asset market liquidity that may or may not be related to macroeconomic fundamentals causes a decline in equity prices. A recession begins as investment deteriorates and output falls since lower asset prices hinder firms' financing abilities in issuing new equities and/or using equity as collateral.

Research has examined the interactions between equity market liquidity and macro fundamentals. Beber et al. (2011) find that the state of the economy can be predicted up to three months ahead by order flow movements. They also discover that information about future returns in the stock and bond markets are contained in the cross-section of order flows across sectors. Relatedly, Kaul and Kayacetin (2009) find that aggregate stock market order flow predict the future growth rates of real GDP and industrial production.

Gibson and Mougeot (2004) show that the recession index is related to a time-varying liquidity risk premium in the US stock market. Also, NÆS et al. (2011) find a strong relationship between stock market liquidity and the business cycle: they show that market liquidity is related to investor participation and that investors' portfolio compositions change with the business cycle. Chen et al. (2018) find that the residual and volatility components of illiquidity have information regarding future economic activity. As Shi (2015) states, the liquidity shock hypothesis affirms that equity prices fall following a sudden drop in asset market liquidity, which may not have resulted from changes in economic fundamentals.

The possible avenues through which the real economy is affected by stock market liquidity shocks are the investment and saving channels. The investment channel explains that investors will invest in productive but long-run projects that are highly illiquid under a liquid secondary market (Bencivenga et al., 1995; Levine, 1991). This statement is supported by Levine and Zervos (1998), who find that both current and future rates of economic growth correlate positively with stock market liquidity after controlling for economic and political factors. This finding is one explanation of the puzzling observation that stock liquidity offers information about the real economy that stock returns cannot fully capture. Because the stock price harbours a mix of information, it seems to provide lesser information about the real economy than does liquidity.

A reduction in investment funds because of lower equity prices triggers a fall in output and investment, resulting in an economic recession. Besides, asset returns respond to time variation in liquidity (see Acharya and Pedersen, 2005; Pástor and Stambaugh, 2003).

The saving channel of liquidity shock transmission to the real economy has also been explored in the literature. Productivity growth accelerates as international risk-sharing through integrated stock markets induces agents to shift portfolios from low-return investments to high-return investments (Devereux and Smith, 1994; Obstfeld, 1994). As argued by Levine and Zervos (1998), the liquidity and risk models imply that international capital market integration and liquidity will have an ambiguous effect on saving rates. In this regard, better risk-sharing and higher returns may lead to a fall in saving rates, such that more liquid and internationally integrated financial markets will slow growth.

Most studies on liquidity shock and its impact on the real economy have focused on the United States, with fewer studies examining the relationship between stock market liquidity and the business cycle in other countries. Galariotis and Giouvris (2015) examine the G7 countries and find that national liquidity has diminished ability in Granger-causing macroeconomic variables. Ellington (2018) finds that during the 2008 recession, illiquidity shocks caused annual GDP growth and inflation to decline in the United Kingdom. Apergis et al. (2015) provide evidence that, in the United Kingdom and Germany, stock market liquidity contains strong and robust information about the condition of the economy.[2]

Apart from the impact of liquidity on macroeconomic outcomes, the co-movement of liquidity across markets has attracted research attention. The literature provides evidence of commonality in liquidity among stocks (Chordia et al., 2000; Dang et al., 2015; Hasbrouck and Seppi, 2001; Huberman and Halka, 2001; Moshirian et al., 2017), which is explained by supply-side and demand-side factors. On the supply side, the funding constraints of financial intermediaries have been examined as a source of commonality (Coughenour and Saad, 2004; Hameed et al., 2010). On the demand side, investigated sources of commonality include correlated trading activity (Chordia et al., 2000; Hasbrouck and Seppi, 2001; Karolyi et al., 2012), investor sentiment (Huberman and Halka, 2001; Karolyi et al., 2012), and the level of institutional ownership (Kamara et al., 2008; Koch et al., 2016). These factors work to generate liquidity spirals and co-movement across markets.

Scholars have investigated liquidity spillovers across various asset classes. Cespa and Foucault (2014) explain that providers of liquidity often learn information about an asset from the prices of other assets, and this scenario generates a self-reinforcing positive relationship between liquidity and price informativeness. Thus, the occurrence of liquidity spillovers is inevitable, such that a small drop in one asset's liquidity can result, through a feedback loop, in a very large drop in price informativeness (a liquidity crash) and market liquidity.

We deviate from existing studies by focusing on the contribution of stock liquidity spillovers in the international market to co-movement in output synchronisation. Based on existing studies of liquidity and economic outcomes, we anticipate liquidity spillovers to matter given the nature of financial globalisation. Thus, the transmission of shocks across countries will reflect in macroeconomic output and its co-movement. For instance, Peek and Rosengren (1997) show how Japanese bank lending arising from the decline in Japanese stock values is transmitted internationally to the United States. They explain that Japanese banks are able to shift much of the asset and loan shrinkage overseas because of their large international presence. Thus, domestic financial shocks are relevant in explaining the economic state of foreign counterparts. The literature has also given some attention to the transmission process of external shocks to output (see, for example, Agenor et al., 1999).

Thus, the mechanisms through which liquidity shocks are reflected in macroeconomic outcomes are similar to the mechanisms in liquidity transmission. In line with the findings and arguments in these studies, we anticipate that the shifting of portfolios from low-return to high-return investments will induce liquidity shock transmissions across assets and across countries. A shift in portfolio choice from low-return stock to a higher yielding stock owned by foreign companies or countries implies a transmission of liquidity across economies, from which the recipient country is anticipated to benefit.

3. Measuring liquidity and output synchronisation

In this study, we compute stock liquidity using the average daily quoted spread of a stock over a week. The quoted spread captures the implicit trading cost for market orders when there is trading at the quoted price without an improvement in the price. For stock i in country j at day t, the quoted spread is measured as:

$$Quoted\ \ spread_{i,j,t} = \left(\frac{Ask_{i,j,t} - Bid_{i,j,t}}{Mean_{i,j,t}}\right) \tag{1}$$

where *Ask* represents the ask price, *Bid* represents the bid price, and the average of the ask and bid prices is the *Mean*. The logarithm of the *Quoted spread* is used, and it is multiplied by -1 so that higher liquidity is depicted by higher values, and vice versa.[3] The weekly average spread represents the market-wide liquidity, and is labelled as *Spread*. In the robustness check, we use the price impact ratio of Amihud (2002), which is labelled as *Amihud*.

Output synchronisation is measured as the negative of divergence, which is the absolute value of real GDP growth differences between country i and j in year t:[4]

$$SYN1_{i,j,t} \equiv -|(Y_{i,t} - Y_{i,t-1}) - (Y_{j,t} - Y_{j,t-1})| \tag{2}$$

where $SYN1$ is our first measure of output synchronisation, and Y is the log of GDP per capita. In the robustness check, we use the correlation approach adopted in prior studies. We also employ this approach for the sensitivity check. Thus, our second measure of output synchronisation is the quasi-correlation of real GDP growth rates (Abiad et al., 2013) of country i and country j in year t:

[2] The effects of market liquidity have been extensively studied (see Dombret et al., 2019; Li and Luo, 2019; Ma et al., 2019).

[3] See Atawnah et al. (2018) for a similar computation.

[4] See Giannone et al. (2008); Kalemli-Ozcan et al. (2013b). Business co-movement over a century is presented in Artis et al. (2011), and other related studies can be found in Candelon et al. (2009); and Leiva-Leon (2017).

$$SYN2_{i,j,t} \equiv \frac{(Y_{it} - Y_i^*) * \left(Y_{jt} - Y_j^*\right)}{\sigma_i^g * \sigma_j^g} \tag{3}$$

where$SYN2$ denotes the quasi-correlation of real GDP per capita growth rates. For country i (j) at year t, the real GDP per capita growth rate is measured by Y_{it} (Y_{jt}) and the mean and standard deviation are measured by Y_i^* (Y_j^*) and$\sigma_i^g \left(\sigma_j^g\right)$, respectively.

4. Measuring liquidity spillover

Using Diebold and Yilmaz (2012) approach of measuring the connectedness of the financial market, we compute measures of connectedness in liquidity across markets. Measuring how liquidity risk can be transferred from one market to another is essential given the increasing integration of the international asset market. The spillovers can measure the co-movement and inter-linkages in the international asset market. In this approach, the generalised vector autoregressive (VAR) framework (Koop et al., 1996; Pesaran and Shin, 1998) is employed, in which the forecast error variance decompositions are invariant to the ordering of the variables. Improving upon the initial spillover index of Diebold and Yilmaz (2009), this approach allows the generation of dynamic links in the variables of interest (see Diebold and Yilmaz, 2015; Diebold and Yılmaz, 2014).[5]

Refined measures of directional transmissions are obtained from the decomposition, enabling identification of the recipients and the transmitters of shocks and separation of shocks originating from a particular series from those received by a specific series. Thus, we can usefully quantify the magnitude of liquidity transferred from one market to another.

In this approach, a covariance stationary N-variable VAR(p) model is denoted as:

$$z_t = \sum_{i=1}^{p} \delta_i z_{t-i} + \varepsilon_t \tag{4}$$

where$z_t$represents N $\times$ 1 vector of endogenous variables; δ_i represents N $\times$ N matrices of autoregressive coefficients, and $\varepsilon_t$represents a vector of error terms assumed to be serially uncorrelated. We can represent the moving average (MA) of a covariance stationary VAR process as $z_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}$, where the recursion $A_i = \delta_1 A_{i-1} + \delta_2 A_{i-2} + \cdots + \delta_p A_{i-p}$ is obeyed by the N $\times$ N coefficient matrices A_i, $A_0$is an N $\times$ N identity matrix, and $A_i = 0$ for $i < 0$.

The H-step-ahead generalised forecast error variance decomposition is specified as:

$$\vartheta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \sum e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i A_h \sum A_h' e_i\right)} \tag{5}$$

where the standard deviation of the innovation term of the j-th equation is given asσ_{jj}, the variance matrix for the error vectorε is Σ, and e_i is the selection vector that takes the value of one for the i-th element and zero otherwise. A_h represents the coefficient matrix which multiplies the h-lagged error terms in the infinite MA representation of the non-orthogonalised VAR.

Interpreting the variance decomposition matrix as the adjacency matrix of a weighted directed network, the fraction of variable i's H-step generalised forecast error variance due to shocks in variable j (the ij-th H-step generalised variance decomposition component) can be shown as ϑ_{ij}^{gH} (ϑ_{ij}^{gH} when normalised by its row sum), $i,j = 1,\ldots, N$, $i \neq j$.

From generalised forecast error variance decomposition, the total connectedness (spillover effect in the whole system) is the ratio of the sum of 'to others' ('from others') elements of the variance decompositions matrix to the sum of all elements:

$$S^g(H) = \frac{1}{N} \sum_{i,j=1, i \neq j}^{N} \vartheta_{ij}^{g}(H) * 100 \tag{6}$$

We can obtain the net pairwise connectedness from a liquidity shock in country i(j) to country j(i) as:

$$S_{ij}^g(H) = \frac{\vartheta_{ji}^{g}(H) - \vartheta_{ij}^{g}(H)}{N} * 100 = S_{j \leftarrow i}^{g}(H) - S_{i \leftarrow j}^{g}(H) \tag{7}$$

5. Methodology and data

We use the generalised VAR approach with a 180-week rolling window.[6] From the generated weekly liquidity series, we compute the pairwise liquidity shock spillovers for each country to gauge the extent to which liquidity is connected across the

[5] Other network methods can be seen in Brownlees et al. (2018), Demirer et al. (2018), and Dungey, Harvey, and Volkov (2019). The use of financial networks in studying economic and financial systems has become highly relevant in recent years (see Caballero, 2015; J. N. Inekwe et al., 2018; John Nkwoma Inekwe and Valenzuela, 2019).

[6] We use 10-step ahead forecast error variance for the variance decompositions, which are invariant to ordering because we follow the generalised VAR framework (Koop et al., 1996; Pesaran and Shin, 1998).

economies. We also calculate the total spillover index. The weekly spillovers generated are summed to yearly aggregates. The final data are the yearly net pairwise values of liquidity shock and their corresponding yearly pairwise values of output synchronisation.

From the *Compustat* (Global) database we obtain ask and bid stock prices, which we use to compute stock liquidity. The first difference of logged liquidity data is used in the computation of spillover indices. We study 24 countries that are well-capitalised and have available data on ask and bid stock prices. The final data cover the period from 1990 to 2018. Similar to previous studies, the other independent variables include population, real GDP, exchange rate, and trade as a percentage of GDP. Data for these variables are obtained from the World Bank database. The data show that the mean value of divergence in real GDP growth per capita over the sample period is 1.39%, and the quasi-correlation is about 0.56. For each country, the summary statistics liquidity indicators used in constructing the spillovers are presented in Table 1.

The basic econometric specification is written as:

$$SYN_{i,j,t} = \alpha_{i,j} + \alpha_t + \beta LIQ_{i,j,t} + \varepsilon_{i,j,t} \tag{8}$$

where $SYN_{i,j,t}$ reflects the co-movement of output as measured by our two synchronisation variables between countries i and j at time t. The pairwise liquidity spillover shocks are captured by $LIQ_{i,j,t}$ and its coefficient is represented by β. Country-pair ($\alpha_{i,j}$)and year effects (α_t) are included. The error term is measured by$\varepsilon_{i,j,t}$.

6. Liquidity spillover and its properties

We examine the time-varying properties of the generated spillover indices. We provide plots of the 'Net' spillovers across the panel in Fig. 1. Since our interest lies in using the generated values to analyse GDP co-movement, we provide little explanation of these plots. For Australia, the results reveal that spillovers produce cyclical movement but with a slightly upward trend in recent years. This shows that there has been liquidity spillover between Australia and the rest of the economies since 2009. The directional spillovers show that, on average, Australia is a net recipient of liquidity spillover. For Belgium, liquidity is transmitted from 2004 onwards, while Brazil is a recipient of liquidity from that year. On average, Belgium is a transmitter of liquidity whereas Brazil is a net recipient of liquidity.

There is a noticeable transmission of liquidity from Canada after 2008. This observation can be linked to the financial crisis of 2008, as measures were subsequently taken to ensure banking stability. Its spillover in liquidity reaches 12% in 2004. Switzerland, Germany, Spain, France, and United Kingdom are net transmitters of liquidity whereas China, Indonesia, and India are net recipients of liquidity.

For the remaining countries, we observe that net transmitters of liquidity are Italy, Netherlands, Norway, and Sweden, while the net recipients of liquidity spillovers are Japan, Mexico, Malaysia, Philippines, Singapore, Thailand, United States,

Table 1
Descriptive Statistics of Net Liquidity Spillover and the Mean Values of Liquidity.

Country Name	Mean	SD	Minimum	Maximum	N	Spread	N	Amihud
Indonesia	−0.785	0.344	−1.398	−0.040	1242	0.0001	1325	0.0387
India	−0.783	0.308	−2.031	0.015	1152	0.0016	1236	0.0494
Philippines	−0.725	0.416	−1.487	0.137	1216	0.0002	1323	0.0309
Malaysia	−0.693	0.364	−1.488	0.522	1309	0.0002	1324	0.0347
China	−0.677	0.421	−1.541	0.332	1328	0.0002	1328	0.0420
Thailand	−0.662	0.330	−1.262	0.287	1183	0.0001	1324	0.0326
Brazil	−0.568	0.294	−1.239	0.259	1246	0.0002	1246	0.0358
Japan	−0.386	0.534	−1.358	1.036	1328	0.0000	1328	0.0262
Singapore	−0.374	0.400	−1.180	0.946	1324	0.0046	1324	0.0330
Mexico	−0.307	0.317	−1.096	0.494	1149	0.0002	1149	0.0221
South Africa	−0.295	0.435	−0.964	0.852	1189	0.0029	1324	0.0287
Canada	−0.182	0.516	−1.500	1.025	1347	0.2216	1347	0.0908
United States	−0.114	0.690	−1.053	1.639	1347	1.3280	1347	0.1182
Australia	−0.022	0.381	−0.983	0.918	1328	0.0303	1324	0.0323
Norway	0.020	0.418	−0.968	1.134	1311	0.0002	1324	0.0307
Sweden	0.135	0.414	−0.796	1.258	1323	0.0012	1324	0.0339
Italy	0.477	0.643	−0.751	1.528	1303	0.0065	1324	0.0284
Germany	0.548	0.396	−0.539	1.493	1275	0.0498	1302	0.0243
Spain	0.562	0.426	−0.211	1.676	1323	0.0005	1324	0.0240
Belgium	0.670	0.762	−0.870	2.082	1216	0.0628	1260	0.0167
United Kingdom	0.686	0.620	−0.501	2.153	1328	0.0142	1326	0.0411
Switzerland	0.939	0.758	−0.684	2.106	1311	0.0121	1324	0.0215
Netherlands	1.134	0.458	0.038	2.045	1323	0.0214	1328	0.0241
France	1.400	0.490	−0.120	2.122	1323	0.0095	1324	0.0216

Mean represents the mean value of Net liquidity spillover. Spread is the mean value of quoted spread, and Amihud is the mean value of the Amihud illiquidity indicator. The number of observations of the liquidity indicators for each country is represented by N. Both Spread and Amihud represent country average weekly values computed from daily firm stock prices. The weekly Spread values are used to compute weekly spillovers for each country.

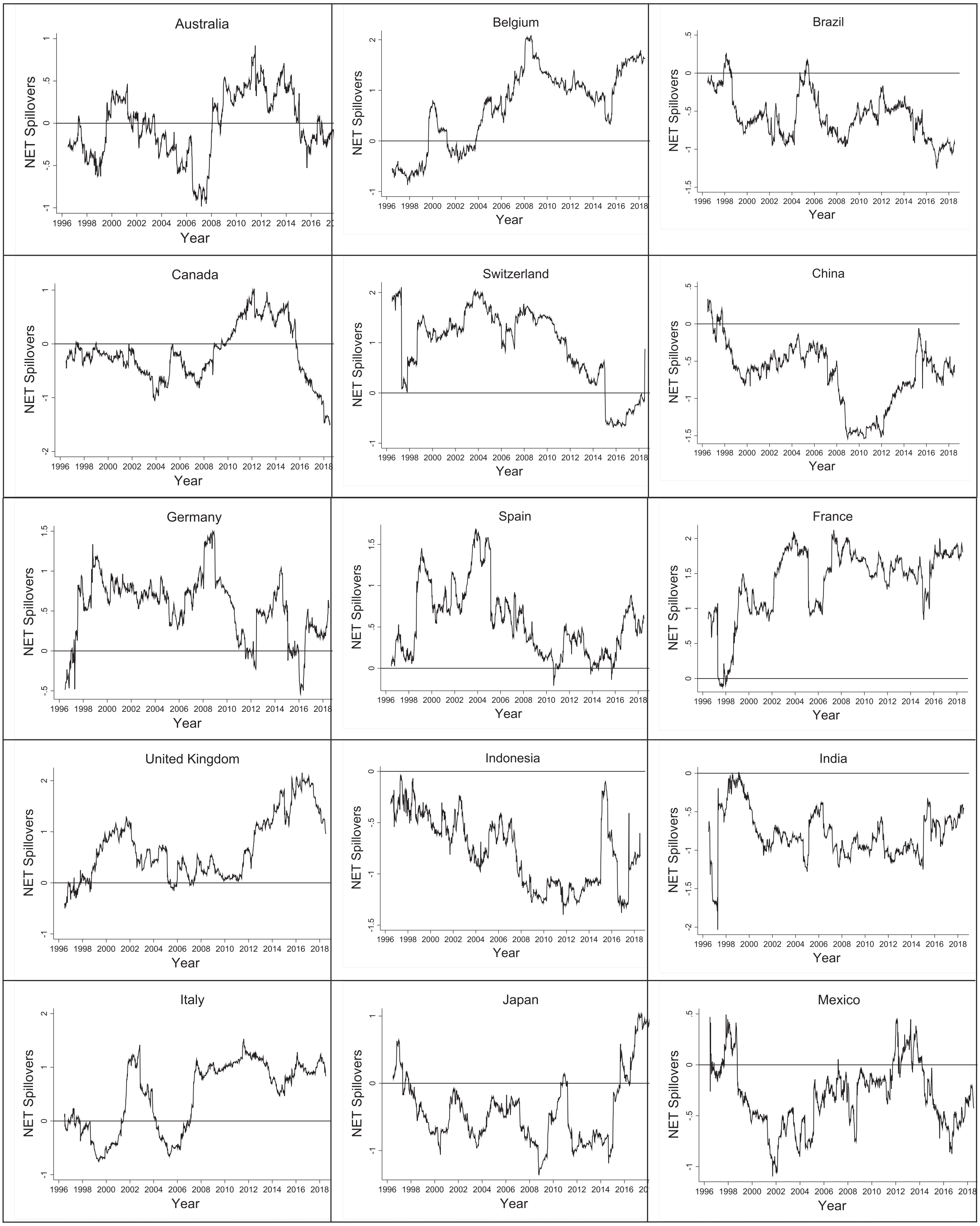

Fig. 1. Net Liquidity Spillovers.

and South Africa. On average, the results clearly show that the European countries are net transmitters of liquidity spillovers. However, a net recipient of liquidity might still have a higher level of within-country liquidity spillovers.

The study provides new evidence on the existence of asset liquidity spillovers. We find that there is time variation in the spillover of liquidity across the global market. The findings support liquidity commonality studies which have shown that

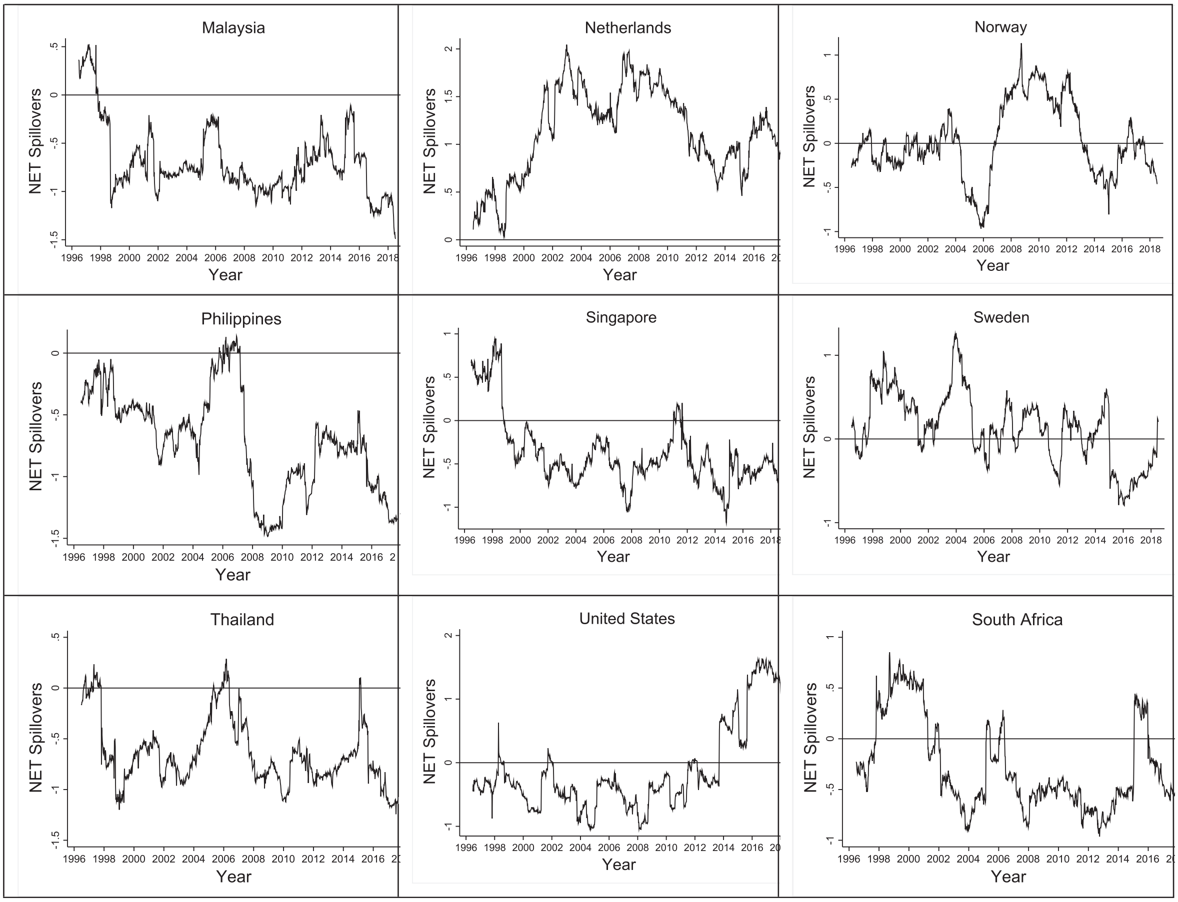

Fig. 1 (*continued*)

individual stocks and stocks in the same industry covary with overall market liquidity (Chordia et al., 2000; Hasbrouck and Seppi, 2001; Huberman and Regev, 2001).

The spillovers can be explained following the literature on covariation in liquidity. As explained by Koch et al. (2016), liquidity can covary when stocks are held by investors who trade at the same time in the same direction. Thus, liquidity spillover may be anticipated if investors across the globe are trading in a similar direction and at a similar time. The observed spillover can be explained following Coughenour and Saad (2004), who hold that covariation of stock liquidity arises because specialists within a specific firm make common adjustments to liquidity provisions based on their information and shared capital.

Fig. 2. Total Liquidity Spillover.

We present the plots of 'Total' spillovers in liquidity in Fig. 2. Similar to the net plots, the year plots of spillovers from the pairwise liquidity shocks have more explicit boom and bust cycles. In most of the study period, liquidity transmission is increasing. During the global financial crisis, liquidity spillovers have high spikes. The upward trending path shows that liquidity spillover or connectedness has been rising and the world economy is experiencing more liquidity shock transfers. The results in Table 1 show that, on average, Indonesia India, Philippines, Malaysia, China, Thailand, Brazil, Japan, Singapore, Mexico, South Africa, Canada, United States, and Australia are net recipients of liquidity spillovers, while Norway, Sweden, Italy, Germany, Spain, Belgium, United Kingdom, Switzerland, Netherlands, and France are net transmitters. In sum, European countries have higher cross-variance shares.

7. Results

In analysing the relationship between liquidity spillover and synchronisation of output, we first examine the fixed effects model using the pairwise spillover index. Both time and fixed effects are included. In investigating the complex link between synchronisation and finance in response to country-specific shocks, it is essential to control for common shocks that may have varying effects across countries. The usual approach is to include time effects or trends in an estimation whose explained variable measures the synchronisation of cycles between countries *i*and *j*. However, this might not eliminate common shocks with heterogeneous effects when fundamental differences exist between economies (see Cesa-Bianchi et al., 2019). Therefore, we also employ the instrumental variable approach.

The issue of omitted variables is another concern. As the robust correlation of business cycle synchronisation is time-invariant, the country-pair fixed effects account for these factors (see Baxter and Kouparitsas, 2005; Kalemli-Ozcan et al., 2013b). The results in the first three columns of Table 2 reveal that liquidity spillover shocks enter the models with a negative sign. This implies that at a higher level of liquidity shock transfer, a lower degree of output synchronisation is attained. For country pairs, we observe that output growth rates diverge with liquidity connectedness. The connectedness of liquidity across economies does not yield synchronisation in per capita income. A standard deviation increase in liquidity shock generates a 0.051 standard deviation decrease in output synchronisation when we account for year effects.

As argued in the literature, the estimation of synchronisation and banking integration faces the issue of reverse causation. Rather than causing business cycle divergence, banking integration may result from synchronisation. The issue is usually addressed by employing lagged values, though this approach is not ideal. In our case, we less anticipate that business cycle synchronisation will cause stock liquidity spillovers. However, we assume that reverse causation might be the case in subsequent models to be analysed. In the last three columns of Table 2, we employ the lagged values of liquidity connectedness to analyse the relationship between output co-movement and liquidity shock transfers. The results show that liquidity spillover shocks enter the models with a negative sign but with a reduced coefficient magnitude. A standard deviation increase in liquidity shock generates a 0.046 standard deviation decrease in output synchronisation when we account for year effects.

To further examine the relationship between spillover in liquidity shocks and output synchronisation, we introduce some control variables that appear in the literature. The results are reported in Table 3. In columns 1a and 1b, we include in the empirical specification population, GDP, and the year and country pairwise dummy variables. The concern that the estimates might be driven by common shocks is mitigated by using time effects. However, the literature argues that omitted time-varying country-pair factors may affect both banking integration and output synchronisation.

Introducing control variables mitigates the possibility that the negative impact of liquidity shocks on output synchronisation is due to incomparable liquidity across economies. The discrepancy in liquidity may result in differences in the growth rate. However, this argument may not apply since our focus in on liquidity spillover. The results show that liquidity spillover induces divergence in output. We find that a standard deviation increase in liquidity shock generates a 0.058 standard deviation decrease in output synchronisation.

In columns 2a and 2b, we include the exchange rate as an additional explanatory variable. The coefficient of the spillover index remains negative with a 0.057 standard deviation decrease in output synchronisation. In columns 3a and 2b, we include trade as an additional explanatory variable. The coefficient of the spillover index remains negative with a 0.058 standard deviation decrease in output synchronisation. The results imply that at a higher level of liquidity shock transfer, a lower

Table 2
Liquidity Spilllover and Synchronisation-SYN1.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
SPL	−0.020***	−0.021***	−0.002*			
	(−0.048)	(−0.051)	(−0.005)			
SPL_past				−0.017***	−0.019***	−0.002**
				(−0.042)	(−0.046)	(−0.005)
Year dummy		yes	yes		yes	yes
PC dummy			yes			yes
Observations	6,072	6072	6072	5796	5796	5796

Standardised coefficients in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Constants are not reported. SPL = liquidity spillover based on the quoted spread and PC = pairwise country dummy. SYN1 = synchronicity index.

Table 3
Liquidity Spilllover and Synchronisation- SYN1 (with controls).

Variables	(1)	(1b)	(2)	(2b)	(3)	(3b)
SPL	−0.024***	−0.002*	−0.022***	−0.002*	−0.022***	−0.002
	(−0.058)	(−0.004)	(−0.057)	(−0.005)	(−0.058)	(−0.004)
Population	−0.351***	−0.002	−0.247***	−0.005	−0.229***	0.001
	(−0.450)	(−0.002)	(−0.308)	(−0.006)	(−0.286)	(0.001)
GDP	0.371***	0.019***	0.297***	0.019***	0.334***	0.027***
	(0.362)	(0.019)	(0.316)	(0.020)	(0.353)	(0.029)
Exchange rate			0.063	0.150***	−0.010	0.144***
			(0.007)	(0.017)	(−0.001)	(0.016)
Trade					0.118***	0.030***
					(0.070)	(0.018)
Year dummy	yes	yes	yes	yes	yes	yes
PC dummy		yes		yes		yes
Observations	6072	6072	5318	5318	5302	5302

Standardised coefficients in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Constants are not reported. SPL = liquidity spillover based on the quoted spread and PC = pairwise country dummy. SYN1 = synchronicity index.

degree of output synchronisation is attained. For country pairs, we observe that output growth rates diverge with liquidity connectedness over time. The connectedness of liquidity across economies does not yield synchronisation in per capita income.

8. Instrumental variable analysis

In the previous section, we assume that the generated pairwise liquidity spillovers are exogeneous to pairwise output synchronisation. Due to the complexity of endogeneity issues, we undertake further identification of liquidity transmission shocks. Measurement error may be an issue as the generated spillovers are restricted to stock liquidity, and other forms of cross-border spillovers are not considered. To remedy this, we follow previous studies by employing the absolute difference between the stock price and $30. This instrument is used to identify liquidity shocks on the basis that an optimal trading range, with more liquid stocks, centres around $30 (see Choi et al., 2009; Hillert et al., 2016).

For identification, we include the initial level of pairwise spillover in the first stage analysis. The coefficients of the instruments are statistically significant, and the over-identifying restrictions are valid. Also, the first stage F-statistics are above the rule of thumb for weak instrument validity. We allow for arbitrary heteroskedasticity and autocorrelation consistent standard errors in the estimations. We focus on the specifications with time and country dummies.

Table 4 reports the results of the instrumental variable technique. The results show that liquidity spillover shocks enter the models with a negative sign and statistical significance. A standard deviation increase in liquidity shock generates a decrease in output synchronisation of 0.444 standard deviation in column 1b, 0.422 standard deviation in column 2b, and 0.423 standard deviation in column 3b. The results show that the fixed effects models are downward biased. The controls are statistically significant, and GDP is positively related with output synchronisation.

Table 4
Liquidity Spilllover and Synchronisation- SYN1 (Instrumental Variable).

Variables	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(3c)
SPL	−0.247***	−0.182***	−0.204***	−0.163***	−0.194***	−0.165***	−0.198***
	(−0.603)	(−0.444)	(−0.527)	(−0.422)	(−0.503)	(−0.428)	(−0.513)
Population	−0.372***	−0.339	−0.269***	−0.308	−0.246***	−0.523	−0.245***
	(−0.477)	(−0.434)	(−0.335)	(−0.385)	(−0.307)	(−0.652)	(−0.305)
GDP	0.344***	0.395***	0.281***	0.357***	0.324***	0.344**	0.340***
	(0.336)	(0.386)	(0.298)	(0.379)	(0.342)	(0.364)	(0.359)
Exchange rate			0.324**	−0.024	0.235*	−0.093	0.255*
			(0.036)	(−0.003)	(0.026)	(−0.010)	(0.029)
Trade					0.137***	−0.164	0.169***
					(0.082)	(−0.098)	(0.101)
Year dummy	yes	yes	yes	yes	yes	yes	
Country dummy		yes		yes		yes	
Sargan test	0.06	0.187	0.830	0.351	0.626	0.445	0.962
F-statistic	89	78	118	58	80	58	74
Observations	6072	6072	5318	5318	5302	5302	5302

Standardised coefficients in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Constants are not reported. SPL = liquidity spillover based on the quoted spread and PC = pairwise country dummy. SYN1 = synchronicity index. Sargan test is the test of the validity of the over-identifying restrictions. F-statistic is from the first stage regression.

9. Sensitivity check

For the sensitivity check, we re-estimate the models using the alternative measure of output synchronisation. In the first three columns of Table 5, we employ the values of liquidity connectedness to analyse the relationship between spillover and output correlation. The results reveal that liquidity spillover can explain GDP per capita correlation across our sample. The results are statistically significant, and a standard deviation increase in liquidity shock generates a 0.065 standard deviation decrease in GDP per capita correlation. Accounting for year effects, a standard deviation increase in liquidity shock generates a 0.052 standard deviation decrease in output synchronisation.

In the last three columns of Table 5, we employ the lagged values of liquidity connectedness to analyse the relationship between output co-movement and liquidity shock transfers. The results confirm that liquidity spillover shocks are relevant to output co-movement. The coefficients are statistically significant and negatively signed, implying that the transmission of liquidity shocks reduces the degree of output synchronisation attained. However, liquidity shock connectedness does not yield synchronisation in per capita income. Accounting for time and country pairwise fixed effects, we find that a standard deviation increase in liquidity shock generates a 0.039 standard deviation decrease in output co-movement. In terms of the coefficient signs and magnitudes, the results are similar to those obtained using the alternative measure of output synchronisation.

Table 6 reports the results when including some control variables. Both time and country pairwise dummies are used to analyse the relationship between output co-movement and liquidity shock transfers. The results show that liquidity spillover shocks have similar effects to those reported in the fixed effects models. GDP and trade seem to induce co-movement, whereas population induces divergence.

10. Additional check

This section employs an alternative measure of liquidity, specifically the price impact ratio developed by Amihud (2002). The price impact ratio of stock index i at day d in week t is denoted as *illiquidity*, calculated as the average daily ratio of the absolute stock return to the dollar trading volume within the week:

Table 5
Liquidity Spilllover and GDP Correlation -SYN2.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
SPL	-0.018^{***}	-0.014^{***}	-0.012^{***}			
	(−0.065)	(−0.052)	(−0.045)			
SPL_past				-0.014^{***}	-0.011^{***}	-0.010^{**}
				(−0.054)	(−0.045)	(−0.039)
Year dummy		yes	yes		yes	yes
PC dummy			yes			yes
Observations	6072	6072	6072	5796	5796	5796

Standardised coefficients in parentheses, *** p < 0.01, ** p < 0.05, * p < 0.1. Constants are not reported. SPL = liquidity spillover based on the quoted spread and PC = pairwise country dummy. SYN2 = the quasi-correlation index.

Table 6
Liquidity Spilllover and Correlation-SYN2 (with controls).

Variables	(1)	(1b)	(2)	(2b)	(3)	(3b)
SPL	-0.014^{***}	-0.012^{***}	-0.014^{***}	-0.012^{***}	-0.015^{***}	-0.012^{***}
	(−0.051)	(−0.045)	(−0.050)	(−0.042)	(−0.052)	(−0.043)
Population	-0.098^{***}	-0.017^{**}	-0.104^{***}	-0.057^{***}	-0.071^{***}	-0.045^{***}
	(−0.187)	(−0.033)	(−0.178)	(−0.097)	(−0.122)	(−0.077)
GDP	0.138^{***}	0.037^{***}	0.133^{***}	0.061^{***}	0.199^{***}	0.084^{***}
	(0.201)	(0.054)	(0.194)	(0.089)	(0.289)	(0.122)
Exchange rate			0.232^{***}	−0.017	0.072	−0.036
			(0.036)	(−0.003)	(0.011)	(−0.006)
Trade					0.215^{***}	0.077^{***}
					(0.176)	(0.063)
Year dummy	yes	yes	yes	yes	yes	yes
PC dummy		yes		yes		yes
Observations	6072	6072	5318	5318	5302	5302

Standardised coefficients in parentheses, *** p < 0.01, ** p < 0.05, * p < 0.1. Constants are not reported. SPL = liquidity spillover based on the quoted spread and PC = pairwise country dummy. SYN2 = the quasi-correlation index.

Table 7
Liquidity Spillovers and Output Synchronisation.

Model Variables	1 SYN1	2 SYN2	3 SYN1	4 SYN1	5 SYN2	6 SYN2
SPL	−0.165***	−0.128***				
	(−0.428)	(−0.455)				
RAMIL			−0.090**	−0.090**	−0.034	−0.047*
			(−0.081)	(−0.081)	(−0.046)	(-0.062)
Population	−0.523	0.799*	−0.579	−0.579	0.059	−0.168
	(−0.652)	(1.369)	(−0.731)	(−0.731)	(0.109)	(-0.346)
GDP	0.344**	0.552***	0.552***	0.552***	0.686***	0.606***
	(0.364)	(0.802)	(0.587)	(0.587)	(1.077)	(0.943)
Exchange rate	−0.093	−0.243*	0.173	0.173	0.023	
	(−0.010)	(−0.037)	(0.021)	(0.021)	(0.004)	
Trade	−0.164	0.039	0.107	0.107	0.212	0.091
	(−0.098)	(0.032)	(0.064)	(0.064)	(0.187)	(0.080)
Year dummy	yes	yes	yes	yes	yes	yes
Country dummy	yes	yes	yes	yes	yes	yes
2008 dummy	yes	yes		yes		
Sargan test	0.445	0.957	0.108	0.108	0.857	0.696
F-statistic	58	58	20	20	20	22
Observations	5302	5302	3106	3106	3106	3562

SPL = liquidity spillover based on the quoted spread and RAMIL = liquidity spillover based on the Amihud iliiguidity index. Standardised coefficients in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. SYN1 and SYN2 are synchronicity and quasi-correlation indices respectively. 2008 dummy = 1 if the year is above 2008 and 0 otherwise (controls for the effects of the global financial crisis). Sargan test is the test of the validity of the over-identifying restrictions. F-statistic is from the first stage regression.

$$illiquidity_{i,t} = \text{average}\left(\frac{|R_{i,d}|}{Vol_{i,d}}\right) \tag{8}$$

where $R_{i,d}$ is the daily return, and Vol is the dollar volume of stock index i at day d in week t. Thus, the computed daily illiquidity measure is averaged to weekly values for each country. Since a smaller value indicates that the stock price is less responsive to trades, smaller values of Amihud's ratio imply higher liquidity. We use the logarithm of Amihud's price impact ratio and multiply it by -1, such that higher values are associated with higher liquidity, and vice versa.[7] The data are sourced from Compustat. The generated liquidity indicator is used to compute the weekly spillovers in liquidity for each country. For the economic analysis, the spillovers are aggregated (summed) to yearly values. We use the real value of Amihud spillover (which is labelled as RAMIL) by controlling for the effects of inflation.

We report the results in Table 7. For the sensitivity check, we re-estimate the models using the alternative measure of output synchronisation, and these are labelled as SYN1 for synchronisation and SYN2 for quasi-correlation indices. For Models 1 and 2, we employ the liquidity spillover index computed from the spread. For identification, we employ our instrumental variable and include the initial level of pairwise spillover for over-identification. The over-identification tests are valid, and we find that a standard deviation increase in liquidity spillovers generates about a 0.45 standard deviation decrease in output synchronisation.

In the last four columns of Table 7, we employ the real value of Amihud spillover to examine its effect on output synchronisation. We employ the first and second lag of this index in identifying its effect. Though we avoid making any casual interpretation, we can see that the results do not differ much as the coefficient signs, significances, and magnitudes are similar when the alternative index is used. Thus, we are confident that spillovers impact on output movements across these countries.

We also compute a newer price impact ratio [average$\left(\frac{|R_{i,d}|}{Vol_{i,d/NS_{i,d}}}\right)$ (NS = number of shares outstanding)] of Florackis, Gregoriou, and Kostakis (2011), and the effective bid-ask spread [$2^*\left(\frac{\text{Price}-(\text{Ask}_{i,j,t}+\text{Bid}_{i,j,t})/2}{(\text{Ask}_{i,j,t}+\text{Bid}_{i,j,t})/2}\right)$].[8] We employ these two liquidity proxies to compute additional indices of spillovers in liquidity. The models are estimated using alternative measures of output synchronisation, labelled as SYN1 for synchronisation and SYN2 for quasi-correlation indices.

For Models 1 and 2, we employ the liquidity spillover index computed from the newer price impact ratio, labelled as RAMIL_new. For Models 3 and 4, we employ the liquidity spillover index computed from the effective bid-ask spread, labelled as SPL_new. For identification, we employ our instrumental variable and include the initial level of pairwise spillover for over-identification. The results are reported in Table 8. The over-identification tests are valid, and we find that a standard deviation increase in liquidity spillovers generates about a 0.1 to 0.16 standard deviation decrease in output synchronisation. The results are consistent with those obtained using the former measures of liquidity.

7 See Bali, Peng, Shen, and Tang (2013) and Atawnah et al. (2018) for similar approaches.
8 On the measurement of liquidity see Abdi and Ranaldo (2017), Fong et al. (2017), and Hasbrouck (2009).

Table 8
Liquidity Spillovers and Output Synchronisation.

Model Variables	1 SYN1	2 SYN2	3 SYN1	4 SYN2
RAMIL_new	−0.046***	−0.004		
	(−0.104)	(−0.014)		
SPL_new			−0.055***	−0.028***
			(−0.164)	(−0.109)
Population	−0.827	0.058	−0.549	0.834
	(−1.036)	(0.111)	(−0.689)	(1.333)
GDP	0.512***	0.658***	0.458***	0.658***
	(0.542)	(1.060)	(0.488)	(0.892)
Exchange rate	0.067	−0.122	−0.056	−0.206
	(0.007)	(−0.021)	(−0.006)	(−0.030)
Trade	−0.004	0.068	−0.073	0.183
	(−0.003)	(0.062)	(−0.044)	(0.141)
Year dummy	yes	yes	yes	yes
Country dummy	yes	yes	yes	yes
2008 dummy	yes	yes	yes	yes
Sargan test	0.704	0.895	0.993	0.232
F-statistic	566	566	494	494
Observations	5059	5059	4074	4074

SPL = liquidity spillover based on the quoted spread and RAMIL = liquidity spillover based on the Amihud iliiguidity index. Standardised coefficients in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. SYN1 and SYN2 are synchronicity and quasi-correlation indices respectively. 2008 dummy = 1 if the year is above 2008 and 0 otherwise (controls for the effects of the global financial crisis). Sargan test is the test of the validity of the over-identifying restrictions. F-statistic is from the first stage regression.

Our results reveal that liquidity spillovers have an important influence on output synchronisation. Similar to liquidity constraints, the cross variances in liquidity can affect country output divergence. Since the 2007 to 2009 financial crisis, shocks to financial market assets and financial globalisation have received enormous attention. Financial globalisation and economic activity are studied with the aim of identifying the benefits of interconnections and the shocks that may arise in one corner and affect others. One major question has been whether financial globalisation has induced output co-movement over several decades. Kalemli-Ozcan et al. (2013b) counter conventional wisdom on this issue by contending that the correlation between business cycle synchronisation and financial integration is ambiguous.

The argument is that under financial integration, adverse (beneficial) collateral or productivity shocks to firms in one country will cause lending to decrease (increase) for both domestic and foreign banks in that country but increase (decrease) in non-affected countries. The consequence will be a divergence in output growth. However, when the banking sector is the recipient of the negative shock, funds will be pulled out of all countries by globally operating banks, thereby transmitting the shock from domestic banks to the international economy, resulting in the co-movement of business cycles across countries.

In theory, higher or lower volatility can occur with banking integration, depending on whether credit demand or credit supply shocks predominate. In their analysis of the US banking system, Morgan, Rime, and Strahan (2004) observe that as banks in one state become more integrated via holding companies with banks in other states, there is a fall in the year-to-year fluctuations in a state's economic growth. There may be convergence in fluctuations between any pair of states when bank linkages between them increase. Thus, interstate banking generates co-movement in state business cycles. Under increased international financial integration, Perri and Quadrini (2018) show that crises are less frequent but are larger and more synchronised across countries.

Our results show that liquidity spillovers can explain output co-movement, thus corroborating studies that have analysed financial integration and output synchronisation. A fall in business cycle synchronisation across countries due to an increase in financial integration is found in (Kalemli-Ozcan et al., 2013a, 2013b). Inferring from the their data, they support the view that financial flows are efficient in their quest for high returns, and in response to idiosyncratic shocks, they behave according to the prediction of the canonical international RBC model. Their result is supported by the findings of Cesa-Bianchi et al. (2019), who conclude that common shocks with heterogeneous effects drive the observed result.

Our results show that liquidity spillovers can generate divergence in output. This can be explained by viewing recipients of liquidity spillovers as having lower liquidity, which tends to lower growth in output. This proposition is supported by previous findings that a significant slowdown in economic growth follows the worsening of liquidity (see, for example, NÆS et al., 2011). The converse happens in a liquidity transmitting country, such that excess liquidity generates a more favourable market environment that enhances growth in per capita income. The outcome of these opposing mechanisms is divergence in output.

11. Conclusion

We enhance current knowledge by computing stock market liquidity spillovers. We demonstrate the existence of liquidity connectedness across economies. Co-movements in the liquidity of individual assets are explained by demand-side and supply-side theory. Prior literature identifies that liquidity co-moves and is time-varying. This study extends previous research on liquidity co-movement by generating time-varying liquidity spillovers across markets and analysing the relationship with output synchronisation. We use daily ask and bid stock prices to compute stock liquidity, and employ the generalised VAR approach with a 180-week rolling window. From the generated liquidity, we compute pairwise liquidity shock spillovers for each country to gauge the extent to which liquidity is connected across the economies. We also compute pairwise synchronisation of GDP across markets. Our study considers 24 countries for the period 1990 to 2018.

In sum, we find liquidity externality across markets, confirming the existence of liquidity spillover in financial markets. The results provide support for liquidity commonality by identifying co-movement of liquidity and time variation. On average, Indonesia India, Philippines, Malaysia, China, Thailand, Brazil, Japan, Singapore, Mexico, South Africa, Canada, United States, and Australia are net recipients of liquidity spillovers, while Norway, Sweden, Italy, Germany, Spain, Belgium, United Kingdom, Switzerland, Netherlands, and France are net transmitters of liquidity. In sum, our sample shows that European countries transmit a higher share of liquidity to other countries.

We find that liquidity spillovers contain useful information for explaining GDP synchronisation across markets. Our results show that liquidity spillovers can generate divergence in output. The effect can be explained by viewing recipients of liquidity spillovers as having lower liquidity, which will act to lower growth in output. In liquidity transmitting countries, the converse happens, such that excess liquidity generates a more favourable market environment which enhances growth in per capita income. Divergence in output is observed through these opposing mechanisms.

A possible alternative explanation is that a liquidity transmitting country is a hub of international investors who shift their portfolios towards that country's stock market, thus favouring its liquidity and, invariably, its productivity. A recipient country, by contrast, is less liquid and the discrepancy results in output divergence. However, this explanation should be considered speculative since our study does not separate transmitters from recipients in analysing output synchronisation.

The main policy implication of our study is the confirmation that liquidity spillovers exist across markets. This indicates that shocks to equity market liquidity are generally important in driving business cycles, such that the amplification or propagation of the business cycle can occur under a liquidity spillover shock. It becomes essential to understand the mechanism behind spillovers in liquidity and what measures can be used to correct imbalance in liquidity across countries.

Our results provide new insights for analysing global liquidity and its effects on the world economy. Liquidity is important in the global financial system as market-wide liquidity shocks affect the economy. Most regulators of monetary and economic stability emphasise liquidity management. Maintaining stable liquidity across markets becomes important as the connectedness of liquidity across economies affects the divergence of income.

While the results reveal that liquidity connectedness seems to magnify local shocks our study does not separate transmitters from recipients in analysing business cycle synchronisation. Future studies could examine the difference in synchronisation between transmitters and recipients at each time.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.intfin.2020.101208.

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