Journal of Economics Library
www.kspjournals.org
Volume 4 June 2017 Issue 2

Financial Equilibrium in the Presence of Technological Change

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Abstract. This article explores the issue of observable instability in financial markets interpreted as a long-term process of adaptation to demand for money, which, in turn, is based on the expected depreciation of fixed assets. Exploration is based on verifying empirically the hypothesis that the velocity of money is significantly, negatively correlated with the pace of technological change. The purpose of exploration is to assess the well-founded of policies, which use financial and monetary tools, rather than the straightforwardly fiscal ones, to stimulate technological change. Empirical research suggests that aggregate depreciation of fixed assets is a significant factor inducing slower a circulation of money.
Keywords. Money, Financial markets, Technological change.
JEL. E10, E30.

1. Introduction

The theory of money and finance systematically turns around the more or less explicit assumption that financial markets are inherently unstable. Seminal contributions in that direction of research start with Adam Smith, who claimed that lack of prudence in the issuance of currency can destabilize an economy. The now classical development by Kindleberger & Aliber (1978-2005) points at an interesting pattern of contradiction in economic history: although financial crises are always perceived, at the moment, as instances of deep disequilibrium, their recurrence suggests, strangely enough, that they are a symptom of some long-term equilibrium, which we do not exactly understand. Another seminal contribution, from Hayman Minsky (1992), suggests that we should always assume that financial markets are unstable and volatile: this is just safer for economic policy. That stream of literature seems to focus on short-term reactions of economic agents to financial stimuli, and tends to assume that the short-term reactions are the only relevant ones. Yet, another theoretical view can be coined from the available literature. The quite convincing developments of post-Keynesianism, especially those coming from Franco Modigliani (see, for example: Modigliani & Brumberg 1954 - 2005; Ando & Modigliani 1963) suggest that in the long-term perspective of a life-cycle, where economic agents have the time and the motivation to correct their line of action, short-term financial decisions sum up to very rational an adaptation to the economic environment. Thus, a general theoretical question can be formulated: is the observable instability of financial markets just an instability, or is it, in fact, the symptom of a deeper, long term process of imperfect adaptation in the economic system as a whole?

There is a practical policy question behind the elegant theoretical curtain. The relative success of quantitative ease policies, especially in the United States, induces the general question whether monetary policy shouldn't break free of the

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tight muzzle of interest rates, and become, instead, a creation of markets rather than simple creation of credit. Some experiences in that respect seem pessimistic. Both the explosion of derivatives in the 1990ies, and the frantic securitization of loans after 2000, seem to have brought more trouble than benefit. Still, there is that intuition that money, used in a clever way, can change things for the better, and quantitative ease proved it to be correct.

Data published by the World Bank allows observing a systematically decreasing velocity of money in the global economy. The observation is based on the metric labelled 'Supply of broad money as % of GDP'. The metric is a ratio of the actual supply of money, in absolute monetary amounts, divided by the Gross Domestic Product. Incidentally, this is exactly the reciprocal of the velocity of money, which is canonically defined as 'V = Q/M'. Under the category labelled 'World', the statistic provided by the World Bank allows calculating an aggregate, global velocity of money at the level of V = 1,85 in 1962. In 1972, that global velocity falls to V = 1.511, to reach V = 0,849 in 2014, and V = 0,815 in 2015. Money is slowing down. A vaguely similar change is observable also at the level of distributive average, calculated as the average velocity of money in the population of countries surveyed by the World Bank. That average is equal to 4,442 in 1962, falls to 3,809 in 1972, then it goes through an intriguing peak between 1974 and 1985, when it sometimes exceeds 8.0, just to pass into a descending trend afterwards and register V = 1,871 in 2014. As we can see, the distributive average in the velocity of money is generally higher and less uniform it its trend than the aggregate average to be found under the label 'World'. This is partly linked to the distinction between the developed economies, on the one hand, and the emerging markets, as well as developing countries, on the other hand. The first category (e.g. Denmark, United States) display a fairly stable, long-term curve in the velocity of money, still with a slightly ascending tendency. The latter, conversely, experience a very profuse supply of money per unit of real output, and a quickly decreasing velocity of money.

Against those stylized facts, we have the basic monetarist theory, which assumes essentially a constant velocity of money, with every significant variation in that respect being considered as a symptom of disequilibrium in financial markets. Facts suggest that what is commonly considered as disequilibrium, could be, in fact, a mechanism of adaptation, in the social system, to some kind of deeper social change. As social change is considered, a range of other facts is to mention. Since 2008, the world of finance has witnessed the turbulent development of the phenomenon called 'cryptocurrencies', or, in other terms, 'block-chained currencies'. Bitcoin is probably the elder in the family, and the best known, but the world of cryptocurrencies comprises today over 800 different ones, although just some 620 have any significant market capitalization, (see, for example: www.coinmarketcap.com or www.bitinfocharts.com). In very crude terms, the probability that a new cryptocurrency emerges somewhere in the world is some 4 times greater than the probability of seeing a new national currency. Cryptocurrencies display those peculiar characteristics, which, fault of a better term, can be called 'proto-money'. These are legal deeds, whose status is somewhere between speculative assets and money strictly spoken, i.e. whose balances can have, for their primary function, either to create opportunities for quick profit, or to settle accounts. Besides, the technology at the base of cryptocurrencies, the so-called 'Block-chain', with its dispersion into many local blocks of transactions, periodically locked with one major deal that checks the price discount rate, is very similar in its logic to the system of issuance and circulation created, once in the past, for the commercial bills of exchange.

Thus, as the global economy creates more and more money per unit of real output, experimentation with new types of money has intensified during the last decade. It looks as if the global economy needed more money. What does it need money for? The last edition of a database known as Penn Tables 9.0 (Feenstra *et al.* 2015) brings two interesting insights in that respect. Firstly, aggregate depreciation of fixed assets, when corrected for national purchasing power parities, makes a growing proportion of the national GDP, across the 182 national economies surveyed in the database. In 1980, aggregate depreciation made, on average, 9,5% of a national GDP. In 2000, that ratio climbed to 12.8%, to reach 18,6% in 2014. Interestingly, when the same depreciation is calculated without correction for purchasing power, just at current national prices of assets, converted into constant 2011 US dollars, the trend looks different: it becomes bell-shaped, with its belly the most protruding upwards during the 1980ies, around 20%, and currently at 18%. It looks as if, over the last six decades, a long-term, inflationary pressure on the prices of fixed assets had taken place. Anyway, when related to purchasing power, the national income of most countries has less and less capacity to compensate the obsolescence of their fixed assets. Secondly, the average share of government expenditures in the national capital stock, in the population of countries studied in Penn Tables 9.0, follows a curve strangely similar to that observable in the global velocity of money. This particular metric can be interpreted as the capacity of governments to redistribute capital through their expenditures, and since the 1980ies it is systematically decreasing.

The global economy creates more and more money per unit of real output, whilst said output displays a decreasing capacity to compensate the depreciation of fixed assets, which allows guessing an increasing speed of obsolescence in these assets. Governments seem to have less and less economic power to redistribute capital. A new generation of currencies, strangely similar to the historically known systems of bills of exchange, is emerging under our eyes. All these phenomena taken together suggest some kind of monetary adaptation to an accelerating technological change. Data published by the World Bank, and primarily provided by WIPO (World Intellectual Property Organisation) allows observing a slowly, but steadily growing value in the ratio of resident patent applications per one million inhabitants, across the globe. Growth in this metric is far from being rocketing, and still, in 2014 there was, on average, 175.6 resident patent applications filed per million people, against 124.2 in 1990. World Development Report 2016, entitled 'Digital Dividends' and issued by the World Bank, interestingly suggests a systematic lag in gains from digital technologies behind the potential of those technologies (World Bank, 2016).

Against the dominant background of the classical monetarism, there is a stream of thought, known since, at least, the 17th century and the principles of mercantilism, which claims that money can be an autonomous social force, and not just a medium of payment. Contemporarily to Adam Smith, Joseph de Pinto engaged in a long-lasting (and probably life-endangering) polemic with Marquis de Mirabeau, arguing that creation of money, also indirectly, via the development of markets for public debt, can be an autonomous force facilitating progress and social well-being (see: Mirabeau 1760; Pinto 1771). A much more modern contribution in that respect had been made by Paul Samuelson (1958), who suggested that money can be a social contrivance, serving to transfer value not just in space, but also in time. Against the dominant assumption that money loses value over time, Samuelson proposed a theoretical network for studying money as a technology serving to transmit accumulated value between generations. The theoretical framework proposed by Paul Samuelson rests on a central assumption that the supply of money can and should increase at a basic rate closely correlated with the rate of demographic growth. The present article experiments with transplanting the same type of reasoning, from generations of humans to generations of technologies, in order to explain the stylized facts mentioned previously.

At any given moment, there are three generations of technologies in use: emergent, established, and declining. The pace of technological change can be seen as the proportion between the relative diversity (or simply the sheer number) of technologies available in each of those generations. The more are there emergent technologies, the greater is the pressure on the obsolescence of the established ones, thus on their transition to the declining generation. If the diversity in emergent technologies, thus, for example, the propensity to patent new inventions, grows systematically, an increasing pressure towards obsolescence appears. The greater is that obsolescence, and the faster is the pace of replacement, in the world of technologies, the greater amount of capital is needed to finance the process. At this point, it is useful to remember that the supply of money is, and historically has always been the supply of account money, not cash money (see for example: Braudel 1981; 1983). Both presently, and historically, the greatest amounts of money have been created to settle intangible capital accounts, not to pay for tangible things. From the practical point of view, money is needed mostly and primarily to assure liquidity in balance sheets, and only secondarily in the markets of goods and services. In other words, when technological change accelerates, it could lead, through increased depreciation and compensatory behaviour from the part of entrepreneurs, to the swelling of balance sheets, and to a correspondingly growing demand for money. That's why, in the following part of this article, the author explores the hypothesis, according to which *there is a significant, negative correlation between the pace of technological change, as measured by the pace of depreciation in fixed assets, and the velocity of money.*

2. The theoretical model

The purpose of the here-presented theoretical model is to explain, why technological progress, for example in terms of labour productivity or dividends on digital technologies, is generally slower than expected, whilst, in the same time, why such progress below expectations takes place in the context of systematically decreasing velocity of money, as well as a decreasing economic power of constitutional states, measured as the share of their expenditures in the available capital stock. Thus, the general theoretical drift developed below goes towards simulating investment decisions, which barely catch on technological progress.

It is assumed that entrepreneurs build their individual balance sheets on the grounds of expected useful life in their assets. Expectations as for the useful life of assets are formed on the grounds of observed, actual depreciation '*D*'. Thus, entrepreneurs accumulate capital so as to provide for the expected depreciation'*D**', which is estimated based on currently observed depreciation and its volatility. Depreciation is significantly, although not exclusively driven by the replacement of established technologies by the new, emergent ones. This implies that both an individual balance sheet of one business, and the aggregate balance sheet of a whole economy is a quasi-random outcome of investment decisions based mostly on the entrepreneurs' willingness to 'stay in the game'. Thus, the present model is a distant echo of the Keynesian classic, with just some assumptions released. Gross investment does not have to be equal to depreciation; it is just based on the observed depreciation. Entrepreneurs can take into account a variable number of factors, yet at the end of the day their main investment goal is to keep their assets valuable. Equity is the quasi-random, uncertain outcome of investment decisions combined with borrowing decisions. The propensity to leverage assets with creditis also quasi-randomly distributed across the population of entrepreneurs, who want to maintain an individually, arbitrary financial liquidity, with money, as a form of assets, expected to have quasi-infinite useful life, i.e. indefinite from the point of view of individual business decisions.

As a result, an aggregate, current demand for credit, or '*DC*' is generated by the whole population of entrepreneurs. Banks respond to shifts in *DC* in an imperfectly efficient way: the total supply of money contains either a lag, or an overhang, regarding the current demand for credit.

Current, aggregate depreciation in individual balance sheets is the outcome of two factors: useful life of assets, and their current book value. The latter, in turn, is the outcome of past anticipation regarding their depreciation. In other words, aggregate depreciation results from two combined processes. The first is a trend regarding the speed of replacement in technologies, essentially imposed by the pace of science. The second is the quasi-random outcome of past investment decisions.

Two, superimposing, geometric Brownian motions in, respectively, aggregate depreciation 'D' and aggregate supply of money 'M':

$$dM_t = \mu_1 M_t dt + o_1 M_t W(D)$$
$$dD_t = \mu_2 D_t dt + o_2 A_t W(D)$$

Where D is depreciation, M stands for the supply of money, W(D) is a Wiener process in depreciation, and A symbolizes the book value of assets.

Those two geometric Brownian motions can be summarized in the hypothesis*: there is a significant, negative correlation between the pace of technological change, as measured by the pace of depreciation in fixed assets, and the velocity of money.*

3. The empirical check

The purpose of the here-presented empirical check is to set an empirical basis for the theoretical model presented in the previous chapter of this article. This encompasses two separate steps. In the first one, at as high a level of aggregation as possible, partial proof should is being produced regarding the occurrence of geometric Brownian motion in, respectively, aggregate depreciation of fixed assets, and aggregate supply of money. In a second step, linear modelling of the link between technological change and velocity of money is undertaken. The relative impact of technological change on the velocity of money is estimated, together with contextual, explanatory variables.

3.1. The dataset

The dataset used for empirical research in this article is essentially Penn Tables 9.0 (see: Feenstra *et al.* 2015), which the author allowed himself to compile with selected data published by the World Bank, mostly regarding the supply of money, as well as the density of population etc. Unless it is specified otherwise, all econometric tests have been conducted on natural logarithms of empirical values from the dataset. For the purposes of the present research, and more specifically for proving, at least partially, the existence of geometric Brownian motion aggregate depreciation and aggregate supply of money, the author has aggregated those variables in the database, on an annual basis. The results of aggregation, and thus the source values for the partial proof of geometric Brownian motion are available, to the best author's knowledge, at his Google Drive, at the following link: [Retrieved from].

3.2. Partial proof of geometric Brownian motion

The existence of geometric Brownian motion can be partially proven by checking the two following conditions: $ln[x(1)]$ has mean $ln[x(0)]+ \mu t$ and variance $\sigma^2 t$. Checking the means, for respectively, aggregate depreciation and aggregate supply of money, has been done in reverse order. For each annual aggregate, the value $[ln(x_t) - ln(x_0)]/t$ has been calculated, as an approximation of the total: drift coefficient μ plus volatility component $\sigma^2 t$. Please, note that the time series of aggregate depreciation in Penn Tables 9.0 start in 1950, whilst data on the supply of money, as published by the World Bank, starts in 1960. Those two years are the respective 'x_0' values for both variables. In a next step, the value $[ln(x_t) - ln(x_0)]/t^2$ has been calculated, as an estimation of the volatility component $\sigma^2 t$, and then subtracted from $[ln(x_t) - ln(x_0)]/t$, in order to narrow down the analysis to the aggregate drift.

As a result, regarding aggregate depreciation, a progressively decreasing volatility component has been identified, ranging from 0,0294 in 1950 to 0,0008 in 2014. The cumulative drift observable in aggregate depreciation starts at 0,0294 in

1951, and reaches 0,0566 in 2014. As for the supply of money, volatility progressively decreases from 0,0144 in 1962, to 0,0011 in 2014, with the cumulative drift starting at 0,0274 in 1961, and reaching 3,1912.

This is a partial, and therefore indirect proof regarding the existence of geometric Brownian motion in the two aggregate variables of the theoretical model. Still, some conclusions can be drawn. Whilst geometric Brownian motion seems to be there in both cases, it also seems to have different characteristics. Changes in aggregate depreciation display relatively slow a drift and very little volatility, whilst the aggregate supply of money is more volatile, and presents a much stronger drift over time.

3.3. Linear modelling - the general case

The general case has been constructed as an attempt to grasp the functional link between the velocity of money and technological change. The velocity of money is calculated as the reciprocal of the variable supplied by the World Bank, namely of the supply of broad money measured as a percentage share of the Gross Domestic Product. As the corresponding variable of the World Bank is simply 'M/Q', its reciprocal, namely 'Q/M' is the exact equivalent of velocity of money. Technological change is represented with just one variable, namely aggregate depreciation per million inhabitants, or, in other words, the intensity of obsolescence in established technologies, measured on a double base made of the capital stock and population.Aggregate depreciation was measured on the capital base corrected for changes in the national purchasing power parities, or, in other words, as a fraction of the value recorded in Penn Tables 9.0 as 'ck'. On the grounds of considerations presented in the preceding subchapter, this capital measure seems less prone to observation bias. This variable is being placed in a broad context, which is being sketched starting with the assumption that the velocity of money has a residual component, constant regarding all the variables included in the model.

Besides the residual velocity of money, the current exchange rate has been introduced into the general case, in a double role. Firstly, in an open economy, the exchange rate is largely exogenous to technological change, and to the functioning of the national banking system. Secondly, it potentially can have a significant impact on the velocity of money. After that, the scale factor, namely theoutput of the national economy (output-side GDP, 'rgdpo' in Penn Tables 9.0), has been added to the model. As aggregate depreciation is one of the hypothetically chief explanatory factors in the model, and it is being calculated on the base of capital stock, price level in investment, has been introduced into the model, in order to represent the loop between two sides of the economy - real and financial – as it comes to the allocation of capital.

Finally, three structural characteristics of national economies have been introduced in the model: density of population, share of government expenditures in the capital stock, and the share of investment in the GDP. Density of population has been dropped into the model for two reasons. In the first place, the author believes that the density of population is a fundamental characteristic of any social structure, still largely neglected in economic research. Besides, the factor of population is the base for calculating important variables in the model, beginning with the chief measure of pace in technological change, namely aggregate depreciation per one million people. Therefore, purely arithmetical endogeneities are being introduced into the model via kitchen door. Including the density of population as a separate variable is an attempt at clarifying, to the extent of possible, the relative explanatory power of those specific endogeneities.The share of government expenditures in the capital stock has been included in the model because of the previously mentioned stylized fact: this share tends to decrease just as the velocity of money decreases, in the global economy. The relative impact of this structural factor can be interpreted as the possible substitution between fiscal stimulation, and the growth of financial markets. As for the share of investment in the GDP, it seems logical to include it into the model, regarding both the measure of technological change (aggregate depreciation per million inhabitants), and the inclusion of price level in investment.

All the economic aggregates expressed in currency units are accounted for in constant 2011 US$. With all the assumptions made above, the general case has been tested as an econometric model based on natural logarithms of the variables involved. Using natural logarithms had two essential functions. Firstly, it allowed providing for the differences in measurement scales, as well as very largely providing for non-stationarity. Secondly, as the natural logarithm is a power, it can be interpreted as incremental change in the Euler's constant. Thus, it is somehow halfway between actually observed values and their first differences, and, by the same means, it allows introducing a reasonable component of marginal change in the model. Tested on natural logarithms, in a total sample of n = 4 263 country-year observations, with the Ordinary Least Squares Method (software: Wizard for Mac OS), the model yielded an accuracy of R^2 = 0,515. A text-like presentation of coefficients is being introduced below, and a formal table of coefficients is presented in the statistical appendix, at the end of this article. All the coefficients yielded, at the t Student test, a significance level p < 0,001, thus significance levels are not being given separately.

Coefficients in the empirically tested general model are the following:

*ln(Velocity of money) = - 0,069*ln(GDP; scale factor)- 0,202*ln(Aggregate depreciation per million pop) - 0,179*ln(Gov share in the capital stock) – 0,108*ln(Density pop) - 0,21*ln(Investment share in the GDP) - 0,217* ln(Price level in Investment)- 0,007*ln(Exchange Rate) + constant ln = 2,444*

In that general case, all the explanatory variables decrease the velocity of money, and therefore stimulate the supply of credit per unit of real output. Still, the velocity of money has a residual constant strong enough to counterbalance the impact of factors included in the model. The hypothetically exogenous exchange rate has surprisingly little to say in the general case, just as the scale factor represented by aggregate GDP. That allows supposing relatively high robustness in the model. Aggregate depreciation per million inhabitants, together with the share of government expenditures in the capital stock, have similar strength and sign in this general case, which seems to confirm author's educated guessing about mutual substitution between fiscal stimulation, and the supply of money. Summing up, for the moment, general empirical check confirms the working hypothesis that there is a significant, negative correlation between the pace of technological change, and the velocity of money. The next step consists in studying variations from the general case, and the possible factors of disturbance.

3.4. Variations from the general case and factors of disturbance

Variations from the general case are alternative models of the same functional link between the velocity of money and technological change, enriched with additional assumptions. They are four special cases: absence of residual velocity of money, stationary economy, closed economy, and finally technological change broken down into three factors (instead of one: depreciation), namely depreciation, patentable invention and energy intensity.

Absence of residual velocity in the circulation of money is a hypothetical case, which could mean either a completely passive banking system, which do not assure any residual supply of credit to the economy, or a banking system completely out of control. In practical terms, this is either credit crunch, or the swelling of a financial bubble.In the same time, taking the residual velocity of money out of the equation allows testing the robustness of the general case, regarding the possible influence of exogenous factors non-accounted for. With the same number of n = 4 263 country-year observations, the so transformed model yields an accuracy of R^2 = 0,784. As in the general case, natural logarithms of all the explanatory variables display a significance in correlation with the velocity of money at the level p < 0,001. One makes exception, namely the exchange rate. The coefficients are textually given below, and the detailed table is to find in the statistical appendix.

*ln(Velocity of money) = - 0,024*ln(GDP; scale factor) - 0,087*ln(Aggregate depreciation per million pop) - 0,232*ln(Gov share in the capital stock) – 0,077*ln(Density pop) - 0,659*ln(Investment share in the GDP) - 0,383* ln(Price level in Investment) - 0,005*ln(Exchange Rate) [p = 0,001]*

This special case indicates that, first of all, even in the absence of any residual velocity of money, the repertoire of factors included in the general case explain up to 78,4% of variance observable in said velocity. Some factors have been obviously left out. In this special case, technological change strictly spoken, measured with aggregate depreciation per one million people, loses much of its impact, to the benefit of interaction with fiscal policy, and, most of all, that of general investment outlays. That, can have a plausible explanation in the theoretical lines of the present research: in the presence of serious disturbance in the banking system, expectations as for the strictly spoken outcomes of technological change just stop mattering, to the benefit of more short-term decisions.

Stationary economy, with constant GDP, and thus with no scale factor in the equation, is a hypothetical case that the author believes to be quite well fitting short-term, individual business decisions, when economic growth is *de facto* unobservable.The assumption of stationary economy does not change much to the overall accuracy of the model, which yields R^2 = 0.494, with the following parameters in the equation, all significant at p < 0,001:

*ln(Velocity of money) =– 0,239*ln(Aggregate depreciation per million pop) – 0,163*ln(Gov share in the capital stock) - 0,124*ln(Density pop) - 0,21*ln(Investment share in the GDP) - 0,225*ln(Price level in Investment) – 0,006*ln(Exchange Rate) + constant ln = 1,985*

In a stationary economy, thus in the absence of observable economic growth, the accuracy of the general model remains pretty high, just as the general drift in the coefficients of regression. One change is substantial: aggregate depreciation per 1 million people becomes the single most important explanatory variable, as if in a stationary case expectations regarding the obsolescence of established technologies were becoming much more important for stimulating the supply of credit.

The special case of closed financial market can be simulated with the exchange rate taken out of the equation and assumed constant. The accuracy of the model remains very close to the general case, with R^2 = 0.512, and all the coefficients of regression significant at p < 0,001, yielding the following equation:

*ln(Velocity of money) = - 0,068*ln(GDP; scale factor) - 0,198*ln(Aggregate depreciation per million pop) - 0,172*ln(Gov share in the capital stock) – 0,112*ln(Density pop) - 0,21*ln(Investment share in the GDP) - 0,227* ln(Price level in Investment) + constant ln = 2,42*

As it is easy to observe, holding the exchange rate constant almost didn't affect the parameters of the equation. The relative volatility of currencies, and thus the basic volatility in national financial markets, seems to be simply irrelevant regarding the general case.

In the general case, technological change is unidimensional, observed solely through aggregate depreciation per one million people. More complex a picture can be studied, by including two components: invention of new technologies, and changes in energy intensity. Obsolescence of established technologies is largely driven by the coming of new ones, which can be estimated with the indicator of resident patent applications per one million people. Technological changes are presently connected in quite an intimate way to energy management, saving, and to the shift towards renewable energies. Thus, the inclusion of energy intensity, through the variable provided by the World Bank under the label 'Energy use per capita in kg of oil equivalent' is likely to bring some additional information to the general case. Thus, the last special case presented here is the general one enriched with the indicators of: resident patent applications per million people, and energy use per capita. Those additional variables have been added by the author to Penn Tables 9.0, yet their inclusion has driven the size of sample down to n = 2 107 valid country-year observations. Of course, endogeneity is expected between the three measures of technological change (i.e. depreciation, patent applications and energy use), and still it is interesting to observe their cumulative impact. With half the sample size of remaining cases, this one sticks to pretty much the same accuracy, with $R^2 = 0.445$, which is comforting regarding robustness in the general logic of the present article. All the coefficients presented below are significant at $p < 0.001$, with two exceptions: energy intensity, significant exactly at $p = 0,001$, and the indicator of patent applications, significant at $p = 0.542$, thus practically random in its impact. The equation develops as follows:

*ln(Velocity of money) = - 0,08*ln(GDP; scale factor) - 0,219*ln(Aggregate depreciation per million pop) - 0,155*ln(Gov share in the capital stock) + 0,005*(PatApp per million pop)+ 0,076*ln(Energy use per capita) – 0,086*ln(Density pop) - 0,408*ln(Investment share in the GDP) - 0,266* ln(Price level in Investment) + constant ln = 1,739*

The breaking down of technological change into more component variables did not bring much to the explanatory power of the general model. Whether it is because of endogeneities, or for other reasons, remains to be explained. Still, the indicators of patentable invention and energy intensity look rather like disturbance factors to the general case.

4. Conclusion

This article develops a line of research, where the way that financial markets work is closely correlated with the pace of technological change, and, more specifically, with the pace of obsolescence in the established technologies. The research has been inspired by the observable concurrence of three big trends in the global economy - decreasing velocity of money, increasing burden of aggregate depreciation on national income, and decreasing average share of government expenditures in the national capital stock – accompanied by the immensely interesting wave of experimentation with the so-called cryptocurrencies.

Empirical research developed in this article generally confirms the initially formulated hypothesis that there is a significant, negative correlation between the supply of money, and the pace of technological change. This correlation pertains to the classical assumption that financial markets are a social mechanism that facilitates the allocation of capital. The here-presented empirical research partly contradicts the view that financial markets have been developing without connection with real life, and have been an autonomous source of economic crises. On the contrary, the author feels entitled to claim that cases of financial instability, like speculative bubbles, can be seen as instances of imperfect adaptation in an otherwise quite rational process, namely that of looking for a good match between technological change, and the mechanisms of financing that change. The imperfectness of that adaptation can be hinted through the formal analysis in terms of geometric Brownian motion, regarding the supply of money and aggregate depreciation. The former is systematically more prone to both volatility and drifting than the latter.

The functioning of financial markers implies two sides: demand and supply. This article focuses mostly on the former, i.e. it attempts at explaining, how can the real sector of the economy generate a growing, and still rational demand for money per unit of real output. The path still to explore is the supply response from the part of financial institutions.

The article does not refer directly to neither of the two classical concerns of financial economics, namely interest rates and inflation. The author considers those grounds as very profoundly studied, and wanted to avoid redundancy. Instead, the purpose of the article is to return to the roots of financial markets, and bring a contribution to explaining their link with the real side of the economy. If not the interest rates, then what could be the practical interest of the here-presented research? The author believes that in the presence of decreasing economic power in governments, and decreasing velocity of money, the latter can be purposefully used to stimulate technological change, e.g. faster prevention of climate change or providing for food security. Still, as interest rates are historically low, there is not much room for experimentation in that direction. However, the phenomenon of translating the old business pattern of block-chained transactions into a technology of block-chains opens new prospects. Cryptocurrencies, instead of being treated as pirates in a world of respectable sailors, could be positive examples of the path to follow, namely to create, purposefully, networks of local portfolios endowed with block-chained units of exchangeable value. As far as the topic of climate change is concerned, Meier *et al.* (2015) have convincingly proven that market-based incentives work definitely better that fiscal stimulation, in the transition towards renewable energies. Why couldn't we envisage cities issuing their own, block-chained, virtual currencies pegged on the value of renewable energy produced in those cities? Why couldn't we conceive migrations between cities smoothed and facilitated by the acquisition, or divestment, of those local currencies?

Appendices

Table 1. *Coefficients of the general case*

variable	coefficient	std. error	t-statistic	p-value
ln(GDP; scale factor)	-0,069	0,006	-11,241	0,000
ln(Aggregate depreciation per 1 million people)	-0,202	0,011	-19,002	0,000
ln(Density of population (people per sq km))	-0,108	0,005	-22,706	0,000
ln(Share of investment in GDP)	-0,21	0,024	-8,867	0,000
ln(Price level in investment)	-0,217	0,014	-15,604	0,000
ln(Exchange rate)	-0,007	0,001	-5,608	0,000
ln(Share of government expenditures in the capital stock)	-0,179	0,021	-8,712	0,000
constant	2,444	0,124	19,732	0,000

Table 2. *Coefficients of the special case with no residual velocity of money*

variable	coefficient	std. error	t-statistic	p-value
ln(GDP; scale factor)	-0,024	0,005	-4,4	0,000
ln(Aggregate depreciation per 1 million people)	-0,087	0,007	-11,766	0,000
ln(Density of population (people per sq km))	-0,077	0,005	-15,026	0,000
ln(Share of investment in GDP)	-0,659	0,015	-44,825	0,000
ln(Price level in investment)	-0,383	0,011	-35,906	0,000
ln(Exchange rate)	-0,005	0,001	-3,225	0,001
ln(Share of government expenditures in the capital stock)	-0,232	0,023	-10,206	0,000

Table 3. *Coefficients of the special case with stationary economy*

variable	coefficient	std. error	t-statistic	p-value
ln(Aggregate depreciation per 1 million people)	-0,239	0,012	-19,351	0,000
ln(Density of population (people per sq km))	-0,124	0,005	-24,225	0,000
ln(Share of investment in GDP)	-0,21	0,024	-8,657	0,000
ln(Price level in investment)	-0,225	0,014	-16,165	0,000
ln(Exchange rate)	-0,006	0,001	-4,866	0,000
ln(Share of government expenditures in the capital stock)	-0,163	0,02	-8,231	0,000
constant	1,985	0,107	18,549	0,000

Table 4. *Coefficients of the special case with constant exchange rate*

variable	coefficient	std. error	t-statistic	p-value
ln(GDP; scale factor)	-0,068	0,006	-11,115	0,000
ln(Aggregate depreciation per 1 million people)	-0,198	0,01	-18,971	0,000
ln(Density of population (people per sq km))	-0,112	0,005	-23,517	0,000
ln(Share of investment in GDP)	-0,21	0,024	-8,909	0,000
ln(Price level in investment)	-0,227	0,013	-17,062	0,000
ln(Share of government expenditures in the capital stock)	-0,172	0,02	-8,522	0,000
constant	2,42	0,123	19,68	0,000

Table 5. *Coefficients of the special case with complex technological change*

variable	coefficient	std. error	t-statistic	p-value
ln(GDP; scale factor)	-0,076	0,008	-9,649	0,000
ln(Aggregate depreciation per 1 million people)	-0,207	0,026	-7,966	0,000
ln(Resident patent applications per 1 million pop)	-0,002	0,008	-0,24	0,810
ln(Energy use (kg of oil equivalent per capita))	0,071	0,023	3,029	0,002
ln(Density of population (people per sq km))	-0,079	0,006	-12,426	0,000
ln(Share of investment in GDP)	-0,392	0,043	-9,059	0,000
ln(Price level in investment)	-0,257	0,021	-12,06	0,000
ln(Exchange rate)	-0,016	0,002	-6,564	0,000
ln(Share of government expenditures in the capital stock)	-0,143	0,03	-4,706	0,000
constant	1,714	0,196	8,741	0,000

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