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# THE INTERCONNECTEDNESS OF STOCK PRICES, MONEY, AND CREDIT ACROSS TIME AND FREQUENCY FROM 1970 TO 2016

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**Abstract.** This article applies continuous wavelet and maximal overlap discrete wavelet transforms to study the co-movements and the direction of causality between money (M3 and M2), bank credit, credit from all sectors vs. stock price dynamics across time and frequency for 12 developed countries. The time-varying linkages were significant typically for credit rather than money developments. Particularly, these linkages appeared during phases of house and stock price boom and bust at a business cycle frequency. The discovered lead-lag patterns give relatively much time for monetary policy authorities to support their financial stability objectives by imposing restrictions on credit. Closing the channel through which credit and stock prices interact may counteract the rising financial imbalances. This finding holds also for the euro area where the monetary pillar is based on broad money. The new application of wavelets allowed discovering the varying linkages that were not necessarily evident in the standard methods of analysing data.

**Keywords:** money, credit, stock prices, wavelets, house price bubbles, stock price bubbles.

**JEL Classification:** E31, E41, E42, E5.

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## Introduction

The harmful effects of financial instability and unsustainable developments in the stock market on the real economy have emphasised the importance of asset prices in policy deliberations in recent years (Congdon, 2021; Caines & Winkler, 2021; Reinhart & Rogoff, 2009). Instability is often the result of asset price volatility accompanied by rapid changes in liquidity conditions (Bordo & Haubrich, 2010; Borio & Lowe, 2002). The mechanism by which stock

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prices react to changes in the money (credit) supply, as well as new information inflow, or inflation uncertainty, leads to a complicated dynamical problem, being the subject of many theoretical considerations (for details, see, e.g., Singh & Nadkarni, 2020; Camilleri et al., 2019; Belke & Wiedmann, 2018; Ariff et al., 2012; Humpe & Macmillan, 2009; Fama, 1990; Brunner, 1961; Friedman, 1961). The general empirical evidence on the link between stock prices and liquidity remains ambiguous (Ahmed et al., 2018). Moreover, while one strand of research highlights the impact of general economic conditions on stock prices (De Sousa et al., 2018; Antonakakis et al., 2017; Papadamou et al., 2017; Kal et al., 2015; Rudzkis & Valkavičienė, 2014; Pirovano, 2012; Flannery & Protopapadakis, 2002; King, 1966), some other studies point out the impact of firm-specific factors (Valcarcel, 2012).

The empirical methods of verifying the liquidity hypothesis have changed over the course of the last years; nevertheless, the main research output has remained the same: the overall evidence is mixed, especially if liquidity denotes money dynamics. Humpe and Macmillan (2009) applied a cointegration analysis and found a non-significant (albeit positive) relationship between the US stock prices and money supply. In Japan, however, the link is negative, which can be explained by the Japanese asset price bubble's collapse in 1991 and the subsequent liquidity trap. In France, Germany, and Portugal, Camilleri et al. (2019), using vector autoregressions (VAR), found that the interaction between interest rates and money supply was a leading indicator of stock prices. However, Belke and Wiedmann (2018) applied the Cointegrated Vector-Autoregressive framework and showed a limited impact of real money developments on stock prices in a sample of five well-developed countries. Instead, the authors showed a positive link between stock prices and money supply in the three emerging markets considered.

Likewise, other notable empirical works reveal discrepant results over several recent years. Although some studies imply a causal relationship between credit (or money) and stock prices (Lee, 2020; Hau & Lai, 2016; Bjørnland & Leitemo, 2009; Bernanke & Kuttner, 2005; Lastrapes, 1998), others suggest the opposite direction (Apergis et al., 2018; Gouteron & Szpiro, 2005; Rigobon & Sack, 2003; Hashemzadeh & Taylor, 1988). The third group of empirical works finds a weak link typically between money and stock prices (see Singh, 1993; Lee, 1992).

This paper aims at analysing the co-movements and the direction of causality between money (M3 and M2 monetary aggregates) and stock prices on the one hand, and between credit (bank credit and credit from all sectors to private non-financial sector) and stock prices on the other hand while using the continuous wavelet transform (CWT) and maximal overlap discrete wavelet transform (MODWT) for twelve industrialised countries[1] since

[1] The analysis is performed for Australia (AU), Canada (CA), the euro area (EA), Iceland (IS), Japan (JP), New Zealand (NZ), Norway (NO), Sweden (SE), South Africa (ZA), Switzerland (CH), the United Kingdom (UK), and the United States (US). The list of the Organisation for Economic Cooperation and Development (OECD) countries stems from the availability of the time series (on the M3 and M2 money supply, credit, real GDP, and stock prices) in the internet databases of the International Monetary Fund (IMF), the Bank for International Settlements (BIS), the Organisation for Economic Co-operation and Development (OECD), and the Federal Reserve Economic Data (FRED) from 1970 to 2016. A notable exception is the inclusion of the euro area in the analyses due to the systemic importance of the European Central Bank and its unprecedented scale QE programmes related to the Great Recession and subsequent euro-area debt crisis. More information on the time series used and data in Section 3: "Data" and notes below figures.

the 1970s. In other words, our aim is to empirically investigate the hypothesis that liquidity conditions proxied by broad money and credit positively influence stock price dynamics. In particular, we use the wavelet phase spectrum (marked with arrows at the wavelet coherency plots) to determine the lead-lag patterns in the time and frequency framework.

To the best of our knowledge, we contribute to the literature in many aspects. First, there are merely few studies analysing the dynamic interplay between money (credit) and stock prices based on quarterly time series range from 1Q 1970 to 4Q 2016, including the Great Recession of 2007–2009, the euro area debt crisis (2010–2012) and quantitative easing (QE). Since leading central banks have employed unconventional measures to support economic growth, a new strand of research has emerged that addresses the impact of QE on asset prices (see, for example, Wu, 2018). The unprecedented liquidity-providing operations employed by major central banks combined with large swings in asset prices form an interesting backdrop for this study. Although stock prices play an important role in the monetary transmission mechanism in numerous theories, the QE triggered the need to refine our understanding of the transmission channels.

Second, against the abovementioned post-Great Recession background, the objective of this study is to answer the question about the relative dominance of credit compared to money dynamics in causing fluctuations in stock prices. Our motivation for this approach is the fundamental changes in the relationship between money and credit after the Great Depression and World War II (WW2), which are still "not fully appreciated" (Schularick & Taylor, 2012). Indeed, there has been a paucity of empirical works that distinguish the impacts of money and credit on stock prices. A notable exception is the study of Singh and Nadkarni (2020) on a sample of 22 emerging market economies. Notwithstanding this, the authors use panel VARs that, for instance, do not allow drawing any country-specific or time-varying conclusions.

Third, we are aware of only a handful of papers using wavelets allowing assessing the time-varying and time-dependent lead-lag patterns and disentangle the short-run from long-run effects within a unified framework (Albu & Albu, 2021). This feature can be opposed to conventional techniques for characterising correlated behaviour in time or frequency. Therefore, we believe that our methodology seems to be a promising tool for the objectives of this article, especially because stock returns vary over time (Campell et al., 1997), and the relationship between money (credit) and stock prices can change over time (Jansen & Zervou, 2017) and frequency (Pícha, 2017; Ratanapakorn & Sharma, 2007). For example, Camilleri et al. (2019) reviewed previous studies on the link between stock prices and macroeconomic indicators, including money stocks, and concluded that "clear cut inferences" in terms of links cannot be made "since these can vary between countries and time periods". In particular, the empirical literature demonstrates that the relationship between monetary policy and stock returns experienced a significant change during the Great Recession (Florackis et al., 2014; Kontonikas et al., 2013). Kurov and Gu (2016), for instance, pointed out that the sign of the estimated stock market reaction to monetary news was reversed in the United States during the global financial crisis.

As far as the novelty of this study for the banking system, stock market, and overall economy is concerned, the following points deserve a particular attention. Our cross-country evidence implies that the dynamics of money and credit can mislead investors and policy makers about future stock prices in the horizon up to 2 years, but may be a useful gauge for central banks to support their medium- and longer-run financial stability objectives. The novel findings across frequency domain may allow adjusting decision of economic forecasters, policymakers and investors in line with their different operational horizons. We believe that our new findings in time and frequency domains might be exceedingly useful for monetary authorities when making policy decisions supporting their medium- and longer-run monetary and financial stability objectives (Dison & Rattan, 2017). We provide novel evidence that stabilising the growth of credit may be especially important when optimistic expectations emerge from Asset Purchase Programmes, during build-ups of house price booms and EQ (namely when the co-movements between money/credit and stock prices are typically strong and significant). In such case, limiting credit fluctuations resulting from the increase in the perceived wealth when stock prices soared may help to reduce "irrational exuberance", herd behaviour, or the costly burst of a stock price bubble in the medium and long run.

The importance of our findings stems from the considerable impact of stock prices on economic activity. For example, changes in household stock market wealth influence consumption and, therefore, economic growth (Apergis et al., 2018). Moreover, higher stock prices induce investment through reducing the cost of capital for firms, in line with Tobin's Q effect. Finally, stock price dynamics can also indicate increasing concerns about the state of the economy, potential problems in credit markets (Bernanke, 2008) and risks to financial fragility (Chen et al., 2021). Vicente and Araujo (2018) evidence that their leading indicators based on current stock returns have strong correlation with future economic conditions. Recently, Davis et al. (2022) by analysing 35 sample countries argued that stock prices signalled the severity and the timing of the collapses of those countries' economic activity because of the Coronavirus pandemic. The importance of stock market for the real economy developments stems also from the fact that it helps to mobilize capital, which companies use to support investments and economic growth. In sum, the link between stock prices and macro fundamentals has attracted the attention of academics and policy makers worldwide (Pan & Mishra, 2018; Pradhan et al., 2014; Marques et al., 2013). The reason is the relevance of the link for risk management, asset allocation and safeguarding financial stability (Shahzad et al., 2021).

Finally, we contribute to the existing literature, as we use a methodological approach delivering findings that may be not evident in standard methods of data analysis that apply pure time- and frequency-domain methods (Hkiri et al., 2018). We argue that combining the time and frequency domains within a single scheme could "build a bridge" between the discrepant results in the subject literature that examines the interdependencies between money (credit) and stock prices. Indeed, our results imply that one of the possible reasons for the discrepancy in the subject literature could be the changes in the aforementioned link across time and frequency. To our knowledge, we are the first to deliver empirical CWT and MODWT evidence on the link between money (credit) and stock prices. As opposed to our approach, the majority of empirical works on the responses of stock returns to monetary policy employ the event study methodology and regress high frequency (typically daily) stock returns on either monetary policy asset purchase announcements or changes in the policy rate.

The kind of study that we perform for different time horizons is important for policymakers. In particular, the question of a short- and especially long-run relationship between the growth rate of the money supply (credit) and stock prices is of utmost importance. As the long-run is composed of a series of shorter-runs, ignoring increases in stock prices (credit) may potentially lead to a credit (stock price) boom in the long run (especially if additional credit is used to further inflate stock prices). This obviously brings along the risks of recession or an economic slowdown if the stock price bubble bursts and the stock price turmoil spreads to the financial sector and ultimately to the real economy. Thus, the paper deals with current policy issue (given the recent increases of stock prices, the prolonged period of QEs and a series of new ones to come). The knowledge on the linkages between money (credit) and stock prices is important especially that our wavelet evidence reveals that the relationship between money (credit) and stock prices can vary in the short, medium and long run (leading to problems with detection and interpretation of the relationship between money/credit and stock prices).

The article is structured as follows. Section 1 elaborates on the theoretical mechanism that explains the interaction between money (credit) and stock prices. Since considerable monetary and credit dynamics are typically associated with the build-up of financial imbalances during a business cycle, we deliberate on it in Subsection 1.2. Section 2 outlines the methodology. Section 3 describes the data. Section 4 presents the results. The CWT evidence for the M3 broad money, bank credit, and stock prices for the four major economies that implemented QE is discussed in Subsection 4.1. In the Subsection 4.1, we focus on the period since the Great Moderation, namely, since 1Q 1984 (McConnell & Perez-Quiros, 2000). The analysis of wavelet coherence from 1970 to 1984 is available upon request. The joined analysis could have violated the assumption of constant background spectra due to the significantly decreased volatility of output and inflation after 1984 in advanced economies. The robustness checks including the MODWT and alternate money and credit definitions are presented in Subsection 4.2.

## 1. Literature review

In this section, a brief review of the literature is provided. First, we describe the theoretical mechanisms explaining the relationship between money (credit) and stock prices. The links between liquidity and stock prices are considered from the perspective of the theory including the classical financial theory and its evolution over time, among other theoretical approaches. Second, possible theoretical explanations of the links between stock prices, money and credit on one side and the business cycle on the other side are introduced.

### 1.1. The mechanism

Several competing hypotheses and theories explain the nature of the relationship between money (credit) and stock markets. An exhaustive comparison of the theories is impossible in a limited space. Instead we outline major theories and hypotheses, their key assumptions, criticism, and some major empirical results (Table 1). A basic tenet of classical financial theory is that liquidity conditions play an important role in stock market developments. An unexpected exogenous increase in the nominal money stock will impact the main transition channels, including the credit channel, the asset price channel, the interest rate channel, and the foreign exchange rate channel (Ruano, 2013). Under both a conventional and unconventional monetary policy situation, it is assumed that monetary expansion will increase the supply of loanable funds. This will push down interest rates in bond markets with a positive impact on equity prices, including bonds and stocks (Dash et al., 2021; Ariff et al., 2012; Sellin, 2001; Thornton, 2001; Lastrapes, 1998). Consequently, stock prices will serve as a channel of monetary policy, as they affect investment activity, corporate balance sheets, household wealth, and household liquidity (Ruano, 2013).

The Keynesian economic theory explains the impact of monetary expansion on stock prices by an increase in their attractiveness in comparison to bonds, which drives up the prices of the former and pushes down the prices of the latter (for details see, e.g. Belke & Wiedmann, 2018; Pícha, 2017). For companies, it is cheaper to issue new stocks and make new investments because investors perceive the value of firms as higher and are willing to buy stocks at higher prices. The atmosphere of confidence and optimism spreads as companies increase their profits, which in turn leads to stronger balance sheets in the real and financial industries (Belke & Wiedmann, 2018). The net worth of firms used as collateral to banks' loans will result in additional lending if banks aim to maintain their preferable leverage ratios, as evidenced by Adrian and Shin (2008). This additional bank lending amplifies the spiral of new investment, asset prices, and liquidity. Therefore, procyclical bank leverage intensifies financial cycles (Park, 2019).

Nasir et al. (2020) show that money supply has a meaningful impact on inflation expectations. However, if the predictions of the inflation rate are incorrect, they may lead to mispricing of assets (Brown et al., 2016, Acker & Duck, 2013). Stock mispricing can appear if investors employ the nominal interest rate to assess future real cash flows in line with the money illusion hypothesis (Modigliani & Cohn, 1979). It is worth noting that inflation expectations are at the core of modern macroeconomic theory and are an important determinant of economic fluctuations including stock prices. Therefore, managing expectations is crucial in modern monetary policy (Baranowski et al., 2021). The New Keynesian models (for example, refer to a recent paper of Sims et al., 2021) are widely used in central banking. The diverse specifications of the Phillips curve in such models can be in line with different schools of economic thought (including the expectations-augmented Phillips curve or the New Keynesian Phillips curve, for example) and predict direct impact of inflation expectations on prices.

Recently, an increasing number of empirical studies tested the hypothesis of whether the abundance of liquidity in the system has led to increases in the price of the stock. Belke and Wiedmann (2018) find that market liquidity expressed in the form of a broad monetary aggregate, the interbank overnight rate, and net capital flows has had a very limited impact on stock prices developments in well-developed economies in recent years. The authors conclude that excessive liquidity is being invested in real estate and commodities rather than stocks. Furthermore, the empirical results show different results with respect to a sample of emerging markets where both real money and capital flow proved to have a significant positive short- and long-term effect on stock prices.

The monetary portfolio (MP) model – a theoretical framework originally developed by monetarists (Brunner, 1961; Friedman, 1961) – is also based on the liquidity assumption. In equilibrium, an investor holds a portfolio of assets including money, and unexpected changes in the money supply cause a disequilibrium in the money balances. Investors respond to the money supply growth by replacing noninterest-bearing assets with financial assets including equities (Meltzer, 1995; Jones & Uri, 1987). Investors respond with a delay, which implies a positive, variable, and long average lag of stock returns behind changes in the growth rates of the money supply. According to money neutrality (Friedman, 1961), "the price level would rise to restore real money balances to their previous level" (Thornton, 2001). Ariff et al. (2012) note that the MP hypothesis remains popular among practicing economists and policy makers, although the linkage between liquidity and stock prices has been questioned in some research studies because of the lack of convincing evidence. The main issue in empirical studies remains how to control the impact of the monetary policy regime on economic measures (Camilleri et al., 2019; Antonakakis et al., 2017; Humpe & Macmillian, 2009; Ratanapakorn & Sharma, 2007).

Alternatively, stock prices might be influenced by inflation uncertainty (Cheung & Ng, 1998). If the money supply increases, the unanticipated inflation might lead to higher interest rates, which can have adverse consequences on the stock market (Ball et al., 1990). Conversely, the impact of inflation on stock prices could also be positive: a higher money stock in the economy may cause higher inflation rates and boost economic activity by raising dividends and stock prices (Gordon, 1962). The abundant liquidity in the system may not lead to increases in goods prices. Instead, it can be transferred to the real estate, commodities and stock market (Rogoff, 2006). In turn, increasing asset prices are typically interpreted as "a sign of confidence and breed optimism" and can lead to "crowd behaviour" (Pepper, 1994; Rajan, 2005), for example, in the form of "herding" and rational speculation. The shift in market sentiment stimulates investors to buy stocks when prices go up and sell when prices go down (Belke & Wiedmann, 2018). There is a relatively large number of contributions attempting to empirically analyse the relationship between inflation and asset prices including stocks delivering ambiguous results (for details, see, e.g., Camilleri et al., 2019; Bampinas & Panagiotidis, 2016; Hyde & Bredin, 2005).

In contrast to the monetary portfolio (MP) model, the efficient market (EM) hypothesis, which was first put forward by Fama (1990), assumes that an efficient stock market exists and therefore any current and past information is fully reflected in current security prices. Therefore, the growth of the money supply (credit) cannot have a systematic lagged effect on stock prices and their returns. Many other authors (among the most prominent (Grossman & Stiglitz, 1980; Tirole, 1982) argued that the EM hypothesis is unstable and impossible because of the existence of cost to obtain information. Prices, however, cannot perfectly reflect all available information, and for market participants who spent resources, it is impossible to receive a compensation (for details, see, e.g., Sewel (2012)).

Empirical evidence for or against the EM hypothesis is growing in both developed and emerging markets (see, e.g., Rossi & Gunardi, 2018; Hamid et al., 2017). Rossi and Gunardi (2018) analysed the calendar anomalies (CAs) that characterised financial markets in France, Germany, Italy, and Spain based on stock exchange indexes using data from the period 2001–2010.

Their calculation results suggest some doubts about the significance of the efficient market hypothesis. In emerging markets, Hamid et al. (2017) tested the weak form of market efficiency while using data on stock market returns for 14 Asia-Pacific countries. The main conclusion is that the monthly prices do not follow random walks in all the countries, allowing investors to collect profits through arbitrage process.

Behavioural finance contradicts the EM hypothesis. Various psychology-based theories suggest that even if asset prices depart from justified long-term levels, it may remain attractive to investors to bet on rising prices. Keynes (1936) pointed out already that stock market levels are not necessarily efficient; they reflect average expectations of market participants rather than fundamental values. Periods of "large-scale irrationality", for example, related to the Great Recession, seem to confirm that financial markets do not reflect all available information. Therefore, in recent years, many financial economists have increasingly claimed that the EM hypothesis does not hold. Interestingly, and against this line of argumentation, Malkiel (2005) shows that professional investment managers do not outperform passive index funds. This finding may suggest that market prices do reflect a large portion of available information.

Behavioural economics is mainly concerned with the bounds of rationality of economic agents. Behavioural economics aims to understand the reasons for the behaviour of economic agents combining the elements of economics and psychology. Behavioural finance theories employ behavioural concepts (such as, for instance, mental accounting, herd behaviour, emotional gap, anchoring, self-attribution) in explaining asset pricing anomalies when traditional finance theories fail to do so. For example, the theory suggests that stock prices can affect household wealth through the housing and stock market channels (Ludwig & Sløk, 2004; Poterba, 2000). An increase in stock prices will induce the wealth of households who have allocated their savings to stocks. Higher stock prices will strengthen the feeling of confidence and security because the probability of financial distress in the near future decreases. This, in turn, will increase the level of spending on durables and equities, and consequently increase economic output.

Recently, a number of alternative theories approaching both the short-term and long-term causalities between monetary policy and equity prices have emerged, among others, Singh and Nadkarni (2020), Camilleri et al. (2019), Belke and Wiedmann (2018), Apergis et al. (2018), Pícha (2017), and Humpe and Macmillan (2009) suggested various theoretical explanations. According to Apergis et al. (2018) and Singh and Nadkarni (2020), Tobin's $q$ can serve as an explanation for the impact of monetary expansion on equity valuation. A high value of $q$ implies that the market price of firms is high relative to the cost of capital which supports companies in their decision to raise capital by issuing new stocks and investing gathered funds in new plants and equipment. This suggests that investment demand will increase because firms can afford purchasing new investment goods with a small issue of assets.

Moreover, Singh and Nadkarni (2020) propose another theoretical channel through which asset prices and credit can be related, and they use asymmetric information and adverse selection hypotheses. As equities serve as important collateral to mitigate information asymmetry, the appreciation of an asset will increase the value of collateral for borrowers, which in turn will give a further boost to the supply of loans and to the valuation of the asset. Singh and Nadkarni (2020) conclude that if significant credit constraints and limited access to external finance within an economy exist, bank credit will represent an important channel affecting asset prices.

Asset purchases by central banks are also expected to influence stock prices (and money/credit variables). The signalling channel works through the standard expectation hypothesis assuming that purchases of securities will have an impact on market expectations. If the short-term policy rate decreases, investors will expect a disproportional decrease in yields of bonds (Pícha, 2017; D'Amico et al., 2012). According to the scarcity channel, an official purchase of long-term debt assets causes an increase in demand and makes this class of securities scarcer. This generates rising bond prices and simultaneously a downward pressure on the interest rates of securities with similar maturities (Pícha, 2017; D'Amico et al., 2012; Modigliani & Sutch, 1966). The idea behind the third transmission channel generally referred to as portfolio balance channel or duration channel is that the purchases of long-term securities raise their price and hence lower term premium across maturities (D'Amico et al., 2012). Ultimately, QE aims to restore confidence, lower interest rates, and increase output and inflation (Meinusch & Tillmann, 2016), and thus it may influence stock prices and push their returns.

In general, the link between money (credit) and stock prices is a part of the broader portfolio allocation problem. The link is influenced by a variety of forces, including self-reinforcing mechanisms through the changing value of collateral, confidence effects, wealth effects, economic policy uncertainty and risk (Chiang, 2019), the financial accelerator mechanism (Bernanke et al., 1999), herding behaviour, the "risk-taking" channel of monetary transmission (Adrian et al., 2019), the related search-for-yield behaviour especially near the zero lower bound on nominal interest rates, or the well-known moral hazard problem if financial companies expect to be bailed out by the central bank in case of a bust of an asset price bubble.

In the two last paragraphs, we would like to deal with two remaining yet important issues. First, despite the fact that our goal is to determine the relationship between money (credit) and stock prices, we pay special attention to the aforementioned relationship during build-ups, and house price booms/busts. Our approach rests on the large impact of house prices on the business cycle (Leamer, 2015) and on waves of optimism and pessimism in the economy (Chahrour & Gaballo, 2021). Such a significant impact of housing on the economy can affect stock prices (Hong & Li, 2020; Bahmani-Oskooee & Ghodsi, 2018; Ali & Zaman, 2017). Indeed, the links between different macroeconomic variables may become stronger during booming house prices (Ryczkowski, 2019; Goodhart & Hofmann, 2008). Accounting for the specific sub-periods related to house price booms and busts, as we do in our paper, is justified also by the economic theory. There are at least three major channels of transmission between house prices and stock prices as explained by the well-known theories related to the wealth effect, credit effect and capital switching.

Finally, we would like to point to the so far missing element of our deliberations, namely the relationship between money and credit. Although our analysis is not concerned (at least directly) with the link between money and credit, we comment in this paragraph briefly on their relationship to acknowledge the link's economic importance and to point to the existence of a triangular relationship between money, credit and stock prices. Generally, the evidence explaining the relationship between money and credit is extremely scarce. One of the reasons for this scarcity is that money and credit are largely jointly determined (for details, see, Tucker, 2008). Despite it, typically during financial crises, money and credit diverge – therefore it is justified to analyse credit and money dynamics separately under some circumstances. For example, Liu and Kool (2018) document that the short and medium term relationship between money and credit overhang is fragile in the euro area. Generally, we can observe a considerable increase in credit relative to money in the second half of the twentieth century (Schularick & Taylor, 2012). Moreover, the relationship between money and credit differs between: a) Commonwealth Countries, b) Denmark and Switzerland, c) Scandinavian countries and the United States (Ryczkowski, 2020b). Although in recent years a few empirical papers of Carvalho (2019), Ryczkowski (2020b), Liu and Kool (2018) faced the issue of money-credit nexus, the growing wedge between money and credit in some countries and its consequences for the monetary policy are still largely unrecognized. Meanwhile the existence, causation and stability of a relation between money and credit has deep consequences for policy (Goodhart et al., 2016).

Table 1. The main theories and empirical evidence (source: own work)

| Theoretical approach | Theoretical explanation | Empirical evidence and short discussion |
|---|---|---|
| Classical financial theory | Several competing hypotheses have been established within classical financial theory with regard to the nature of the relationship between money (credit) and stock prices over time scales and frequency bands. Notwithstanding this, liquidity conditions are essential in the development of the stock market through the main transition channels (the credit channel, the asset price channel, the interest rate channel, and the foreign exchange rate channel). For details, see, e.g., Dash et al. (2021); Belke and Wiedmann (2018); Ariff et al. (2012); Sellin (2001); Thornton (2001); Lastrapes (1998). In particular, the interest rate channel, recently argued to transmit QE to the real economy, has two major sub-channels: signaling and portfolio rebalancing, both heavily debated since the 2007 Great Recession. | The theory assumes that investors behave with rational expectations and search for utility maximization. In consequence, market values float around fundamental values. This assumption has led to criticism, for example, from the point of view of behavioural finance. The criticism seems to be especially strong during financial crises when classical models cannot straightforwardly interpret the behaviours of economic agents. In sum, the existing evidence is mixed. For example, Belke and Wiedmann (2018) applied the Cointegrated Vector-Autoregressive (CVAR) model to assess whether liquidity conditions play an important role in stock market developments. Empirical evidence shows a very limited impact of real-money developments on stock prices in well-developed countries including US, Euro area, Japan, and UK. On the contrary, the findings for emerging countries (South Korea, Brazil, Thailand) show that liquidity conditions have had a significant effect on stock market dynamics. It must be, however, noted that after the 2007 Great Recession, many classical channels were argued to transmit the unconventional monetary policy to the macroeconomy and to stock prices ultimately (although the magnitude of that impact is subject to extensive debates). The mostly advocated channels are the portfolio balance channel, the signalling channel and the credit channel. Perhaps a certain compromise between the classical theory and its criticism of rationality are the papers of Mukherjee and De (2019) and Huck et al. (2020). The authors argue that investors are never fully rational or behavioural, and that investors are actually quite rational when faced with a poisoned market, respectively. |

*Continue of Table 1*

| Theoretical approach | Theoretical explanation | Empirical evidence and short discussion |
|---|---|---|
| Efficient market (EM) hypothesis | The general idea is that rational economic agents use all available information when making their decisions about purchasing or selling stocks in competitive financial markets. In consequence, it should be impossible to "beat the market" since stocks reflect all available information. Money (credit) supply growth cannot have a systematic lagged effect on stock prices and their returns under the assumption of efficient stock market, for details, see, e.g., Fama (1990). | The EM hypothesis is based on the classical assumption of rational expectations. The EM hypothesis has become undoubtedly one of the cornerstone theories explaining market behaviour. Indeed, modern academic finance rests on the assumption that markets are fundamentally rational. For example, one of the most famous models in the discipline of finance, namely the Capital Asset Pricing Model (CAPM) is based on the assumption of market rationality. However, the assumption of EM has undoubted limitations. In particular, the large stock market crashes like the one related to the 2007 Great Recession revealed market inefficiencies and was a reason for a strong criticism of the EM hypothesis. In consequence, the overall empirical evidence is mixed (Lee et al., 2013). For example, Sewell (2012) conducted five statistical analyses of daily, weekly, monthly and annual Dow Jones Industrial Average log returns while using data from 1928 to 2012 and conclude that the US stock market tend to be efficient. On the other hand, the research studies based on data from the 1980s and 1990s mostly reject the EM hypothesis (for details see Sewell, 2012). Notably, some analyses after 2000 tend to support market efficiency in well-developed markets (Rossi & Gunardi, 2018; Sewell, 2012). |
| Monetary portfolio (MP) hypothesis | The monetary portfolio model assumes the existence of substitution effects: An increase in the money supply will cause shifts in asset portfolios. For details, see, e.g., Ariff et al. (2012); Thornton (2001); Meltzer (1995); Jones and Uri (1987); Brunner (1961); Friedman (1961) | The overall empirical evidence is mixed, since there is no convincing inference in terms of the relationship between stock prices and money stock. The major reasons for the mixed evidence stem from varying patterns for industrial and emerging economies (Belke & Beckmann, 2015) and from varying impact of monetary policy on firms and stocks with different characteristics (Maio, 2014). Moreover, many methodological issues arise on how to control the impact of the monetary policy regime on economic measures (for details, see, e.g., Camilleri et al., 2019; Antonakakis et al., 2017; Humpe & Macmillian, 2009; Ratanapakorn & Sharma, 2007). |
| Inflation based theory | An unexpected increase in money supply might boost inflation and have a positive or negative impact on stock prices. For details, see, e.g., Belke and Wiedmann (2018), Rogoff (2006), Rajan (2005), Cheung and Ng (1998); Pepper (1994). | The problematic interpretation of the theory may stem from the fact that positive or negative correlations between the inflation and stock prices may depend on the relative strength of numerous theoretical channels at work (Antonakakis et al., 2017). For example, Bampinas and Panagiotidis (2016) report that there is no significant co-integrating relationship between stock prices and inflation rates (expressed as CPI) based on US data over the period 1993–2012. Contrary to this, Hyde and Bredin (2005) analysed the relationship based on data for Belgium, Canada, France, Germany, Ireland, Japan, the U.K. and the U.S. while using the single- and two-transition function regressions over the period 1980–2004. The main conclusion is that inflation and interest rates are crucial in terms of stock returns developments. |

*End of Table 1*

| Theoretical approach | Theoretical explanation | Empirical evidence and short discussion |
|---|---|---|
| Behavioural financial theories | When traditional theories become insufficient in explaining stock prices, behavioural finance offers various explanations of market anomalies that are based on psychological influences and biases of investors and financial practitioners. For details of the behavioural finance and its historical developments, see, e.g., Kapoor and Prosad (2017). | Behavioural factors as explained by the modern behavioural finance theories can clarify many asset pricing anomalies (Guo et al., 2017) when traditional finance theories fail to do so. Notably, according to some prominent economists behavioural finance is not necessarily opposed to the EM theory. On the contrary, they argue that even in face of the 2007 Great Recession, behavioural finance complements or even reinforces efficient markets theory (Ball, 2009). The major criticism of behavioural finance is that behavioural finance is rather a "collection of ideas and results" (Ball, 2009), and not a comprehensive unified theory able to predict stock prices. |

### 1.2. Stock prices, money, and credit during a business cycle

There are intense discussions in the academic literature investigating the link between financial asset prices and business cycles, with a focus on stock prices (Poshakwale et al., 2019; Chen & Hwang, 2019; Fama, 1990). One of the possible theoretical explanations of the relationship between stock prices and business cycles rests on the assumption that, in an efficient stock market, asset prices reflect signals from the external environment including monetary and fiscal policy shocks. With a lag, these shocks are reflected in the real economy, and therefore stock markets represent a channel mirroring signals about future developments in terms of companies' payouts and output growth (Panopoulou et al., 2010).

Alternatively, other theoretical explanations of the link between stock prices and business cycles depart from the efficient market hypothesis. They demonstrate, for example, that a sentiment shock may drive stock price bubbles and impact on the real economy through endogenous credit constraints (Miao et al., 2015). As noted by Ioan (2015), the stock market can be interpreted as the main catalyst of the economic downturn, in particular due to "mass psychology acting under the impulse of manipulation, emotions, fear or exuberance". Against the rational expectations hypothesis, Adam and Merkel (2019) argue that the extrapolative predictions of investors about the expected future of capital gains can be transmitted into the real economy by sending inefficient price signals about desirable investments, consumption patterns, and hours worked. Moreover, Winkler (2020) demonstrates that shocks in asset prices and real activity can be exaggerated through the combination of financial frictions and agents' learning-based asset pricing that follows a two-sided feedback mechanism.

Empirical studies typically confirm that financial indicators play an important role in predicting asset price cycles (Gerdesmeier et al., 2010) that impact the real economy stance. The explanation of their considerable role may stem from the international simultaneity of business cycles (Osińska et al., 2016; Bruzda, 2015) and asset price cycles (Alessi & Detken, 2011) as well as significant co-movements of domestic financial and real business cycles (Bruzda, 2017). In particular, Alessi and Detken (2011) found that the global measures of liquidity, especially the global private credit gap, are the best indicators of asset price cycles.

Global liquidity may influence domestic credit and domestic broad monetary aggregates when foreign investments are settled through the banking system, which in turn affects domestic asset prices. An increasing number of empirical analyses document that financial interrelationships play an important role in the transmission of shocks between countries (Georgiadis & Jančoková, 2020; Choi et al., 2017). Some authors even claim the existence of a global financial cycle driven often by the US monetary policy (Miranda-Agrippino & Rey, 2020). Cross-border monetary spillovers from the core economies to foreign economies can materialise through tighter credit market conditions abroad (Akinci & Queralto, 2019).

Schularick and Taylor (2012), among others, argue that credit growth is a particularly powerful predictor of financial instability for 14 countries over the years 1870–2008. Corsi and Sornette (2014) warn that "the financial bubble fuelled by the growing credit expansion through the financial accelerator leads to super-exponential dynamics of the financial variables that would end, if unchecked, into […] explosive behaviour in finite time". They also argue that "the excess money creation disguises itself in the prices of financial assets which instead covertly accelerate [...] money growth until the complete collapse of the system occurs" (Corsi & Sornette, 2014). Helbling and Terrones (2003) showed that if credit market is booming, strong signals are sent to equity prices in industrial countries in the post-war period. In the euro area as well, booming stock price indexes are related to money overhangs, although the link between real money growth and asset price boom is rather weak, as opposed to the link between asset prices and credit growth (Sousa & Machado, 2006).

Recently, the direction of causality between stock prices and business cycles has received increasing attention in academic studies (Tiwari et al., 2016; Stock & Watson, 2003). Tiwari et al. (2016) analysed the short- and long-run co-movements of the US historical business cycles and commodity and asset prices over the time span 1859–2013. Significant relationships were documented particularly in the short run; however, it cannot be said conclusively which is the leading variable. Liu and Sinclair (2008) analysed the link between stock prices and economic growth in mainland China, Hong Kong, and Taiwan (namely in Greater China). They found out that economic growth is the main determinant of movements in stock prices in the long run; however, in the short run, stock markets represent an essential indicator of future economic growth. Binswanger (2000, 2004) distinguishes the stock market boom since the early 1980s from the stock market boom between the late 1940s and the mid-1960s, when stock prices were driven by real output growth. He explains that currently stock prices are more independent of the real economy due to unrealistic expectations leading to speculative bubbles.

In sum, evidence suggests that monetary and credit developments, among other variables, can be considered good early warning indicators of the turning points in a business cycle and of rising financial imbalances in the economy. However, the direction of causality between money, credit, stock prices, and real economy may change in time, and it depends on the length of the horizon investigated. Moreover, in other studies, credit dynamics are argued to be a relatively better indicator of stock price developments and business cycles than money dynamics, which can be explained following the line of argumentation, for example, of Liu and Kool (2018) or Gerdesmeier et al. (2010).

## 2. Methodology

Numerous empirical works on the relationship between stock price changes and business cycles were based on single-equation or multivariate vector autoregressive and panel models. The restrictiveness of the parametric models in terms of the true autocovariance structure of the growth-returns nexus is considered to be their drawback. The long-range dependence requires a dynamic model with an unusually long-lag structure (Panopoulou et al., 2010).

Alternatively, the CWT can be used to study the link between financial variables and stock prices. We use the wavelet phase difference (4) [which is visualized with arrows at the wavelet coherency plots] to determine the lead-lag patterns in the time and frequency framework. The wavelet phase difference outperforms the conventional Granger causality test as it does not assume a single, causal link for the whole investigated time span at each frequency band (Grinsted et al., 2004). Moreover, if a wide range of frequencies is involved, the popular windowed Fourier transform results in an underrepresentation of the low frequency components instead. The CWT does not also require arbitrary cut-off of the frequency bands or resolving to split the investigated periods into subsamples. Ultimately, CWT seems to be a promising tool for the purposes of the article, and indeed wavelets are recently receiving increasing attention in the economics literature. The first papers that applied CWT to study asset prices are relatively new (Tiwari et al., 2016; Bruzda, 2017), although the authors have not investigated money and credit developments against stock prices.

The CWT of a square-integrable signal $g$:

$$CWT_g\left(a,b\right)=\frac{1}{\sqrt{a}}\int_{-\infty}^{+\infty}g\left(t\right)\overline{\psi\left(\frac{t-b}{a}\right)}dt, \tag{1}$$

where $\psi$ is the analysing wavelet, analogous to the use of sines and cosines in the Fourier analysis. The "small wave", namely, wavelet, is an oscillatory function of finite length. It is assumed to be well localised on the time and frequency axes, should fulfil the admissibility conditions (Aguiar-Conraria & Soares, 2014), and has a unit energy ($a > 0$ is the scale parameter and $b \in \Re$ is the translation parameter). In other words, a wavelet is a stretched version of a mother wavelet localised both in time and in frequency domains. Hence, the signal $g$ is decomposed into translated and dilated versions of $\psi$. For a mother wavelet, we use the complex Morlet wavelet:

$$\psi\left(t\right)=\frac{1}{\sigma^{1/2}\pi^{1/4}}e^{-\frac{t^2}{2\sigma^2}}e^{ik_0t}, \tag{2}$$

where $\sigma > 0$ and $k_0$ are constants (Grossmann & Morlet, 1984). Whereas the Morlet wavelet consists of a complex sine wave within a Gaussian envelope, the non-dimensional frequency $k_0$ determines the amount of oscillations and affects the balance between the satisfactory frequency and time localisations. The function's integral is close to 0. $\psi\ (f) = 0$ for $f < 0$ for all values of $\sigma > 0$ and $k_0$ if $\sigma^2 k_0^2 > 1$. We set $\sigma = 1$ and $k_0 = 6$ (Torrence & Compo, 1998) so that we have a close relationship between the wavelet scale and the Fourier frequency (Aguiar-Conraria & Soares, 2014). We use functions included in the ASToolbox (Aguiar-Conraria & Soares, 2014) and the cross wavelet and wavelet coherence toolbox for MATLAB (Grinsted et al., 2004). Additionally, we have added a graphical interpretation of the wavelet phase spectrum (arrows that represent the lead and lag patterns) to the coherency plots (4). Tests of significance assumed constant AR(2) background spectra.

We analyse time-localised co-movements of monetary aggregates or credit measures on the one hand and stock prices on the other hand using wavelet coherence – the corresponding multiple correlation coefficient:

$$K_{xy}^2(a,b) = \frac{\left|s\left\{XWT_{xy}(a,b)\right\}\right|}{s\left\{\left|CWT_x(a,b)\right|\right\} s\left\{\left|CWT_y(a,b)\right|\right\}}, \tag{3}$$

where $s$ denotes a smoothing operator in time and scale. The Hanning window with the size parameter equals two, and there is zero padding on the boundaries. The wavelet coherence or the square root of the wavelet coherence is similar to the conventional correlation coefficient and to the dynamic conditional correlation analysis. It takes values from zero (no co-movements, blue colour) to one (the strongest co-movements, yellow colour). The second power of the wavelet coherence can be understood as an $R$-squared coefficient in a regression of money/credit growth in the past, present, and future values of stock price developments.

In each wavelet coherence plot, we have drawn black curved lines, which mark the cone of influence (COI), and arrows, which mark the wavelet phase difference. Areas outside or overlapping COI ought to be interpreted with caution because the results may be distorted by zero padding (Mallat, 2009). The wavelet phase difference (4) allows us to delineate the lead-lag relationship between variables in the time-frequency space:

$$\varphi_{xy}(a,b) = a\tan\frac{\Im\{XWT_{xy}(a,b)\}}{\Re\{XWT_{xy}(a,b)\}}, \tag{4}$$

where $\varphi_{xy}(a,b) \in (-\pi,\pi]$, $\Re$ and $\Im$ are the real and imaginary parts, respectively, and the function "atan" is treated as the (2-argument) four-quadrant inverse tangent. In (4), the cross wavelet transform (XWT) is defined as $XWT_{xy}(a,b) = CWT_x(a,b)\overline{CWT_y(a,b)}$ for two signals, while $x, y \in L^2(R)$. If phase arrows head right, then we have a positive instantaneous correlation between money/credit and stock prices. If phase arrows head left, there is a negative instantaneous correlation. In case they are perfectly up, money/credit is leading stock prices by $\pi/2$, and in case they are perfectly down, stock prices are leading.

We use the wavelet gain coefficients (available upon request) with bootstrap confidence intervals:

$$G_{xy}(a,b) = \frac{\left|s\left\{XWT_{xy}(a,b)\right\}\right|}{s\left\{\left|CWT_{xy}(a,b)\right|^2\right\}}, \tag{5}$$

to quantify the change in amplitudes of stock price signals to a change in amplitudes of money or credit signals for the 8-16-year cycles. The coefficient equals exactly one if 1% money or credit growth translates into 1% increase in stock prices within the 8- to 16-year horizon. Confidence intervals were generated according to VAR(2) models.

We supplement our wavelet analysis with the examination of power spectra. The wavelet power spectrum allows us to identify changes in the significance of the bivariate coefficients due to power changes (structural breaks) in the individual spectra (available upon request).

We followed Alessi and Detken (2011) and defined a stock price boom as a period of at least three consecutive quarters in which the real value of the index exceeds the recursive trend plus 1.75 times the recursive standard deviation of the series (the latter being calculated with a Hodrick-Prescott filter, $\lambda$ = 100,000). In accordance with Fatás et al. (2009), stock and house price busts denote periods when the four-quarter trailing moving average of the annual growth rate of stock and house prices, in real terms, falls below a 20% and 5% threshold, respectively. Finally, we defined a house price boom following Goodhart and Hofmann (2008) as a consecutive positive deviation of real house prices from a smooth Hodrick-Prescott trend of more than 5% lasting at least 12 quarters. Notwithstanding this, in the subject literature, there are also alternative methods of defining stock and house price booms (Gerdesmeier et al., 2010; Jaeger & Schuknecht, 2007; Bordo & Jeanne, 2002; Detken & Smets, 2003; Berg & Pattillo, 1999).

Finally, we introduce the MODWT, where the scale parameter is discretised to integer powers of $2^j$, $j$ = 1, 2, 3, ... We use the Daubechies wavelet of length two for the orthogonal filter in the MODWT decomposition. The estimator of the wavelet cross correlation is defined as follows (Whitcher et al., 2000):

$$\tilde{\rho}_{\tau,xy}\left(\lambda_j\right)=\frac{\tilde{\gamma}_{\tau,xy}\left(\lambda_j\right)}{\tilde{\sigma}_x\left(\lambda_j\right)\tilde{\sigma}_y\left(\lambda_j\right)}, \tag{6}$$

where $\tilde{\sigma}_x\left(\lambda_j\right)$ and $\tilde{\sigma}_y\left(\lambda_j\right)$ are the square root of the two time series wavelet variances, $\lambda_j$ stands for the scale, and $\tau$ stands for the lag. The MODWT estimator of the cross covariance $\tilde{\gamma}_{\tau,xy}\left(\lambda_j\right)$ is defined as follows (Whitcher et al., 2000):

$$\tilde{\gamma}_{\tau,xy}\left(\lambda_j\right)=\frac{1}{\tilde{N}_j}\sum_{t=L_j-1}^{N-\tau-1}\tilde{w}_{j,t}^{(x)}\,\tilde{w}_{j,t+\tau}^{(y)}. \tag{7}$$

Alternatively, we verify the db4, Sym2, and Sym4 filters.

## 3. Data

Our quarterly time series range from 1Q 1970 to 4Q 2016 with few exceptions described in notes below the figures and tables. To analyse wavelets, we use the logarithmic growth rates of X-12 ARIMA seasonally adjusted time series with the detection and correction of outliers.

We use two total credit definitions: credit to private non-financial sector (PNFS) derived from banks and credit to PNFS from all sectors. Both credit time series come from the new Bank for International Settlements (BIS) database. Our credit data focus on borrowing from non-financial corporations, households and non-profit institutions serving households (while the aggregate of these sectors we refer to as the PNFS). The credit data are compiled at market value on a non-consolidated basis. The BIS break-adjusted credit series were obtained by adjusting levels through standard statistical techniques (Dembiermont et al., 2013). It is worth noting that the total credit definitions employed by us contain the cross-border component based on the BIS international banking statistics. This means that credit time series that we use capture credit extended by banks located also abroad. Therefore, our credit series account for credit from all sources, not only that extended by domestic banks. Since exact data on credit were compiled by the BIS with the help of central banks to achieve comparability and consistency, to save space we do not go into more details. We refer to Dembiermont et al. (2013) instead. The article explains in detail on several pages the key concepts underlying the compilation of the credit time series, statistical criteria applied, the characteristics of the underlying series used and the statistical techniques employed.

Accounting for the cross-border component in total credit definitions is important because the cross influence between money/credit and stock prices across countries may largely be the result of the global liquidity conditions. Alessi and Detken (2011) found that the global measures of liquidity are the best indicators of asset price cycles as opposed to domestic monetary and credit conditions. Additionally, the cross-country influence between stock prices may arise from at least two channels: the impact of monetary policy conducted abroad (Bhattarai et al., 2021; Kolasa & Wesołowski, 2020) and the link between stock prices in different countries (Wen & Li, 2020; Tang et al., 2019), among other channels.

We use broad money aggregates (M3 and M2) in line with empirical studies on the correlation between monetary growth and inflation (for example: Camilleri et al., 2019; Goodgart & Hofmann, 2008). We consider M3 as a measure of money to be consistent with the monetary pillar of the European Central Bank as well. Data on M3 (US, CA, JP, SE, ZA) and M2 (US, NZ, IS, JP, SE, CH, ZA) monetary aggregates come from the International Financial Statistics database of the International Monetary Fund (IMF). Only if the time series of a required length were not available, they were extracted from the Federal Reserve Bank of St. Louis (FRED). The exception concerns the United Kingdom, where broad, break-adjusted money time series are from the Bank of England (used as a proxy for M3).We do not take into account narrower monetary aggregates, like M1 due to their poor informative content[2]. Real GDP data (used to adjust monetary growth rates as a robustness check) in volume estimates for the annual levels in the national currency are from OECD (expenditure approach).

Nominal stock price indices (2010 = 100) come from OECD's Monthly Monetary and Financial Statistics database. For the time series on housing prices, we use nominal residential property price indices (2010 = 100) from the BIS Residential Property Price database. Both house and stock prices time series were adjusted to real values when determining house and stock price boom and bust phases. For this purpose, we used the OECD consumer price inflation index for all items.

At first, it is convenient to look at the basic statistics of quarterly growth rates of credit, broad money and stock prices (Table 2). The evidence implies that there is a very close one-to-one relationship between the growth rates averaged over the long run of M3 and stock prices in some countries, more specifically in the United States, Japan, the euro area, Canada, the United Kingdom, South Africa and Australia (the last four countries after the real GDP adjustment). This suggests that money might be an important determinant of stock prices especially in the above-mentioned countries. The evidence implies that there is also a very close one-to-one relationship between credit and stock prices in the euro area, Japan, the United States, and Switzerland.

[2] See: https://fredblog.stlouisfed.org/2021/01/whats-behind-the-recent-surge-in-the-m1-money-supply/

Table 2. Quarterly growth rates of credit, broad money and stock prices between 1Q 1970 and 4Q 2016 (source: own work)

| Economy | Bank Credit | Credit from all Sectors | M3 | M3 mod. GDP | Stock prices | | |
|---|---|---|---|---|---|---|---|
| | *average* | | | | *average* | *median* | *std. dev* |
| United States | 1.6% | 1.9% | 1.9% | 1.2% | 1.8% | 2.0% | 6.4% |
| Australia | 3.2% | 2.7% | 2.7% | 1.9% | 1.7% | 2.2% | 8.0% |
| Canada | 2.6% | 2.2% | 2.2% | 1.5% | 1.7% | 2.1% | 7.2% |
| Japan | 1.3% | 1.3% | 1.5% | 0.9% | 1.5% | 1.7% | 8.4% |
| United Kingdom | 2.6% | 2.6% | 2.4% | 1.9% | 2.0% | 1.9% | 8.1% |
| Sweden | 2.0% | 2.1% | 1.9% | 1.3% | 3.0% | 3.5% | 9.4% |
| Norway | 2.5% | 2.4% | 1.7% | 1.1% | 3.0% | 3.5% | 10.7% |
| New Zealand | 3.1% | 3.1% | 2.6% | 2.0% | 1.4% | 1.7% | 8.1% |
| Switzerland | 1.3% | 1.3% | 1.2% | 0.9% | 1.5% | 1.6% | 7.1% |
| South Africa | 3.4% | 3.4% | 3.3% | 2.7% | 3.0% | 3.3% | 8.9% |
| Euro Area | 1.0% | 1.1% | 1.5% | 1.1% | 1.4% | 2.8% | 8.1% |
| *average* | 2.2% | 2.2% | 2.1% | 1.5% | | | |
| *median* | 2.5% | 2.2% | 1.9% | 1.3% | | | |
| *std. dev* | 0.8% | 0.7% | 0.6% | 0.5% | | | |

*Notes*: average stock price growth (all economies): 2.0%, median stock price growth (all): 1.7%, std. dev of stock price growth (all): 0.6%. Corrected monetary growth rate (M3 mod. GDP) is the monetary growth M3 minus real GDP growth. Data for the EA are shorter. The EA time series start from 3Q 1997 (M3), from 1Q 1999 (M3 mod. GDP), from 3Q 1997 (bank credit), from 1Q 1999 (credit from all sectors). from 4Q 1990 for stock prices. Stock price time series for Iceland since 4Q 1993, and for Norway since 4Q 1986.

Next, it is worth analysing the time series in time-domain in Figure A1. We can observe that stock price, broad money, and credit indexes all typically experience an upward trend[3]. This leads typically to a high correlation between broad money/credit and stock price indexes. The correlation often exceeds 0.9 – especially in case of M3 monetary aggregate. Nevertheless, it is worth noting three interesting observations. First, stock price indexes are evidently more volatile then broad money and credit indexes. Therefore, in the short-run we could expect a weaker relationship between money/credit and stock prices. In the long run, the relationship should be stronger due to the typically upward trends of money/credit and stock price dynamics. Secondly, the relationship is expected sometimes to be closer to unity, but sometimes smaller than one-for-one (when stock price index grew more relatively than credit index for example) – generally this observation is in line with the findings from Table 2. Third, we can notice that especially in case of credit, the upward trend has in many countries broken most often after the Great Recession – suggesting problems in the credit

[3] The exceptions from the upward stock price trend concern predominantly Japan and Iceland. In Japan, the economy stagnated after the price bubble burst in the early 90s, leading to the time period often referred to as "The Lost Decades". In Iceland, we can notice the devastating impact of the Icelandic financial crisis in late 2008 (with a default of the three major privately owned commercial banks).

markets. Despite it, stock price indexes continued their upward trend – stimulatory actions of many central banks after the 2007 Great Recession were one of the reasons.

Although Table 2 and Figure A1 can be convenient for a first assessment, they say nothing about how the relationship changes in the time-frequency space, or what the direction of causality between the analysed variables is. Chapter 4 on wavelets investigates these issues with more advanced methods. The relationship between money (credit) and stock prices is depicted simultaneously in the time (from 1Q 1970 to 4Q 2016), and frequency, namely the time horizon (up to 24 years cycle) domains.

## 4. Empirical results

To facilitate the presentation of our results, we will refer to the following three time horizons: short, medium, and long-run ones. We define a medium run as business cycle frequencies from 2 to 8 years. Indeed, the business cycle theory is mainly concerned with fluctuations in the range of 1.5 to 8 years (Christiano & Fitzgerald, 2003)[4], while we round this lower bound for the ease of interpretation. Cycles shorter than two years, we call short run ones. Cycles longer than 8 years, we associate with a long run.

### 4.1. Overview of the general results for the US, Japan, euro area, and the UK since 1984

This chapter focuses on the economies where QE was introduced to an unprecedented scale: the United States, the United Kingdom, the euro area, and Japan. The justification for a more detailed study of the four economies stems from their relatively large contribution to the world GDP and from the unprecedented QE policies implemented there in response to the 2007 Great Recession. Such policies are intended to encourage spending in the economy and increase the prices of assets and the amount of money available (McLeay et al., 2014). QE can, however, lead to unintended consequences (Ciżkowicz & Rzońca, 2017) and exert a strong impact on other countries.

An interesting background for the story is that the four economies are characterised by various business cycles[5], timing and relative size of QE, and different post-Great Recession macroeconomic effects (Ryczkowski, 2020a; Koeda, 2019; Weale & Wieladek, 2016). This chapter adds to the inconclusive literature on the role of money and credit[6] in modern central banking (Belongia & Ireland, 2018). In particular, we contribute to the relatively limited

[4] Such a definition of a typical business cycle frequency can be found in many other studies including research papers of central banks (see, National Bank of Belgium http://aei.pitt.edu/11002/1/wp131En.pdf).

[5] The business cycle displays unusual features in terms of duration, speed, and structural changes especially in Japan, where the house price bubble burst in late 1989 and the so-called "Lost 20 Years" began, a period of economic stagnation (see Urasawa, 2018). The level of synchronisation of the United Kingdom had the highest variability over time among all of the euro-area countries (Campos & Macchiarelli, 2020). In turn, studies on the business cycle synchronisation typically show that the cycles of the United States and the euro area are correlated with some lag. However, Bertoldi and Orsini (2020) point to the different growth performance of the two economies since the Great Recession.

[6] In chapter 4.1 and subchapter 4.1.1 – to save space–money denotes M3 broad money, and credit denotes bank credit. A short summary of the results for M2 monetary aggregates and credit from all sectors can be found in chapter 4.2. More detailed results are available upon request.

literature on the interdependencies of money, credit, and stock price dynamics (Singh & Nadkarni, 2020) by shedding new light on the relationship between them from the time-frequency perspective and post-Great Recession viewpoint.

Some notable empirical studies that evidence high-frequency (short-run) relationship between money growth and credit growth on the one hand and stock prices on the other hand, *inter alia*, include Hesse et al. (2018), Wei (2010), and Adalid and Detken (2007). Instead, we find that the co-movements were rarely statistically significant in the horizon up to 2 years (the upper part of Figures 1–4)[7]. However, when the co-movements were significant, they were predominantly negative (arrows pointing left, see note 4 below Figure 1). Our empirical results for the short-run cycles up to 2 years can be opposed to the expectations of a positive impact of money supply or credit growth on stock prices stemming, for example, from the wealth effect, the portfolio theory[8], and other theories that suggest the positive impact of money supply or credit growth on economic activity and stock prices.

The negative co-movements can reflect a substitution effect (Friedman, 1988) or, alternatively, unanticipated future inflation uncertainty related to money and credit dynamics (Humpe & Macmillan, 2009). Possibly, factors other than money and credit play a more important role in determining stock prices in the time horizon up to 2 years[9]. For example, behavioural factors as explained by the modern behavioural finance theories can clarify many asset pricing anomalies (Guo et al., 2017). The behavioural factors may make it hard to extract stable co-movements especially in the short run when the investor sentiment is an important determinant of time-varying predictability (Hammami & Zhu, 2020). Additionally, we propose the explanation suggested by Adalid and Detken (2007) that "during normal times, however, the relative predictive power of liquidity shocks seems to shift from asset price inflation to consumer price inflation". This shift from liquidity to inflation (instead of asset prices) in normal times could violate the link between money (credit) and stock prices making it non-significant.

Moreover, the empirical studies that reveal a significant relationship between money (or credit) and stock prices typically consider very short periods of time around events related to shocks that stem, for example, from asset purchase announcements. In our study, we are investigating actual changes in money and credit, not central banks' announcements. Therefore, we do not aim to invalidate the findings of previous authors about the significant relationship between money (or credit) and stock prices at very high frequencies around some specific events. We rather believe we complement those studies by pointing that the relationship may become insignificant or negative once the time horizon reaches 2 years.

The largely non-significant link between the dynamics of money or credit on the one hand and stock prices on the other hand for cycles shorter than 2 years influences investors and central banks. From the investors' point of view, this finding suggests that stable profitable trading rules that solely use information on the dynamics of money or credit seem not to exist in the investing horizon up to 2 years. From the perspective of monetary policy, this finding implies that solely using information on money or credit to anticipate stock price

[7] The finding holds generally in all of the twelve sample countries (Figures A2–A3).

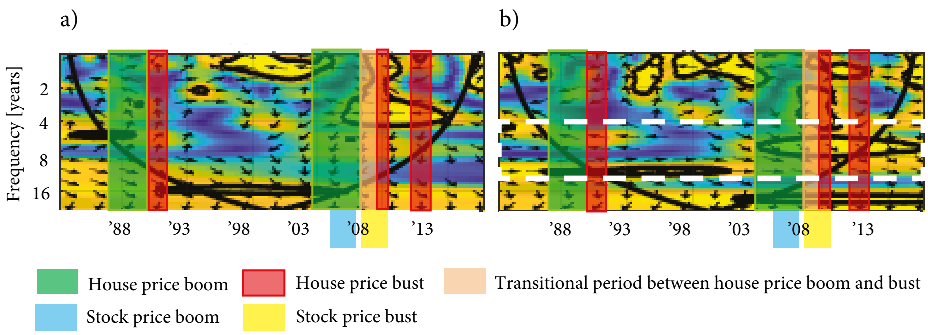
[8] The theory suggests the existence of a positive link, since an increase in money supply creates a portfolio shift from money (that is not bearing interest) to financial assets including stock market.

[9] Accordingly, we cannot reject the existence of more complex short-run macroeconomic relations.

developments can be misleading during such a short cycle. This suggests that policymakers should use neither money nor credit to evaluate or target short-run stock price dynamics not to destabilize the financial system. Indeed, in line with our argumentation, Shahzad et al. (2021) argue that news and "ephemeral developments" drive stock prices at high frequencies rather than macro fundamentals.

Against the short-run backdrop, in the United States, Japan, and the euro area, we evidenced a strong, significant, and positive link (marked with white dashed lines in Figures 1b–3b) between credit and stock prices near the typical business cycle frequency (2–8-year cycle) generally over the whole time span after 1984. The relationship between money and stock prices was less clear and often statistically non-significant (Figures 1a–4a) as also shown by Belke and Wiedmann (2018) and Sousa and Machado (2006), for example.

The above result may be, however, opposed to studies that reveal an important explanatory role of money in determining stock prices (Chung & Ariff, 2016). The possible explanation of the largely non-significant link between money and stock prices could be that money does not affect the centre of stock return distribution (Taamouti, 2015) or, alternatively, that money is directed to commodities and real estate (Belke & Wiedmann, 2018). In turn, the reason for our discrepant findings regarding money and credit could stem from the




*Note 1:* The frequency is explained on the vertical axis and ranges from one quarter (short-run) up to 24 years (long-run). The time is displayed on the horizontal axis and ranges from 1Q 1984 to 4Q 2016.

*Note 2:* The coherence is increasing from the blue (no or weak co-movements) to the yellow (strong co-movements close to a one-to-one relationship) coloured areas.

*Note 3:* Statistically significant estimates of the wavelet coherence are marked with black contours for the 0.1 level.

*Note 4:* Arrows pointing to the right side stand for a positive instantaneous correlation between money/credit and stock prices; arrows pointing to the left – negative instantaneous correlation; arrows vertically up – money/credit dynamics lead stock prices by exactly $\pi/2$; arrows vertically down – stock prices lead money/credit dynamics by exactly $\pi/2$.

*Note 5:* The black, curved *U*-shaped lines delineate the cone of influence, regions affected by the boundary conditions that need to be interpreted with caution. The reason is that they may be affected by zero padding on the boundaries.

*Note 6:* Number of bootstrap samples: 500.

*Note 7:* Transitional period is when one methodology suggests a boom but the other one has already detected a bust.

Figure 1. Wavelet coherence between: a – M3 and stock prices; b – bank credit and stock prices for the US (source: own work)

generalised decoupling of money and credit since the 1970s (Schularick & Taylor, 2012) so that a sizeable increase in credit can appear without a substantial money overhang (Liu & Kool, 2018). In consequence, it is more appropriate to analyse money and credit separately (Ryczkowski, 2019).

The significant and positive link (marked with white dashed lines in Figures 1b–3b) between credit and stock prices suggests that monitoring credit (instead of money) may be more appropriate at a typical business cycle frequency. The discovery may be potentially useful for longer-run investors to construct forecasting methods. It can also be utilised by monetary policy authorities if they wish to weaken or strengthen the link between credit and stock prices in the medium and long run. The findings are in line with the financial market and credit market association evidenced in, for example, the studies of Shahzad et al. (2017) and Mateev and Marinova (2019).

In the United States, Japan, and the euro area from 1984 to 2016, the positive, stable link between credit dynamics and stock prices near the typical business cycle frequency (marked with white dashed lines in Figures 1b–3b) can be explained, for example, through the theories that predict a positive relationship between credit and economic activity (Humpe & Macmillan, 2009) [and consequently stock prices] and a positive association between changes in rational speculation and liquidity conditions (Belke & Wiedmann, 2018).

As opposed to the United States, Japan, and the euro area, significant co-movements of credit and stock prices in the United Kingdom were absent from 1984 until 2006 (Figure 4b). The possible explanation could be that the level of synchronisation of the United Kingdom had the highest variability over time among all of the euro-area countries (Campos & Macchiarelli, 2020). In turn, the appearance of significant co-movements near 2005 shortly before the Great Recession could be related to the credit price effect (Kapopoulos & Siokis, 2005). The credit price effect links the rise in house prices with improved economic conditions, profitability of companies, and stock prices through the rising value of collateral and reduced borrowing costs.

Stock prices lead credit dynamics in the same direction in the United States from 2003 to 2016[10] and in Japan and the euro area from 1984 to 2016 around a typical business cycle frequency (marked with arrows heading down and right between the white dashed lines in Figures 1b–3b). The initial rise in stock prices leads credit expansion at roughly an 8-year cycle frequency (however, up to an even 16-year cycle–compare the areas marked significant between the white dashed lines and the frequency axes in Figures 1b–3b).

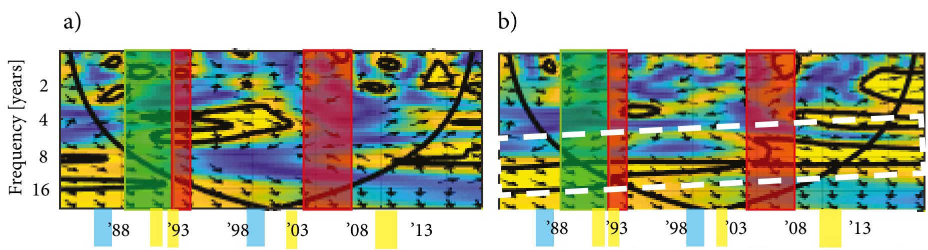
This evidence consistent with the equity wealth effect in the United States, Japan, and euro area suggests that when the values of stock prices change, people feel more or less financially secure. Consequently, they adjust their household leverage to spend accordingly more or less to purchase new stocks and other goods. If they purchase new stocks, this can create the self-reinforcing effects of stock prices and credit expansion and foster the "irrational exuberance". Such an interpretation is in line with the leverage procyclicality (Adrian & Shin,

[10] The beginning of a house price bubble in the United States in 2003 (see, Table A3 in the Supplement) has supposedly changed the link between credit and stock prices. After 2003, people purchased more stocks as the value of their mortgages rose. Before 2003, the positive instantaneous correlation between credit and stock prices was evidenced in the long run (namely, at roughly a 16-year cycle), which was consistent with the efficient market model.

2008) and the herding behaviour of economic agents. Accordingly, equity wealth effects on consumption can appear (Apergis et al., 2018), which seems to be a complementary outcome to what was presented above.

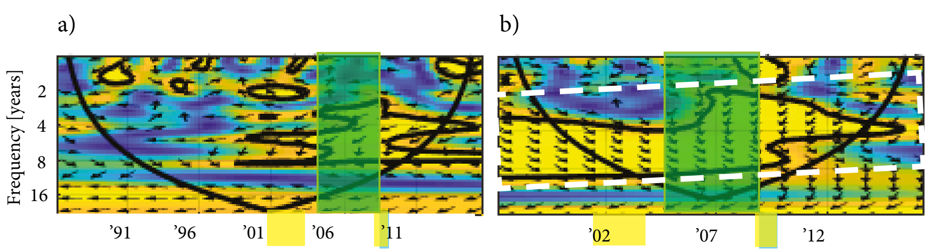
However, we show that once stock prices increase, the credit expansion will not appear simultaneously. It appears that households need time to realise that their financial situation has improved. Consequently, the few years lag between the initial change in stock prices and the procyclical credit dynamics gives relatively much time for monetary policy authorities to potentially "lean against the wind". Similar to the short-run non-significance of credit dynamics and stock prices evidenced by us, Apergis et al. (2018) reveal that long-horizon equity wealth effects are accompanied by the absence of short-horizon causality. Our findings suggest that in order to maintain the stability of the economy at a business cycle frequency, monetary authorities can decrease the amplitude of short-run credit fluctuations. This may be done using, for example, the macroprudential policy (Brzoza-Brzezina et al., 2015).

Interestingly, in the euro area, wavelets also suggest that information on the potential need to repair the rising imbalances would not come from broad money (the relationship is negative and insignificant before 2000), a variable used in a monetary pillar, but from credit developments instead (the relationship is positive and significant for the whole available time span). In the euro area, we have found evidence consistent with equity wealth effects: stock prices lead to credit developments almost exactly by π/2. Equity wealth effects in the euro area were also evidenced by De Bondt (2011), who found their significant impact on consumption.



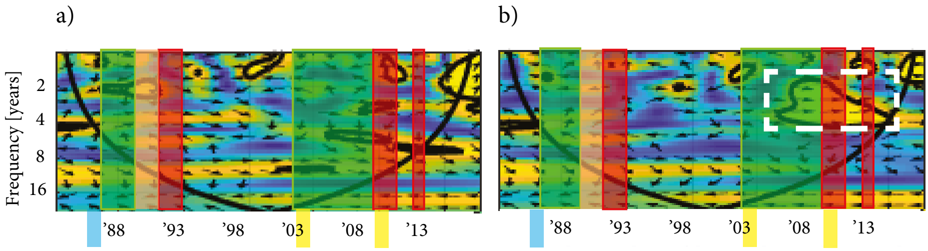

*Note*: see legend and notes below Figure 1.

Figure 2. Wavelet coherence between: a – M3 and stock prices; b – bank credit and stock prices for Japan (source: own work)




*Note*: see legend and notes below Figure 1. Plot *a* starts from 1Q 1987, plot *b* from 3Q 1997.

Figure 3. Wavelet coherence between: a – M3 and stock prices; b – bank credit and stock prices for the euro area (source: own work)




*Note*: see legend and notes below Figure 1.

Figure 4. Wavelet coherence between: a – M3 and stock prices; b – bank credit and stock prices for the UK (source: own work)

Finally, the significant relationship of credit dynamics and stock prices during the Great Recession in the four most developed financial markets at a typical business cycle frequency seems to confirm that stabilising the growth of credit can potentially allow limiting increases in stock prices above fundamentals within a business cycle and smooth the consumption. Such a region-specific behaviour, as argued by Burlon et al. (2018), could bring about a welfare improvement by counteracting the effects of the optimistic expectations which stem from Asset Purchase Programmes. A more detailed analysis of the co-movements of money and credit on the one hand and stock prices on the other hand during QE is presented in the subsequent chapter.

#### 4.1.1. Wavelet results during QE

In the United Kingdom, we found positive instantaneous co-movements since 2006, which were earlier largely absent, between bank credit and stock prices for the 2–4-year cycle (Figure 4b). Possibly, credit and stock returns reacted simultaneously to economic news, consistent with the efficient market model. The clear change in the aforementioned link may imply that the Bank of England's asset purchases through extending liquidity could have had significant effects on GDP, inflation (Weale & Wieladek, 2016), and, consequently, the stock market (Chortareas et al., 2019). Our finding shows that easing monetary policy during a crisis can bring about immediate and positive effects on stock prices (compare Kurov & Gu, 2016, for similar findings for the Federal Reserve).

The unconventional stimulus could have changed the relationship also in the United States. Since 1990 until late 2003, significant and positive co-movements of M3 and stock prices concerned cycles of 12–16 years. At that time, stock prices provided useful information about M3 developments supporting the long-run equity wealth effect. Since the Great Recession, the relationship between money and stock prices moved to cycles shorter than 4 years (from 2007 until 2013). It was, however, negative (Figure 1a). This reflects the fact that money has largely stagnated, while credit and stock prices increased. Therefore, our results are not discrepant with studies pointing to a significant role of the US QE in increases in stock prices (Wu, 2018). It seems that the beginning of a house price bubble in the United States in 2003 (see Table A3 in the Supplement) changed the link between credit dynamics and stock prices from a link consistent with the efficient market model (positive instantaneous correlation near the 16-year cycle) to a one consistent with the equity wealth effect (near the 8-year cycle) (Figure 1b).

In the euro area, as opposed to the UK and the US, the lead-lag patterns during the Great Recession or during the QE have not changed. Moreover, we showed that money and credit did not lead stock prices, and the link between money (credit) and stock prices was not even close to an instantaneous one (Figure 3). Other authors also pointed to a negligible role of monetary shocks in explaining the dynamics of stock prices in the euro area. Berg (2012) rather suggested the important role of technology shocks in moving stock prices, and Henseler and Rapp (2018) evidenced a substantial cross-sectional variation of the stock prices of non-financial firms in response to the European Central Bank's (ECB) Asset Purchase Programmes. We interpret our findings that the ECB has not targeted either stock prices or its unconventional actions as insufficient to convince investors of the incoming economic growth. In line with our interpretation, Creel et al. (2016) argued that the main focus of the ECB was primarily on interest rates, and Albonico et al. (2019) demonstrated that the ECB's policy was not concentrated on lending and contractionary.

In Japan, between 2001 and 2013, we did not identify significant co-movements of money and stock prices at the typical business cycle frequency, even though since 2001, the Bank of Japan has enforced QE to end deflation[11]. The explanation as shown by Kurihara and Nezu (2006) could be that external shocks have impacted Japanese stock prices rather than the largely impotent tools of the central bank. Indeed, other authors also pointed to a poor performance of the Japanese unconventional stimulus (Michaelis & Watzka, 2017). Notwithstanding this, in Japan, Figure 2 reveals significant co-movements of money and stock prices (money leads stock prices) at various frequencies most clearly since 2013. It may give hope that the "Abenomics policies from 2013" work; that is, they could have persuaded investors that the new monetary stimulus would finally bring about improvement in economic growth, especially that Okimoto (2019) notes that the threat of deflation was largely avoided. This hopeful conclusion is, however, discrepant with the fact that credit largely stagnated despite considerable monetary growth since the 1990s. The decoupling of money and credit may suggest that the discovered significant co-movements of credit and stock prices in Figure 2 may merely reflect the poor behaviour of credit, Japanese economy, and stock prices altogether.

In sum, we revealed discrepant linkages between money and credit dynamics on the one hand and stock prices on the other hand across the four economies during unconventional monetary policy. The evidence for the United States and the United Kingdom can be generally interpreted as consistent with the positive impact of QE on economic activity (Weale & Wieladek, 2016) and, consequently, on stock prices. In the euro area, we showed that neither money nor credit dynamics influenced stock prices. This finding supports the evidence, for instance, presented by Ryczkowski (2020a) that the unconventional measures in the euro area were less satisfactory in influencing the real economy than in the United States. The possible

[11] Before QE, namely, from 1984 to 1990, money and stock prices showed positive, significant co-movements in the long run (cycles of + 12 years). From 1993 to 2000, we evidenced a significant link between stock prices and money (stock prices lead money changes) across the 3–7-year cycle, while Japan experienced unprecedented recession and deflation.

explanation could be that the ECB did not aim to stimulate the recovery but to protect the transmission mechanism instead. Finally, the case study of Japan may result from insufficient stimulation (Michaelis & Watzka, 2017) and other problems inherent in the Japanese economy (Ito & Mishkin, 2004).

Finally, we add a short comment on the stock price developments after 2017. Since this year, stock prices indexes continued their upward trend, which was sharply broken once the coronavirus pandemic spread outside China. Davis et al. (2022) report that the value-weighted prices slumped by 40 percent between 17 February and 23 March in the advanced economies – a drop that is many times larger than any standard asset-pricing model would imply. Major central banks initiated purchases of financial assets at an unprecedented scale in a combat with the economic slowdown resulting from the COVID-19 pandemic. Policy measures aimed at supporting the economy reinforced by the optimism that vaccines will help return the economy to normal, allowed the stock price indexes not only to recover but also to continue increasing far more than the pre-pandemic levels. The afore-mentioned stock price developments accompanied by large increases in credit reinforced by recent accommodative monetary policy, and strongly rising house prices, create a risk of stock price burst in the light of our findings. We think that the risk increases also due to many other factors discussed in the academic literature on the downsides of QE. In particular, expansionary post-pandemic policies could have supported also unprofitable but operating firms – which are often referred to as "zombies" (Helmersson et al., 2021). There is also a problem of the growth of non-performing loans among small and medium sized banks (Lasak, 2021), and many other potential risks related to overly expansionary QE without the proper exit strategy.

### 4.2. Robustness checks

The major results hold when we adjusted money for the real GDP growth. They also hold for the alternate credit and money definitions, namely, for the credit from all sectors and M2 money supply (see Supplement; non-reported results are available upon request). The MODWT revealed only few significant correlations using different filters (see Table 3 for the "db2" filter and bank credit vs. stock prices). The plausible explanation is the difficulty in finding a time-invariant link between money (credit) and stock prices at a relatively narrow, predefined fixed frequency up to 8 years long (this is the maximum interpretable frequency in Table 3 using the MODWT and our time series). We argue that a stable, significant relationship is more probable either in the longer run or during specific sub-periods, or at a time-varying frequency, which can be better captured by the CWT (as shown in the previous chapter).

We interpret both the CWT and MODWT findings together as follows: the significant relationship between credit (money) dynamics and stock prices is rather more probable during build-ups and house price booms than, as presented in Table 3, at fixed narrow frequency bands and over the whole time span under investigation. Indeed, the CWT shows that co-movements of bank credit and stock prices were significant in 71% of the time during build-ups and house price booms for all of the sample countries[12]. This interpretation is

[12] For credit from all sectors, as well as for GDP adjusted and unadjusted M3 and M2, the respective percentage values were similar.

Table 3. Multiscale correlation between bank credit and stock prices based on the MODWT from 1Q 1984 to 4Q 2016 (source: own work)

| Country/region | Frequency scales: years, p value in round brackets | | | | |
|---|---|---|---|---|---|
| | 0.25–0.5 | 0.5–1 | 1–2 | 2–4 | 4–8 |
| The United States | –0.23 (0.05)* | –0.51 (0.001)*** | –0.15 (0.55) | 0.16 (0.68) | 0.66 (0.34) |
| Australia | –0.17 (0.16) | –0.20 (0.24) | –0.26 (0.30) | –0.24 (0.51) | 0.17 (0.83) |
| Canada | 0.01 (0.92) | 0.04 (0.80) | 0.07 (0.78) | 0.51 (0.16) | 0.67 (0.33) |
| Japan | –0.02 (0.84) | 0.18 (0.30) | –0.08 (0.76) | 0.17 (0.65) | 0.16 (0.84) |
| The United Kingdom | 0.03 (0.81) | –0.03 (0.86) | 0.40 (0.10)* | 0.01 (0.98) | 0.04 (0.96) |
| Sweden | 0.07 (0.58) | 0.003 (0.98) | –0.11 (0.66) | –0.01 (0.97) | –0.23 (0.77) |
| Norway | –0.16 (0.22) | –0.07 (0.70) | 0.18 (0.51) | 0.38 (0.39) | 0.86 (0.34) |
| New Zealand | –0.11 (0.34) | –0.16 (0.35) | –0.18 (0.46) | 0.30 (0.44) | 0.55 (0.44) |
| Iceland | 0.41 (0.06)* | 0.42 (0.35) | –0.09 (0.80) | 0.55 (1.00) | 1.00 (1.00) |
| Switzerland | 0.10 (0.39) | –0.03 (0.86) | 0.07 (0.77) | 0.08 (0.84) | 0.03 (0.97) |
| South Africa | 0.04 (0.75) | –0.09 (0.59) | –0.36 (0.14) | 0.09 (0.82) | 0.51 (0.49) |
| Euro area | –0.27 (0.11) | –0.12 (0.61) | –0.11 (0.78) | 0.28 (0.72) | – |

*Notes:* The statistical significance is denoted by the asterisk where *, **, and *** designate the 10%, 5%, and 1% levels of significance. The "db2" filter is reported.

consistent with the more detailed MODWT findings (not reported). In the United Kingdom, for example, the MODWT revealed significant co-movements of bank credit and stock prices from 4Q 2002 (when a house price boom started) to 2013 (multiscale correlation coefficient = 0.78, p value = 0.07, 2–4-year cycle, "db2" filter). Accordingly, the CWT indicates that significant co-movements appeared roughly two years later, namely, since 2005, and prevailed to 2013.

As far as it concerns the United States, the United Kingdom, and Japan, namely, the three economies that implemented QE to an unprecedented scale, the detailed MODWT (not reported) and CWT results were generally consistent. They turned out to be discrepant only in the euro area, where MODWT showed lack of significant link between credit and stock prices. This finding can, however, stem from short credit time series available for the euro area. Their length allows investigating the MODWT in greater detail than in Table 3 at a maximum frequency of merely 4 years (if we use sub-samples that represent normal times and house price booms). In sum, we confirm the dynamic volatility linkages between stock and real estate markets (Mi & Hodgson, 2018). Moreover, time and frequency-varying link discovered by us can be an interesting starting point for more advanced econometric modelling.

## Discussion and conclusions

This article analyses the co-movements and lead-lag patterns of money and credit dynamics on the one hand and stock prices on the other hand for 12 developed countries from 1970 to 2016. Continuous and discrete wavelet transforms explain the inconclusiveness of the literature on the interplay between money (credit) and stock prices through changes in the relationship between them across time and frequency. Our results are thus not evident in standard pure time-domain and frequency-domain methods of analysing data.

Since 1984, detailed results vary across countries. However, we typically document short-term nonsignificance (up to a 2-year cycle), medium and long-run link (up to a 16-year cycle) between stock prices and credit with a few years lag, negative co-movements for money reflecting a substitution effect or unanticipated inflation uncertainty, and again a nonsignificant link for the cycles from 16 to 24 years. Interestingly, significant co-movements were detected in the time periods of QE and, additionally, on average, in around 70% of the time during house price boom and bust. This finding supports the theories about the dynamic volatility linkages between QE, stock and real estate markets. The total credit definitions employed by us contain the cross-border component and capture credit extended by banks located also abroad. Accounting for the cross-border component in total credit definitions is important because the cross influence between money/credit and stock prices across countries may largely be the result of the global liquidity conditions.

As far as the novelty of this study for the banking system, stock market, and overall economy is concerned, our cross-country evidence implies that the dynamics of money and credit can mislead investors and policy makers about future stock prices in the horizon up to 2 years, but may be a useful gauge for central banks to support their medium- and longer-run financial stability objectives. We provide novel evidence that stabilising the growth of credit may be especially important when optimistic expectations emerge from Asset Purchase Programmes, during build-ups of house price booms and EQ (namely when the co-movements between money/credit and stock prices are typically strong and significant). In this case, we recommend limiting credit fluctuations resulting from the increase in the perceived wealth when stock prices soared. This may help to reduce "irrational exuberance", herd behaviour, or the costly burst of a stock price bubble in the medium and long run.

We contribute to the literature in many aspects. First, this is one of few studies analysing the dynamic interplay between money (credit) and stock prices based on an almost half a century long dataset that includes the Great Recession of 2007–2009, the euro area debt crisis (2010–2012) and post-Great Recession quantitative easing (QE). Second, we reveal the largely unrecognized in empirical literature relative dominance of credit compared to money dynamics in causing fluctuations in stock prices typically in the medium run, and document country-specific and time-frequency-varying insights. Third, we contribute to the existing literature, as we report findings that may be not evident in standard methods of data analysis that apply pure time- and frequency-domain methods. Indeed, our results imply that one of the possible reasons for various discrepancies in the empirical literature on the relationship between money(credit) and stock prices could be the changes in the aforementioned relationship across time and frequency. Finally, as opposed to our approach, the majority of empirical works on the responses of stock returns to monetary policy employ the event study methodology and regress high frequency (typically daily) stock returns on either monetary policy asset purchase announcements or changes in the policy rate.

Our results have several policy implications. The typical few years delay between the initial change in stock prices and the procyclical credit behaviour buys time for monetary policy authorities to respond to the expected credit dynamics. Closing the channel through which stock prices and credit interact may weaken their typically lagging but supposedly self-reinforcing relationship. Stabilising the growth of credit may be especially important when the co-movements between money/credit and stock prices are strong and significant, namely typically in around 70% of the time during house price booms, busts, and QE. We argue that this interpretation concerns the euro area too, although the special role in the "monetary pillar" is attributed to money. We recommend that the ECB should assign a dominant role to credit instead to money in assessing the impact of the stock price developments on inflation and the economy. As the long-run composes of a series of shorter-runs, ignoring medium-run increases in stock prices may potentially lead to a credit boom in the long run. This obviously brings along the risks of recession or an economic slowdown at least in case additional credit is used to further inflate stock prices. If not appropriately supervised by the financial stability bodies, the self-reinforcing effects between stock prices and credit could emerge in the long run, which brings along problems in the future when the stock price bubble finally bursts and the stock price turmoil spreads to the financial sector and ultimately to the real economy. Therefore, our paper deals with current policy issues (given the recent strong stock price increases, and the prolonged period of QEs and a series of new ones to come). The knowledge on the linkages between money (credit) and stock prices is important especially that our wavelet evidence reveals that the relationship between money (credit) and stock prices can vary in the short, medium and long run (leading to problems with detection and interpretation of the relationship between money/credit and stock prices).

It is important to emphasize that the world economy is subject to cross-country spillovers through financial channels. In our paper, however, we do not differentiate between domestic monetary policy shocks and shocks from the core-economy monetary policy via financial spillovers, despite the fact that such an effect exists. We believe it would be interesting to account for financial spillovers in the future analyses from the time-frequency perspective. Finally, the long-run macroeconomic time-series that we use can have structural breaks at certain points in time and frequency that can violate the assumption of constant background spectra. It cannot be ruled out that in such cases our estimates can be affected. The examination of wavelet power spectra is available upon request.

This article provides a wavelet perspective on the largely unrecognised manner in which money and credit interact with stock prices. There are other several ways to extend the analysis in this paper. It would be insightful, for example, to combine our time-frequency findings with advanced econometric modelling to account for other macroeconomic variables and further deepen the still not satisfactory recognised link between liquidity and stock prices. Finally, it would be interesting to analyse the post-pandemic developments once the time series would be long enough to allow for interpretations at least at the business cycle frequency from the continuous wavelet perspective.

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## Author contributions

Both authors conceived the study. Maciej Ryczkowski was responsible for the design and development of the data analysis. Marek Zinecker was responsible for the theoretical framework and data analysis. Both authors were responsible for the interpretation and discussion of the research results.

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