Reshaping financial systems: identifying the role of ICT in the diffusion of financial innovations.
Recent evidence from European countries.

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Abstract:

Over the last decades, information and communication technologies (ICT) have been profoundly reshaping global economic landscape. This work aims to contribute to the present state of knowledge by exploring the links between ICT penetration and the introduction of financial innovations - exchange traded funds (ETFs) in several European countries between 2004 and 2015: the United Kingdom, Germany, France, Spain, Italy, Poland and Hungary. Japan and South Korea have also been chosen for comparison purposes. The methodological framework includes mathematical models of the diffusion of innovation, and both panel and country-specific models are employed to verify the hypothesized relationship between increasing ICT penetration and ETF market development. The findings indicate that new technologies (ICT) have been adopted in all the countries selected. The development of ETF markets has been strongest in Italy and France and weaker in the other countries, especially Poland and Hungary. The results highlight significant differences in the diffusion of ETFs among European countries and suggest that ICT has an important role. However, despite the high level of ICT adoption in most of the countries analysed, ETF diffusion has not taken place in all the cases. Generally speaking, the European countries still lag behind Japan and South Korea.

Keywords: information and communication technologies, exchange traded funds, financial innovations, diffusion of innovations, stock exchanges, index derivatives.

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1. INTRODUCTION.

Over the last decades, a rapid diffusion of new information and communication technologies (ICT) has been reshaping and profoundly transforming the global landscape (Lechman, 2013, 2014, 2015). This has coincided with dynamic changes across financial markets, including the introduction of innovative financial instruments (Lechman and Marszk, 2015) that contribute to global financial diversity. One of the most rapidly growing categories of innovative financial products is exchange traded funds (ETFs) – funds structured to mimic the performance of selected financial assets, usually stock indexes (Marszk, Lechman and Kaur, 2017). Units of ETFs (in contrast with conventional investment choices, e.g. mutual funds) are listed and traded on stock exchanges and can be bought and sold in a similar way to listed stocks, bonds and derivatives. The growing popularity of ETFs, the increase in the sums involved and the rate of turnover are predominantly enhanced by low trading costs, low tracking errors, high liquidity and (in some countries) high tax efficiency (Agapova, 2011; Aggarwal and Schofield, 2014; Lechman and Marszk, 2015). The global value of assets invested in ETFs reached a record high value of almost 2.9 trillion USD at the end of 2015, and there were ca. 6100 such funds available worldwide (ETFGI, 2016). In comparison, 5 years earlier at the end of 2009 the corresponding figures were just over 1 trillion USD and fewer than 2 thousand ETFs. This demonstrates the extremely highly dynamic development of the ETF market.

The first ETFs were launched in the early 1990s, and in Europe in 2001 (Deville, 2008). However, the growth dynamics of the ETF markets (understood as increasing values of assets accompanied by an increased turnover rate) in different countries differed significantly. These discrepancies can be attributed to a number of factors, for instance cross-country differences in ICT penetration rates. The largest market in the world is that in the United States (ICI, 2016a, 2016b).

In recent years, ETFs have gained much popularity among investors on a global scale, but in Europe (here understood as the EU member countries; in other European countries the ETF markets remain underdeveloped) their use is still low compared to other advanced economies such as the United States, Japan and South Korea. It is important to note that comparing the European ETF market to its American counterpart is problematic because ETFs have a much longer history and wider recognition in the USA. Choosing Far Eastern countries (Japan and South Korea) for comparisons with European stock exchanges seems a more plausible solution as in these countries the histories of ETF listings are comparable.

The factors influencing the development of ETF markets, particularly in comparison with other instruments offering a similar investment exposure (e.g. stock index futures and options), remain to a large extent a topic neglected by scientific research (with a few exceptions, including Lechman and Marszk, 2015). This constitutes a significant research gap, especially when the growing importance of ETF and their possible impact on global, regional and local financial systems are considered. This has already been recognized by some supervision institutions (Financial Stability Board, 2011; International Monetary Fund, 2011; Ramaswamy, 2011).

Even though the diffusion of financial innovations has been discussed in a number of publications in recent decades, most studies have focused on the banking sector (e.g. Persons and Warther, 1997; Hayashi and Klee, 2003; Akhavein, Frame and White, 2005; Frame and White, 2012). Other studies have been relatively rare (Frame and White, 2004). To the best of our knowledge, no studies have considered the diffusion of innovative financial products traded on exchanges (such as ETFs). Earlier studies of innovations in the capital markets mostly concentrated on asset-backed securities or junk bonds (see, e.g., McConnell and Schwartz, 1992; Molyneux and Shamroukh, 1996; DeMarzo and Duffie, 1999). Since the global financial crisis, this category of research has been marginalized due to a decreasing popularity of these instruments (Philippas and Siriopoulos, 2012). Moreover, no international comparisons have been made. Some attempts to outline the theory of ETF adoption have been made by Diaz-Rainey and Ibikunle (2012) and Awrey (2013), but the process of diffusion has not been discussed.

The main aim of this paper is to provide empirical evidence on the relationship between ICT penetration and the diffusion of innovative financial instruments – ETFs. ETF diffusion patterns in European financial markets will be identified and long-term forecasts of further development will be attempted.

Until recently, ETFs were mainly considered substitutes for index funds in passive investing strategies because of their similar features and users. However, an increasing popularity and complexity of the products available has led to growing interest among various players in the financial markets. ETFs are now compared not only to index funds but also to derivatives. Discussion of this field, focusing on the relative benefits of ETFs versus futures, was one of the key debates in the financial industry at the end of 2015 and the beginning of 2016 (Eurex, 2016). This also constitutes a new research perspective. To the best of our knowledge there have been no empirical works covering this subject, although a theoretical background was provided by the framework suggested by Gastineau (2010).

This paper comprises seven sections. Section Two outlines the aims and scopes of our research. Section Three presents the theoretical background and explains some issues associated with ETFs: their basic features, how they compare with stock index derivatives and the relationship between ETFs and ICT. Section Four outlines the methodological framework and Section Five presents the data sources. Section Six presents the results of the empirical study and is divided into four parts: an overview of ICT diffusion in the countries selected, a presentation of preliminary descriptive evidence on ETF market development, a discussion of our major empirical results obtained using diffusion models, and an evaluation of the relationship between ETFs and ICTs. Section Seven provides our general conclusions.

2. AIMS AND SCOPE OF THIS RESEARCH.

The main aims of our research are to contribute to the present state of knowledge by providing in-depth empirical evidence on the relationship between ICT penetration and the diffusion of innovative financial instruments – ETFs, to identify ETF diffusion patterns in the European financial markets examined, and to make long-term forecasts of their further development.

More specifically, we aim to:

- examine key trends in the growing access to ICT as a prerequisite for the global development and diffusion of financial innovations (here: ETFs);
- analyse financial innovation diffusion trajectories across major European stock exchanges (in the United Kingdom, Germany, France, Spain and Italy) in comparison with those in Japan

and South Korea, which we treat as benchmark countries as they have highly developed ETF markets;

- identify the financial innovation diffusion trajectories on the main CEE stock exchanges (in terms of ETF turnover) – Poland and Hungary – in comparison with Japan and South Korea (benchmark countries) and the main European stock exchanges selected (the United Kingdom, Germany, France, Spain and Italy);
- provide long-term predictions of financial innovation development across the countries examined, trying to establish the possible future path of ETF market development in Europe and therefore the possible consequences for financial systems and the policy measures required, including steps to be taken at the regional level, i.e. applying to all the major European financial markets;
- verify the hypothesis of an impact of growing ICT penetration on ETF market development in selected countries (including both panel and country-specific estimates).

In order to do the above, we use both annual and monthly time series with ETF data from the economies selected between 2004 and 2015. Given that the hypothesized impact of ICT on ETF diffusion is not immediate but instead may be distributed over time, we assume a one-year lag when analysing the impact of the growth in access to new technologies on the development of financial innovations. Therefore, to verify the quantitative association between ICT and ETFs we use data from 2003 to 2014 for ICT and from 2004 to 2015 for ETFs.

3. THEORETICAL BACKGROUND.

3.1. Basic features of ETFs.

In their basic form, exchange traded funds (ETFs) can be defined as baskets of securities traded on a stock exchange (similar to shares of listed companies), usually through brokerage firms (Ferri, 2009). ETFs are innovative financial instruments and they were launched on the financial markets in the 1990s and 2000s. Their prices closely replicate (i.e. track) the prices of certain financial assets, in most cases stock market indexes (Hehn, 2005). ETF shares (units) can be traded during a stock exchange's trading hours at prices determined by the market participants. The prices of ETF shares are usually close to their net asset value (which is related to the prices of the assets tracked). The ETF market can be divided into two segments: primary and secondary (Hill et al., 2015). ETF shares are created or redeemed on the primary ETF market in the course of transactions between the managing company (fund sponsor) and authorized participants (large financial institutions). Such transactions can involve delivery of the underlying assets (in the case of physical ETFs) or cash (in the case of synthetic ETFs, i.e. ones based on derivatives, which are popular mostly in Europe) in exchange for the ETF shares. As a result of transactions on the primary market, which are a part of the arbitrage mechanism, ETF tracking errors (deviations in the returns on ETFs from the returns on the tracked assets) are in most cases low. The secondary market consists of transactions on stock exchanges involving the sale or purchase of ETF shares between market participants (individual or institutional investors) without any interaction with the managing company. The specific features of the trading process depend on a number of factors, including the legal form of the ETF, the replication method applied by the fund managers and the assets tracked.

The growing popularity of ETFs in the last decade has mostly been the result of the benefits they offer investors compared to conventional financial instruments, particularly the sub-category of mutual funds with similar aims – index funds. These advantages stem from the mechanisms for the creation and distribution of ETFs. The key benefits relative to index funds include: lower tracking errors and lower tracking costs (in some circumstances, index funds are more cost-efficient – this depends on the trading frequency and the investment period), higher liquidity (units of index funds are usually priced once a day and have daily buying/purchasing cycles) and greater tax efficiency in some countries (e.g. in the USA) (Agapova, 2011, Aggarwal and Schofield, 2014, BlackRock, 2015, Lechman and Marszk, 2015).

3.2. ETFs compared to stock index derivatives.

Exchange traded funds, stock index futures and stock index options may be regarded as competing products within the category of (portfolio basket) index financial instruments. Together with a few other instruments, they constitute the equity index arbitrage complex – a group of related financial instruments based on common underlying assets (usually a basket of assets). This is a group of instruments with related values because of the similarity of their underlying financial assets (Gastineau, 2010). The underlying assets are usually stock market indexes or stock baskets determined by the index rules. The equity index arbitrage complex consists of three instrument categories (less commonly used instruments have been omitted):

1. Traditional securities: baskets of equities and ETFs;
2. Symmetric derivatives: stock index futures and equity/index swaps;
3. (Non-symmetric) convex instruments: stock index options.

In this classification, ETFs are included in the first category because they are combinations and extensions of the underlying traditional assets, not because they lack innovative features. The values of symmetric instruments are straightforward functions of the prices of the underlying assets, whereas the prices of convex instruments do not move proportionately.

The following discussion regards three groups of instruments traded on exchanges: ETFs, stock index futures and stock index options. Stocks, the most basic instruments, are not discussed. Instruments which belong to an arbitrage complex are perceived by investors as substitutes, not only because of the similarity of the underlying assets but also because of the potential for (usually limited) arbitrage profits. This means that their prices are related. Treating the arbitrage complex as an object of analysis is a suitable way to perform research concerning modern financial markets, as feedback between increasing trading volumes and decreasing trading costs on the one hand and arbitrage complexes on the other has been observed on most of the world’s stock exchanges (Gastineau, 2010).

Before the current dynamic development of the ETF market, these innovative instruments were considered alternatives to futures or options, mostly for short- and long-term risk management by large investors. Gastineau (2010) presents the results of a preliminary comparison based on data from the US market (the assets tracked were S&P 500 stocks). The key characteristic compared is the cost of these two alternatives. The costs of ETFs for risk managers result from the cost of gathering the stocks in a creation basket (it is assumed that transactions are conducted on the primary ETF market due to their size) or opposite transactions – commission fees, management fees and market impact. In the case of futures, the main costs are roll risk (the cost of extending the contracts after they end) and market impact. As a result, futures seem to be a better choice for short-term risk management, whereas ETFs are beneficial in the long term due to their lack of rolling expenses.

In recent years, ETFs have become increasingly popular alternatives to futures and options, not only as risk management tools for specific categories of investors but also for a wider group of market participants. The reasons for this change in the financial landscape can be traced back to the financial crisis of 2008 and regulatory decisions made in its aftermath, which were aimed at reducing systematic shock risks (Goltz and Schröder, 2011; Arnold and Lesné, 2015). As a result of the increased cost of capital for investment banks, growing operational (e.g. improved transparency) and capital requirements, and liquidity constraints – mainly linked to the Basel III regulations (Madhavan et al., 2014), the cost of traditional instruments such as futures or options grew and ETFs became relatively more cost-effective, for example in obtaining long-term exposure. Moreover, because of the high level of competition among ETF providers and economies of scale, the costs of investments in ETFs, especially in equity index ETFs (the closest substitutes for index futures and options), have been significantly declining – on average by about 40% between 2008 and 2014 in the case of the largest ETFs (Arnold and Lesné, 2015).

The differences between ETFs and stock index futures and in particular their relative advantages and disadvantages will now be described. Despite their different features, which make direct comparisons difficult, most of the relative advantages and disadvantages of futures with respect to ETFs which are discussed below also apply to options (as derivatives traded on regulated exchanges, which in many cases may be alternatives to futures, and even more importantly to ETFs (Thomsett, 2016)).

The similarities between ETFs and stock index futures include (Goltz and Schröder, 2011; Arnold and Lesné, 2015):

- identical trading venues – most turnover occurs on stock exchanges,
- high liquidity,
- multiple market participants,
- intra-day pricing (on exchanges),
- minimal counterparty risk.

TABLE 1 ABOUT HERE

Table 1 presents some selected main features which distinguish ETFs from stock index futures. The key difference, which influences the relative costs of these two categories of instruments, lies in the rolling costs of futures contracts, i.e. the costs of entering a new contract after the expiry of the previous one, which involve both explicit costs (trading commissions and bid-ask spreads) and potential mispricing (Madhavan et al., 2014; Arnold and Lesné, 2015). The main relative advantages of futures can be observed in the following features: the capital required, leverage, and short sale possibilities. The strengths of ETFs are higher accessibility, wider product ranges, minimal management requirements prior to exiting, no predefined maturity and easier foreign investment. To sum up, similarly to the use in risk management discussed in the preceding paragraphs, even for the broad investing audience ETFs may be considered more efficient long-term investment instruments, whereas futures are regarded as more suitable short-term choices (Eurex, 2016). It should be noted, however, that the final choice depends not only on the holding period but also on the investment strategy. According to the results of a study conducted by the CME Group (2016), in the case of leveraged or short sale positions index futures are relatively more beneficial, regardless of the holding period.

It should be underlined that the framework presented above only applies to equity ETFs, and many more types of these instruments are currently available, such as fixed income and commodity ETFs. However, despite the increasing heterogeneity of ETFs, equity ETFs (based on the equity market, usually stock market indexes) are still by far the largest category.

3.3. ICT as a factor influencing the development of ETF markets.

In this study we intend to refer to various factors conditioning the effective functioning of financial markets and enabling a wide and rapid spread of financial innovations (here, exchange traded funds). Among the broad array of factors determining the functioning of the latter, it is claimed that ICT makes an important contribution to strengthening financial systems and financial development (see, for example, Wurgler, 2000; Yartey, 2008). Moreover, Stigler (1961) and Morck, Yeung and Yu (2000), for instance, argue that financial markets are in some ways ‘information markets.’ Bearing this in mind, ICT may reshape their functioning as it enables information and data dissemination, decreasing numbers of market failures like, *inter alia*, time delays and information asymmetries. Morck, Yeung and Yu (2000) also claim that ICT allows rapid and unbounded flows of information and that these facilitate the decentralization of financial markets and makes them work more efficiently, mainly due to the fact that physically separated actors can gain new opportunities, for instance to purchase assets not available in their original location. Regarding information flows, access to high-speed broadband requires further examination, as wide bandwidth communication systems are notable for their significant information-carrying capacities, allowing for increases in financial market activities (e.g. trading) (Lechman and Marszk, 2015). However, some authors claim that ICT may produce growing financial instability (see Ilyina and Samaniego (2011), for instance, who emphasize the growing volatility of financial markets, and Perez (2002) and Pozzi, Di Matteo and Aste (2013), who claim that existing cross-country digital gaps may generate financial exclusion and thus global financial systems may become less stable).

It is important to note that the empirical evidence on the impact of growing ICT access and use on financial development is significantly fragmented and lacks robustness. Some evidence may be found in Shamim (2007). This pioneering study covering empirical linkages between increasing ICT penetration and financial markets in 61 economies over the period 1990-2002 finds that ICT positively impacts financial development. Similar evidence for developing countries is provided by Claessens et al. (2002), who also claim that the development of ICT infrastructure may positively contribute to financial development in developing and emerging economies. In addition, in a study of African economies Andrianaivo and Kpodar (2011) show that broad adoption of ICT positively impacts financial inclusion, and as a result generates positive spillovers for financial development and economic growth. Sassi and Goaied (2013), in a study covering the MENA region, find that a higher ICT penetration rate positively affects financial development, and, in addition, if the two-way relationship is important, it is a stimulus for economic growth.

ICT may affect financial markets and the spread of financial innovations (including ETFs) in various ways. The role that ICT plays in ETF market development can be observed on both the demand and supply sides of the market. As Lechman and Marszk (2015) state, one should bear in mind that due to the fact that ETFs are products listed and traded on stock exchanges, their development depends to a large extent on changes occurring in capital markets, including those caused by increasing ICT penetration.

The demand-side factors are linked to the features of ETFs, which make them more beneficial for investors than other similar options, particularly mutual funds, and therefore lead to growth in demand for these products. These advantages are magnified by a higher level of stock market development, which is effectively preconditioned by growing ICT penetration. The introduction and development of electronic trading systems enables profound transformations of the microstructures of stock markets (Nishimura, 2010). A high level of automation in the trading process causes a reduction in trading costs, and consequently facilitates more efficient risk-sharing together with improvement of the liquidity and efficiency of pricing mechanisms (Hendershott, Jones and Menkveld, 2011). Moreover, electronic trading increases the rate of dissemination of information between different markets and market participants (Nishimura, 2010). This is enabled and magnified by wider access to the internet and greater network bandwidths.

The cost of investing in ETFs is mostly comprised of expenditure linked with exchange trading. Therefore, the introduction and development of electronic trading systems, which results in lower trading costs, increases the attractiveness of these funds compared with mutual funds (Lechman and Marszk, 2015). Another benefit of ETFs is that there is a lower level of tracking error than for comparable mutual funds (index funds) as a result of the arbitrage transactions which minimize deviations of ETF prices from the prices of the instruments tracked. In order to limit tracking errors, such transactions need to be conducted with maximally limited time delays and transaction costs, together with access to up-to-date market information, particularly concerning the prices of both underlying securities and ETF shares. Electronic trading systems and wide access to fast internet connections enable market participants to act quickly and conduct transactions based on the latest market data. Moreover, real time communication facilitates yet another benefit of ETFs: it provides investors with a price continually determined on the stock exchange by the interaction between market supply and demand, and enables them to buy or sell ETF shares at any moment during trading hours.

The factors influencing the supply side of ETF markets are linked to new possibilities of introducing these products and of developing new and increasingly complex types of ETFs. The impact of increasing ICT penetration on the supply side of ETF markets may be summarized as follows:

- Transferring securities between institutions engaged in trading in ETF shares requires advanced settlement systems in order to ensure the timeliness and correctness of operations. Such systems operate more cost-effectively when based on constantly upgraded technologies (Schmiedel, Malkamäki and Tarkka, 2006), with a crucial role for fast broadband internet connections. Without such technologies, offering ETFs is either impossible or the costs are too high to compete with mutual funds;
- ICT facilitates timely responses to the latest data and the transfer of funds between physically distant markets, which is particularly important for emerging market ETFs as their transaction costs are higher and their liquidity is lower than those of developed markets (Blitz and Huij, 2012).

ICT also plays an important role in facilitating the cross-listing of ETFs, i.e. listing a given product on more than one stock exchange (Calamia, Deville and Riva, 2013). In such situations, the shares of ETFs are traded on one stock exchange whereas the underlying tracked assets are traded on another. As a result, in order to gain the typical advantages of ETFs, such as low tracking errors and low costs, the trading and settlement systems on both exchanges must be based on advanced technologies (widely implemented ICT). Market participants must also be able to obtain timely data on exchange rates and have the possibility of conducting linked transactions in order to manage the exchange rate risk. Both of these are facilitated by technologically advanced currency markets.

To sum up, it seems clear that the development of ETFs and trade in them is impossible without electronic trading systems and access to ICT by various groups of market participants. The threshold level of ICT adoption necessary for the mere introduction of a first ETF on a local financial market does not seem to be very high (as exemplified by ETFs traded on emerging markets such as Indonesia or India). All European countries under study here have probably already reached this level. However, the implications for policy resulting from the links between ETF diffusion and ICT penetration are not so straightforward. The rates of diffusion of new technologies in various countries and the diffusion of financial innovations differ significantly and so there is a need to study the trajectories of the processes considered, not only their starting points. Moreover, ETF markets are not homogenous: the products traded differ, e.g. in terms of the replication method used (physical versus synthetic ETFs), which means that the structure of an ETF market (and consequently its impact on the financial system) may also be influenced by the level of ICT penetration. The development of synthetic ETFs requires relatively more advanced technology because a more complicated creation and settlement mechanism is needed than in the case of physical ETFs (for details, see, e.g., Kosev and Williams, 2011; Johnson et al., 2012; Naumenko and Chystiakova, 2015).

4. METHODOLOGY.

To achieve the main aims of this study, we adopt a methodological framework allowing for identification of the evolution over time of the processes reported across the financial markets regarding, *inter alia*, ETF diffusion. Therefore, apart from standard descriptive statistics, we use innovation diffusion models (Geroski, 2000; Rogers, 2010; Kwasnicki, 2013; Lechman, 2015), which are employed to approximate ETF diffusion trajectories and model projected future ETF development patterns. An analogous approach to the identification of ETF market evolution is reported in a study by Lechman and Marszk (2015), who analyse ETF diffusion paths in selected emerging markets.

To reveal ETF market development patterns, we use the empirical framework of the innovation diffusion model developed in the influential works of, *inter alia*, Mansfield (1961) and Dosi and Nelson (1994), who analysed the phenomenon by adopting the concept of evolutionary dynamics. This concept may be expressed mathematically as a logistic growth function, which when written as an ordinary differential equation is as follows (Meyer, Yung and Ausubel, 1999):

$$\frac{dY_x(t)}{dt} = \alpha\, Y_x(t). \qquad (1)$$

If $Y(t)$ denotes the level of variable x, t is time and α is a constant growth rate, then Eq. (1) explains the time path of $Y(t)$. If we introduce e to Eq. (1), it can be reformulated as:

$$Y_x(t) = \beta e^{\alpha t}, \tag{2}$$

or alternatively:

$$Y_x(t) = \alpha \exp \beta t, \tag{3}$$

with notation analogous to Eq. (1) and β representing the initial value of x at $t = 0$. The simple growth model is pre-defined as exponential. Therefore, if left to itself x will grow infinitely in a geometric progression. Indiscriminate extrapolation of $Y_x(t)$ generated by an exponential growth model may lead to unrealistic predictions because due to various constraints systems do not grow infinitely (Meyer, 1994). Therefore, to solve the problem of 'infinite growth,' a 'resistance' parameter (Kwasnicki, 2013) is added to Eq. (1). This modification introduces an upper 'limit' to the exponential growth model, which now gives the original exponential growth curve a sigmoid shape. Formally, the modified version of Eq. (1) is a logistic differential function, defined as:

$$\frac{dY(t)}{dt} = \alpha Y(t)\left(1 - \frac{Y(t)}{\kappa}\right), \tag{4}$$

where the parameter κ denotes the upper asymptote imposed, which arbitrarily limits the growth of Y.

FIGURE 1 ABOUT HERE

As mentioned, adding a resistance parameter to exponential growth generates an S-shaped trajectory (see Fig. 1). Eq. (4), the 3-parameter logistic differential equation, can be re-written as a logistic growth function which takes non-negative values throughout its path:

$$N_x(t) = \frac{\kappa}{1+ e^{-\alpha t-\beta}}\ , \tag{5}$$

or, alternatively:

$$N_x(t) = \frac{\kappa}{1+\exp(-\alpha(t-\beta))}\ , \tag{6}$$

where $N_x(t)$ stands for the value of variable x in time period t. The parameters in Eqs. (5) and (6) represent the following: κ is the upper asymptote, which determines the limit of growth and is also labelled 'carrying capacity' or 'saturation;' α is the growth rate, which determines the speed of diffusion; and β is the midpoint, which determines the exact time (T_m) when the logistic pattern reaches 0.5κ. However, to facilitate interpretation it is useful to replace α with a 'specific duration' parameter, defined as $\Delta t = \frac{\ln(81)}{\alpha}$. With Δt, it is easy to approximate the time needed for x to grow from 10%κ to 90%κ. The midpoint (β) describes the point in time at which the logistic growth starts to level off. Mathematically, the midpoint is the inflection point of the logistic curve. Incorporating Δt and T_m into Eq. (6) produces:

$$N_x(t) = \frac{\kappa}{1+exp\left[-\frac{\ln(81)}{\Delta t}(t-T_m)\right]}\ . \tag{7}$$

In our research, we aim to use the methodological framework for innovation diffusion models briefly presented above. In the first part of the analysis we assume that the growing value of ETF unit turnover can be regarded as diffusion of ETFs on local financial markets. However, in the main part of our analysis we assume that the process of the growing ETF share of the total turnover of comparable investment options (in the equity index arbitrage complex) is analogous to the process of diffusion of innovations across heterogeneous socio-economic systems. We assume that ETFs are innovations which due to a 'word of mouth' effect (Geroski, 2000) and emerging network effects are gradually adopted by increasing numbers of investors (users). We also rely on a basic assumption that investors (users) in financial innovations (here, ETFs) may freely contact 'non-investors' ('non-users'), i.e. people either not using ETFs before or previously choosing other similar options, which leads to adoption by this group. The process of growing adoption of financial innovations (ETFs) is effectively enhanced by unbounded access to information ensured by, for instance, broad adoption of information and communications technologies.

In short, we assume that ETFs diffuse on financial markets and gain a growing share of the total turnover of comparable investment options (apart from ETFs, stock index futures and stock index options (Gastineau, 2010)). In the basic version of the 3-parameter logistic growth model as defined in Eq. (6), we presume that $N_x(t) = ETF_i(t)$ represents changes in the ETF share of the total turnover of comparable investment options over time *t* in country *i*. Put differently, it shows changes in country i`s level of ETF financial market penetration. The parameter κ is represented as κ_i^{ETF}, which is the ceiling (upper asymptote/system limit) on the process of ETF diffusion on financial markets. The estimated parameter κ_i^{ETF} denotes the potential ETF share of the total turnover of comparable investment options on the financial market in country *i*, but under the rigid assumption that the ETF diffusion (development) trajectory follows the sigmoid pattern generated by the logistic growth equation.

Next, the parameter α (as in Eq. (6)) is represented as α_i^{ETF}, which is the speed of ETF diffusion on the financial market in country *i*. Hence, the estimated parameter α_i^{ETF} shows how fast the ETF share of the total turnover of comparable investment options is increasing on the financial market selected. Moreover, using parameter α_i^{ETF} we calculate the 'specific duration,' defined as $\Delta t = \frac{\ln(81)}{\alpha_i^{ETF}}$, which represents the time needed to pass from $\kappa_i^{ETF} = 10\%$ to $\kappa_i^{ETF} = 90\%$.

The parameter β is expressed as β_i^{ETF}, and its estimated value denotes the midpoint ${T_m}_i^{ETF}$, which indicates the exact time when 50% of κ_i^{ETF} is reached. Hence, ${T_m}_i^{ETF}$ represents the time (year/month) when the process of ETF diffusion reaches the half-way point if we assume that it is heading toward κ_i^{ETF}.

Thus, the modified specification of Eq. (6) is:

$$ETF_i(t) = \frac{\kappa_i^{ETF}}{1+exp\,(-\alpha_i^{ETF}(t-\beta_i^{ETF}))}\,, \tag{8}$$

with notation as explained above.

The parameters in Eq. (8) can be estimated using ordinary least squares (OLS), maximum likelihood (MLE), algebraic estimation (AE) or nonlinear least squares (NLS). However, as Satoh (2001) suggests, NLS returns the best predictions as its estimates of standard errors (of $\kappa_i^{ETF}, \alpha_i^{ETF}, \beta_i^{ETF}$) are more valid than those returned using the other methods. Adopting NLS allows time-interval biases, which occur in the case of OLS estimates (Srinivasan and Mason, 1986), to be avoided. However, NLS has the disadvantage that estimates of the parameters may be sensitive to the initial values of the time-series adopted.

In addition, to examine whether there are relationships between growing ICT penetration and ETF diffusion, we use panel data analysis, which is complemented by estimation of analogous country-wise regressions. First, we try using a fixed effects regression, which yields:

$$\varphi_{iy} = \alpha_i + \gamma_1 x_{1iy} + \cdots + \gamma_n x_{niy} + \varepsilon_{iy}\,, \tag{9}$$

where i denotes the country and y the year. Eq. (8) may be reformulated introducing country dummies:

$$\varphi_{iy} = \alpha_i + \gamma_1 x_{1iy} + \cdots + \gamma_n x_{niy} + \delta_2 C_2 + \cdots + \delta_n C_n + \varepsilon_{iy}\,. \tag{10}$$

In Eqs. (9) and (10), α_i denotes unobserved and time-invariant fixed effects, δ_n is the coefficient for binary-country regressors, C is the country dummy, and n represents the number of countries in the sample. For Eqs. (9) and (10) to satisfy the exogeneity assumption, we assume that $E\left(\varepsilon_{iy} \big/ x_{iy},\ \alpha_i\right) = 0$, with x_{iy} standing for the explanatory variable. To confirm the adequacy of the fixed effects regression, we perform a Hausman test (Maddala and Lahiri, 1992) to verify the null hypothesis $H_0\!: cov\,(\alpha_i, x_{iy}) = 0$ if a random effects regression is asymptotically more efficient than a fixed effects model; otherwise a fixed effects regression is more suitable. In the case that the random effects model turns out to be more appropriate, we estimate:

$$\varphi_{iy} = \gamma_0 + \gamma_1 x_{1iy} + \cdots + \gamma_n x_{niy} + \alpha_i + \varepsilon_{iy}\,, \tag{11}$$

with notation analogous to Eqs. (9-10). By convention, in random effects models it is assumed that variation across countries (or other entities) is random and thus uncorrelated with the explanatory variables. In addition, to trace country-specific characteristics with respect to the relationships analysed, we estimate individual country regressions which have the general econometric form:

$$\theta_i = \omega_0 + \omega_{1,i} + \cdots + \omega_{mi} + \varepsilon_i, \quad (12)$$

where i denotes the country and m is the number of explanatory variables.

5. DATA.

Our research covers stock exchanges in two countries in the CEE region – Poland and Hungary; another five EU countries with the longest history of ETF trading – France[1], Italy, Germany, the United Kingdom and Spain; and two Asian economies – Japan and South Korea. We treat Japan and South Korea as benchmark economies regarding the level of ETF penetration on stock exchanges. The time coverage is a result of data availability. For the period 2004-2015 a balanced data set is available for most of the countries included in the analysis, while for the CEE countries the time span of the analysis is shorter as ETFs were launched there later than in the advanced European economies.

The financial instrument databases used in the study are the dataset provided by the World Federation of Exchanges (World Federation of Exchanges, 2016), datasets provided by the selected stock exchanges and reports published by these institutions. The most important financial indicators used are the turnover values (in USD millions) on the stock exchanges of the instruments selected: ETFs, stock index options and stock index futures.[2]

As for ICT, we use two types of data. First, we use the number of fixed broadband subscriptions (FBS) per 100 inhabitants in a country. Second, we use Internet Users (IU), which represents the 'proportion

[1] Our analysis covers the Euronext exchange considered as a whole (due to data availability), and thus (in addition to France) also includes the Netherlands, Belgium and Portugal. However, most of the turnover is reported to be in the French segment and so we decide to consider this exchange as if it was located in France. Consequently, we also use other indicators for France.

[2] Due to a lack of reliable data on the turnover of stock index futures and options on the main stock exchange in the United Kingdom (caused by changes in the organizational structure of the London Stock Exchange Group), the analysis for this country only covers values of ETF trading.

of individuals who used internet from any location in the last three months.' All the data on ICT access and use come from the World Telecommunication/ICT Indicators database 2015 (19th Edition, December 2015).

6. EMPIRICAL ANALYSIS.

6.1. ICT development - descriptive and graphical evidence.

To shed more light on the process of changing access to and use of ICT across the economies selected, we use annual time series on fixed broadband networks between 1998 and 2014 and internet user penetration rates for the period between 1990 and 2014. These key measures showing the progress of ICT diffusion in the countries selected between 1990 and 2014 are presented in Table 2 (and graphically in Fig. 2). No significant differences in the processes of ICT diffusion in the economies analysed can be observed. In terms of internet users, in each country we observe a rapid growth in the share of the population using an internet connection. At the beginning of the time period analysed (1990), in all countries less than 1% of the population had access to ICT as measured using this ratio (the highest result is observed for Germany, but it is only 0.12%; the lowest is for Hungary: 0.003%). After more than two decades of very rapid growth, in 2014 the ratio in all countries was greater than 60% (in the United Kingdom it reached almost 92%). Similarly rapid changes are observed in access to fixed broadband networks (measured using the share of the population with fixed broadband subscriptions). This grew annually by 34% in Germany and by even 48% in Hungary and Poland, reaching levels ranging from 23% in Italy to 41% in the United Kingdom in 2014. We can therefore state that none of the countries in our study differ significantly in terms of access to and use of ICT. What is also important is that the two CEE countries considered (Hungary and Poland) do not diverge from the more advanced European and Asian economies in this respect.

The results of panel regression estimations (see Table 1 in Appendix) suggest that the share of the population using the internet may well be explained by the share of the population with access to fixed broadband networks. All the coefficients reported are positive and statistically significant. This means that the proportion of the population using the internet can be considered a key indicator of access to ICT.

TABLE 2 ABOUT HERE

FIGURE 2 ABOUT HERE

6.2. Exchange traded fund market development. Preliminary evidence.

Our investigation of the development of the ETF markets starts with an analysis of summary statistics on the key changes in two measures: the turnover value and the percentage share of the total turnover of index financial instruments (see Table 3).

The first two countries which will be considered are the Asia-Pacific states, Japan and South Korea, which were chosen for comparison purposes. The lowest ETF turnover value in Japan was observed near the beginning of the time period analysed, in January 2005, when it amounted to ca. $1290 million; in South Korea the minimum turnover was ca. $111 million in February 2005. As in most of the other countries, the leading index financial instrument category over the whole time period considered was stock index futures, both in terms of turnover and of their total market share. The period of fast ETF market development began sooner in South Korea than in Japan (see Fig. 3): in South Korea in the second half of 2011 (in August 2011 ETF turnover in South Korea reached its highest value) and in Japan between the end of 2012 and the beginning of 2013. If the ETF shares in the total market for index financial instruments are considered (see Fig. 4), the ETF markets reached their highest levels of development in both countries near the end of the 2004-2015 time period (in Japan in October 2015 and in South Korea in July 2014), which indicates a growing popularity and diffusion. ETFs were the only category of instruments whose market shares grew over the 2004-2015 time period while the shares of both stock index futures and options declined. The mean ETF market shares in Japan and South Korea were 1.5% and 1.14% respectively.

In the time period analysed there were only two countries in the CEE region where ETFs were listed on the local stock exchanges: Poland and Hungary. In Poland, the highest values of ETF turnover were reached several months after their launch in September 2010, in August 2011 (see Table 3 and Fig. 3). However, in 2012 turnover severely declined and reached a minimum level of only $0.9 million USD in November 2012. From 2013 to 2015 trading in ETFs was still at a rather low level. However, in April 2015 ETFs reached their maximum share of the total market: 0.39%, which was mostly caused by a one-month spike in ETF trading (yet it was still one of the lowest shares among the countries considered). In Hungary, ETFs were launched much earlier than in Poland (in 2007) but their turnover was significantly lower (a mean monthly value of $0.6 million USD compared to $5.5 million USD in Poland). As in Poland, the highest turnover values were observed soon after their introduction. However, in terms of ETF market share, the highest value in Hungary was reached (as in the Polish market) near the end of the time period analysed, in May 2015 (see Fig. 4). In contrast to the Polish exchange, the turnover of other related financial instruments (stock index futures and options) on the Hungarian market was extremely low: in most months there were almost no transactions in options and the value of futures trading was steadily declining. As a result, the mean turnover values in Hungary were minimal in comparison to the other stock exchanges considered. The very low turnover of ETFs in both Poland and Hungary was mostly caused by the low number of such financial products. In Poland, the number of ETFs grew from 1 to 3 (yet only one of them was listed exclusively in Poland and it accounted for the majority of turnover; the other two were cross-listed). In Hungary, there was only one ETF listed between 2007 and 2015 and it had a minimal turnover. The lack of further development was caused by a number of factors, including a lack of awareness of ETF features among market participants and the relatively small size of the financial markets, which limited the possibility of gaining benefits from the larger scale of offerings by ETF managers.

In the five advanced EU countries selected, the only country with no ETFs listed at the beginning of the time period analysed was Spain (ETFs were launched in Spain in July 2006). The time span of the analysis for the United Kingdom starts in 2006 due to a lack of data. In terms of ETF turnover (see Table 3 and Fig. 3), in Italy and the United Kingdom growth of the ETF market was somewhat stable and the highest values were reached near the end of the time period (as in Japan and South Korea). In France and Germany, ETF turnover grew until 2011, when it sharply declined, which may be explained by the eurozone crisis and falling stock prices (in the other three advanced EU economies a decline in ETF turnover in 2011 was also observed but it was relatively weaker). After 2011, turnover in France began to grow, whereas in Germany it was stable. The Spanish ETF market developed in a different way. After much variability until 2011, it entered a stage of stability between 2012 and 2013, and from the end of 2013 it started growing. This shows that the development of the ETF markets in these countries was to some extent shaped by similar determinants (e.g. the euro-zone crisis), although there were also some country-specific factors despite the high level of financial market integration.

Regarding ETF market shares, some substantial differences between the four countries can be noticed (see Table 3 and Fig. 4; the United Kingdom is omitted for the reasons outlined in Section 5). In Spain and Germany, the market share of ETFs was very low over the whole period. The case of Germany is particularly interesting. The mean value of ETF turnover in this country was the highest among all the countries analysed (including Japan and South Korea) and one of the highest in the world. Nevertheless, their average market share was the second-lowest (it was only lower in Poland), which shows that the role of ETFs in Germany was negligible compared to that of other index financial instruments. This also indicates some potential problems in the measurement and evaluation of ETF market development – the conclusions reached may differ significantly depending on the chosen definition of this process (although in most cases they are rather similar). In both France and Italy, the market share of ETFs increased considerably: in France particularly from 2014 and in Italy from 2009. The mean market share value of ETFs in Italy was the highest of all the countries under study (5.6%) yet still much lower than the shares of the other index instruments. The rapid development of the Italian ETF market may to a large extent be explained by the acquisition of the Italian stock exchange by its British counterpart, which is one of the largest in Europe in terms of the number and turnover of ETFs. The two markets have been integrated in some areas, which considerably boosted the Italian stock exchange's growth opportunities.

Fig. 5 shows that the correlation between the ETF market share and the ETF turnover value was positive in all the countries selected apart from France and, to a lower extent, Spain. However, even for France and Spain in most cases a higher turnover was accompanied by a higher market share. This means that analyses of turnover values and market shares should yield similar results. In the remainder of this study we will use the market share as the indicator of ETF market development as changes occurring in ETF markets should not be viewed in isolation but instead put in a broader context, thus showing the position of these innovative financial products in the financial system. Our preliminary analysis of changes occurring in the ETF markets will be expanded in the next sections. First, we will attempt to analyse the main features of the ETF diffusion process and predict its trajectories. Second, we will assess the impact of ICT and financial-market determinants using both panel and country-specific approaches.

TABLE 3 ABOUT HERE

FIGURE 3 ABOUT HERE

FIGURE 4 ABOUT HERE

FIGURE 5 ABOUT HERE

6.3. Exchange traded funds: diffusion models.

As an aim of this study is to provide in-depth insight into the development process of ETFs across countries, we adopt a logistic growth model (for details, see Section 4) because use of this type of model allows the development trajectories of different variables in economic systems to be approximated and evaluated. Moreover, it allows the characteristic phases of the process of diffusion to be distinguished, such as the early diffusion phase, take-off, the exponential growth phase and saturation (maturity phase). During the early diffusion phase, the number of contacts between adopters and non-adopters of a given innovation is still small, which may hinder its dissemination and so in this stage of diffusion the process is still reversible. However, under favourable conditions easy contacts allow a *domino effect* to come into play and hence diffusion may speed up. Driven by various market forces, reductions in the cost of adopting innovations and multiple applications and uses of them, the number of new-users can rapidly increase and the curve takes off. It then enters a fast diffusion phase, when the diffusion process usually proceeds exponentially. Finally, a maturity (stabilization) phase is reached, during which the rate of diffusion again becomes slow and no significant growth in the number of new users of the innovation is reported. In addition to revealing these phases, a simple logistic growth model returns good forecasts of future development (Kucharavy and de Guio, 2011).

Following the above-mentioned approach and using monthly time series for the period 2004-2015, we develop logistic growth patterns and estimate parameters (see Section 4) representing the ETF share of total index financial instrument turnover for each country individually. The results of our analysis are presented in Fig. 2 in the Appendix, which shows the current and predicted ETF share diffusion paths, and in Tables 4 and 5, which summarize the country-wise logistic growth model estimates and the parameters for the predicted diffusion trajectories.

TABLE 4 ABOUT HERE

The graphical evidence presented in Fig. 4 suggests that ETF diffusion patterns in some countries (i.e. growing ETF shares) may be well described by the logistic (sigmoid) growth trajectory. In some cases, the characteristic phases of the S-shaped path can be distinguished (also see the analysis for other countries in Lechman and Marszk (2015)). Initially slow changes in the ETF share of total turnover of index financial instruments are followed by a sudden take-off and then the ETF share pattern enters the rapid growth phase. However, it is important to note that the shapes of the ETF share diffusion paths across the countries examined are different and so they need special attention.

Let us first take a closer look at the two Asian countries – Japan and South Korea. In Japan, ETFs reached their maximum share – 5% – in October 2015 and in South Korea the maximum was 4% in July 2014. Despite the slight differences in ETF financial market penetration in the timeframe examined, in the two countries the ETF share diffusion paths exhibit visible similarities. The early (initial) diffusion phase is easily distinguishable. ETF financial market penetration is low and growth in the share of total turnover is spasmodic. Therefore, to some point the ETF share during this period is reversible. In both countries, the share of total turnover alternately increases and falls between 2004 and 2011 and so no regular (systematic) growth is identifiable. However, in South Korea in 2011 a specific take-off can be observed and the share of total turnover starts to grow fast, doubling between

July and August 2011. From then onwards ETFs gradually gain popularity in South Korea and their market share steadily increases. By the second half of 2011 the diffusion trajectory has entered the exponential growth phase. The estimated parameters of the logistic growth model are statistically significant (see Table 4) and the model's R^2 is about .95, which suggests a very good fit between the empirical data and the theoretical model. The ceiling (upper asymptote) is estimated to be κ_i^{ETF}=3.52%. This parameter represents the potential (maximum) level of the ETF share of the total turnover of index financial instruments – under the rigid assumption that the ETF diffusion pattern follows the theoretical trajectory generated by the logistic growth model. The estimated midpoint – the exact time when the share reached 0.5κ – is Tm_i^{ETF}=101.3. The rate of diffusion is estimated at α_i^{ETF}=.09, but as this parameter yields no direct economic interpretation we use it to calculate the 'specific duration.' α_i^{ETF}=.09 means that Δt_i^{ETF}=47.3, which may be interpreted as the number of months needed to pass from 10% to 90% of κ_i^{ETF}.

Regarding Japan, a unique take-off when the path enters the exponential growth stage is identifiable. From 2004 until the second half of 2012, changes in the ETF share of total turnover are negligible and potentially reversible. However, between the middle of October and November 2012 the ETF share doubles and from then onward it grows, but with several temporal falls. The logistic growth estimates for Japan (see Table 4) reveal some obvious misspecifications (see, for example, the estimated value of the upper asymptote: κ_i^{ETF}=8,516,876), even though the R^2 of the model is quite high. The misspecification in the logistic model estimates for Japan is mainly due to the fact that after the take-off the ETF share grew abruptly but it was still located at the beginning of the exponential growth stage.

The picture which emerges from analysis of the ETF share in the two selected CEE countries – Poland and Hungary – differs radically from that for Japan and South Korea. As already mentioned in the previous section, in neither Poland nor Hungary did ETFs gain much popularity and their share of total turnover remained extremely low over the time period analysed. In Hungary, the growth of the ETF share of total turnover was minimal and its role in shaping the financial market was negligible. In Poland, a diffusion of ETFs across the domestic financial market was reported but still their role and share of the total turnover was marginal. It should be noted that between 2004 and 2015 the ETF share of the total turnover was close to zero. This leads to the conclusion that in both Hungary and Poland a diffusion of ETFs did not take place and so logistic growth models should not be applied. Table 4 presents the estimates of logistic growth models for Poland and Hungary, but as in both cases the R^2 of the models is zero the parameters returned are misleading and inconclusive.

Finally, we discuss the results of the analysis of ETF diffusion for the four developed financial markets selected: Italy, Germany, France and Spain.[3] In Germany, a diffusion of ETFs on the domestic financial market was not observed and ETF market penetration remained below 1%. As in the cases of Hungary and Poland, the logistic growth model estimates are not reliable. Despite the fact that the R^2 of the model is 0.27 (see Table 4), the value returned for the midpoint (T_m) is negative and so cannot be treated as valid. The situation in Spain is analogous, with a very low ETF share of total turnover during the time period examined. At the end of 2015, Spain was still located in the early diffusion stage, and as a result reliable estimates of a logistic growth model are not possible (the logistic growth parameters returned cannot be treated as valid).

In the other two advanced European economies – France and Italy – the ETF share was relatively high between 2004 and 2015. In both cases, the ETF diffusion patterns take off into self-sustaining growth after the early diffusion stage, during which increases in the ETF share were slow. In the case of Italy, the specific take-off occurred relatively early compared to the other economies examined. It should be noted that between June and July 2008 the ETF share almost doubled (from 1.8% to 3.4%) and the take-off took place shortly afterwards – between the middle of December 2008 and January 2009, when the ETF share increased from 3.7% to 8.0%. All the parameters returned from the logistic growth model estimates for Italy are statistically significant. The R^2 of the model is about 0.76, which suggests a good fit between the empirical data and the theoretical model. Even though the R^2 of the model is lower than that for Japan, there are no obvious misspecifications as the diffusion of ETFs is relatively well described by the logistic growth trajectory. The upper asymptote is estimated as κ_i^{ETF}=8.56%, i.e. higher than for South Korea. The estimated midpoint is Tm_i^{ETF}=52.9. The rate of

[3] The case of the United Kingdom is not discussed in this section for the reasons given in the previous section.

diffusion is α_i^{ETF}=.113, i.e. slightly higher than in South Korea. Δt_i^{ETF}=38.7, which can be interpreted as the number of months needed to pass from 10% to 90% of κ_i^{ETF}.

For France too, the diffusion of ETFs is well described by the logistic growth trajectory, despite the fact that in this case the early diffusion stage was relatively long. The take-off into the exponential growth phase did not happen until between the middle of December 2013 and January 2014, when the ETF share of total turnover grew abruptly. Even though the diffusion of ETFs (in terms of market share) on the French financial market is well approximated by the logistic growth pattern, the parameters estimated for the logistic growth model are not valid. The upper asymptote (ceiling) is reported as κ_i^{ETF}=7,755,333, which is a definite overestimation.

Regarding the process of ETF diffusion in our country sample, the eight economies can be divided into two groups. The first group encompasses four countries – Japan, South Korea, France and Italy – where an early diffusion stage was followed by a take-off into an exponential growth phase along a sigmoid trajectory. These four countries managed to leave the early diffusion stage, during which ETF share growth was slow and spasmodic, and take off into rapid growth. In the other four countries, the ETF share did not leave the early diffusion stage and remained virtually locked at a low level.

TABLE 5 ABOUT HERE

This empirical analysis of ETF diffusion trajectories can be enriched by providing additional specifications of the predicted development of ETFs across the economies selected. Table 5 summarizes the predicted country-specific ETFs diffusion paths and Fig. 2 in the Appendix portrays them graphically. Fixing the critical level of the upper asymptote (κ_i^{ETF}) at 5%, 7.5%, 10%, 15%, 20%, 25% and 30%, we forecast logistic growth model parameters under the rigid assumption that ETF market development will follow an S-shaped trajectory. The results for Japan and South Korea are similar. For κ_i^{ETF} fixed at 5%, the predicted Tm_i^{ETF} for Japan and South Korea are June 2013 and August 2013 respectively. However, significant differences are forecast for the 'specific duration' – Δt_i^{ETF}. For Japan this is about 111 months and for South Korea 89 months. These differences are a direct consequence of different predicted rates of diffusion – .04 and .049 respectively. This implies that the predicted speed of ETF diffusion is relatively higher for South Korea than for Japan. The forecast midpoints for κ_i^{ETF}=7.5% are very similar in both cases. It is important to note that these forecasts should not be treated as reliable as the predicted midpoints refer to past dates. Similar doubts should be raised regarding the forecasts for an upper asymptote of 10%. For Japan, the predictions for higher levels of κ_i^{ETF} show that in the coming years the ETF market should grow rapidly and κ_{Jap}^{ETF}=30% could potentially be reached by October 2021. For South Korea, the analogous predictions are even more optimistic, as κ_{Kor}^{ETF}=30% may be reached by June 2021, a few months earlier than in Japan. The predicted 'specific durations' with κ_i^{ETF}=30% for these two countries are about 15 years for Japan and about 13.5 years for South Korea.

For Hungary, with κ_i^{ETF}fixed at 5% the predicted Tm_i^{ETF} is June 2027 and the 'specific duration' forecast is about 320 months, i.e. more than 26 years. The predicted rate of diffusion is 0.014, which implies that the speed of ETF diffusion will be much lower in Hungary than in South Korea and Japan. The forecasts for higher κ_i^{ETF} show even more distant midpoints and so they cannot be treated as being very reliable (and also because of the low R^2 of the models).

Italy has already reached the levels of κ_i^{ETF}=5%, 7.5% and 10%. With κ_i^{ETF}fixed at 15%, the predicted Tm_i^{ETF} is April 2012 if the Italian ETF market follows an S-shaped trajectory. The predicted rate of diffusion is similar to that in Hungary, i.e. much lower than in South Korea and Japan.

Regarding Spain, with κ_i^{ETF}fixed at 5% the predicted Tm_i^{ETF} is July 2021 (considerably sooner than in the case of Hungary) and the 'specific duration' forecast is about 300 months. The rate of diffusion predicted is 0.015, which is consistent with the results obtained for Hungary and Italy. Finally, for France with κ_i^{ETF}fixed at 7.5%, the predicted Tm_i^{ETF} is July 2015 if the French ETF market follows the S-shaped trajectory. The rate of diffusion predicted for this level of κ_i^{ETF} is 0.028, but for higher levels it is slightly lower, which suggests that the diffusion of ETFs on the French market will be much faster than in other European countries, and that it will occur at a rate comparable to those of Japan and South Korea.

The ETF diffusion paths predicted for Germany and Poland are not valid and so they will not be discussed. It should be underlined that all these forecasts are uncertain and should be treated with caution. The predicted future diffusion paths are not purely random but rather assume an S-shaped trajectory and all the predictions show a high level of sensitivity to historical data. Special caution is urged regarding the predictions referring to relatively high fixed ceilings like 20%, 25% and 30%, where the accuracy of the forecasts is questionable and they are to some extent misleading and inconclusive.

6.4. RELATIONSHIPS BETWEEN THE DIFFUSION OF ETFS AND ICT: EMPIRICAL VERIFICATION.

The main aim of this section is to empirically verify a potential association between changing ICT penetration and ETF market development across the countries analysed between 2004 and 2015. To provide comprehensive in-depth insight into the issue and identify relationships (or a lack of them) between the variables examined we use both graphic visualization and panel analysis. First, we graphically analyse two types of relationship: that between the value of ETF turnover and the ICT penetration rate approximated by the fixed broadband penetration rate (FBS) and internet users (IU); and that between the ETF share of total turnover of index financial instruments and ICT penetration. To do this, we use locally weighted scatter plot smoothing (lowess).

FIGURE 6 ABOUT HERE

Fig. 6. portrays the relationships between ETF diffusion and ICT penetration across all the economies examined between 2004 and 2015, and Fig. 7 visualizes the analogous relationships for each individual country. The existence of a positive association between ETF market development and increasing ICT penetration can easily be seen in Fig. 6 (for panel data), but these statistical links are even more visible for individual countries (see Fig. 7). Across the economies analysed, in the period

2004-2015 increasing ICT penetration rates were accompanied by growth in both the value of ETF turnover and increasing ETF shares of the total turnover of index financial instruments. These regularities can be seen for both the ICT indicators (FBS and IU) – see the plots in Fig. 6. The correlation coefficients calculated for the pairs of variables indicate that the strongest relationship can be found between IU and the value of the ETFs traded on the stock exchanges; in this case the value of the correlation coefficient is estimated at 0.51. It can be seen that when IU penetration rates remained below 40% the value of ETFs was relatively low but when access to and use of the internet became more common and IU penetration rates were between 60% and 80% there was an abrupt growth in ETF turnover. This allows the conclusion that widespread internet use is one of the most important prerequisites for ETF expansion on stock exchanges. These observations are consistent with the results displayed by the plot presenting the statistical relationship between FBS penetration rates and ETF turnover value. In this case the correlation coefficient is 0.48. A seemingly slightly different picture emerges when we look at the plots using ETF shares in Fig. 6. The coefficients for the correlations between ETF shares and FBS and IU are 0.35 and 0.16 respectively (excluding outliers), which suggests relatively weak associations between growth in ICT penetration and the ETF share of turnover of index financial instruments. It is important to note that the correlation coefficient between the value of ETF turnover and the ETF share of total turnover of index financial instruments is only 0.45 (for graphical evidence, see Fig. 3 in the Appendix), which proves that an increasing value of traded ETFs does not directly affect their market share. This is obviously also determined by changes in the turnover of other financial instruments which are (or might be) competitors of ETFs. It is therefore sometimes possible that even a rapid growth in the value of ETF turnover will have a negligible effect on changes in their total market share.

FIGURE 7 ABOUT HERE

Fig. 7 provides country-specific evidence of the statistical association between ICT penetration (approximated by the IU indicator) and the ETF share. In three countries – France, Japan and South Korea – the path approximating the relationship between the ETF share and IU shows that below a certain level of IU penetration the ETF share remains at a relatively low level. However, once the IU penetration rate reaches about 80% the ETF share starts to increase rapidly. This might suggest that a level of IU≅80% is necessary to reach an ICT penetration threshold that enables an expansion of financial innovations and that diffusion of them depends on new sophisticated technologies. In France, Japan and South Korea, with respective correlation coefficients of 0.70, 0.65 and 0.67, there is a strong correlation between IU and the ETF share. In Italy, the ETF share started to grow at a lower (compared to France, Japan and South Korea) IU penetration rate, between 30% and 40%. However, the correlation coefficient between these variables is still 0.81, which demonstrates a strong statistical relationship between them. The correlation coefficient for Spain turns out to be the highest among the countries studied – 0.85. In this case too, growth in the ETF share took place once the IU penetration rate reached a level of about 70%. Similar results are found for Germany and Hungary: once IU passed 70% and 60% respectively, the growth in the ETF share increased rapidly. It is important to note that in the cases of Germany, Spain and Hungary, this 'boost' in the ETF share is *only* relative, because in absolute terms the ETF shares remained low during the period examined. For instance, in Germany between 2008 and 2009 the ETF share increased from 0.18% to just 0.61%, which despite representing a growth of 238% is still less than 1% in terms of total turnover. The cases of Spain and Hungary are similar. As for Poland, ETFs were only listed from 2010, which gives only six annual observations, a number too limited for conclusions to be drawn.

To explore the quantitative relationship between ICT penetration and ETF market development more comprehensively, we apply panel analysis. The response variable is defined as the ETF share (of the total turnover of index financial instruments): $ETFshare_{(i,y)}$, where i indicates the country and y the year. The explanatory variables are $IU_{(i,y-1)}$, $FBS_{(i,y-1)}$ and $ETF_{(i,y)}$ – the value of ETFs, with analogous notations. We hypothesize that increasing ICT penetration may potentially positively impact ETF market development. Additionally, we assume a 1-year lag for ICT deployment to impact on ETF market growth. As in the previous analyses, we use annual data for ETFs and ICT between 2004 and 2015. Bearing in mind that $IU_{(i,y-1)}$ and $FBS_{(i,y-1)}$ are highly correlated (r^2=0.97), to avoid collinearity issues we restrict the analysis to just one ICT explanatory variable – $IU_{(i,y-1)}$, and use $FBS_{(i,y-1)}$ as an instrument in an instrumental variables regression, assuming that there exists direct causality between access to a fixed broadband network (FBS) and the share of the population using the internet (IU)

TABLE 6 ABOUT HERE

Table 6 summarizes the panel regression results regarding the quantitative relationship between ICT penetration and ETF market development across the eight countries examined between 2004 and 2015. In a first step, we ignore how the observations might be grouped among the economies and we rely on pooled OLS estimations. First, we estimate a pooled OLS model – OLS(1) – including just one explanatory variable: $LnIU_{i,y-1}$. In this case, the results are not satisfactory as the R^2 of the model is zero and the returned coefficient has a negative sign and is statistically non-significant. This would indicate that there is no statistical association between the changing ETF share of the total turnover and the diffusion of new technologies. However, relying on the graphical evidence and the results of the Wald test (F(3,81), prob>F=0.00) we argue that at least one polynomial should be included in the regression. Moreover, we hold that the changing share of ETFs is – at least to some extent – preconditioned by changes in the total value of the ETFs traded on stock exchanges. Hence, we decide to include another explanatory variable in our regression: $LnETF_{i,y}$. This indicates the absolute value of the turnover of ETFs in country i in year y. Finally, relying on the graphical evidence we estimate the following random effects regression:

$$ETFshare_{iy} = \gamma_0 + \gamma_1 LnIU_{i,y-1} + \gamma_2 (LnIU_{i,y-1})^2 + \gamma_3 (LnIU_{i,y-1})^3 + \gamma_4 LnETF_{i,y} + \alpha_i + \varepsilon_{iy} .$$

In the next step, we use pooled OLS specifications : OLS(2) and OLS(3). The estimations obtained seem superior to the first one. In OLS(2) the IU variable is still statistically non-significant but $LnETF_{i,y}$ has the expected positive sign and is statistically significant, which indicates that increases in the total value of ETF turnover are accompanied by growth in their market share. The next regression, OLS(3), where second and third order polynomials are included – $(LnIU_{i,y-1})^2$ and $(LnIU_{i,y-1})^3$ – has the best fit with the empirical data as the R^2 is 0.37. Moreover, in this case all the regression coefficients have the expected signs and are statistically significant. Next, to re-estimate our model we use a random effects specification. Finally, to test the stability of our results and to control for possible endogeneity issues emerging, we perform two random effects instrumental variable regressions using two types of instruments, namely a lagged explanatory variable and, alternatively, the Fixed Broadband Subscriptions variable[4]. Additionally, we employ the Breusch-Pagan test to verify whether any panel effects are identifiable across the countries included in the sample, and, alternatively, if the use of simple OLS would generate more consistent results. For all the random effects specifications the results of the Breusch-Pagan test suggest that pooled OLS would give inconsistent results and so a panel effect can be traced. The results obtained from random effects models are similar to those generated by pooled OLS specifications. RE(3) is the best fitted model and indicates the existence of a third-order polynomial relationship between the ETF share and the IU variable, and it also shows that changes in the ETF share and the value of ETF turnover are positively associated. These results are consistent with those obtained from G2SLS IV RE specifications (1) to (4), in each case suggesting a relatively strong positive relationship between the changing ETF share, the diffusion of new technologies and the increasing value of ETF turnover on domestic stock exchanges. Estimations of country-specific models (see Table 2 in the Appendix) confirm these results in most cases. However, because of the very limited number of annual observations they may not be highly reliable and so we focus on the panel regression models.

7. CONCLUSIONS.

This extensive research was designed to analyse the emerging potential impact of new information and communication technologies on the development paths and dynamics of financial innovations recently introduced on stock exchanges in the United Kingdom, France, Germany, Spain, Italy – which have been treated as benchmark economies with relatively well developed stock exchanges – Japan, South Korea – two Asian economies where the dynamic of ETF development has been high in recent years – Hungary and Poland – two CEE economies where financial innovations have relatively short histories.

We first broadly examined the diffusion paths of ICT (approximated by fixed-broadband networks and internet user penetration rates) in each country individually between 1990 and 2014. We extensively explored how ICT expanded across the countries. Undoubtedly, regardless of cross-country

[4] We assume that the share of the population using internet is directly dependent on access to, *inter alia*, fixed broadband networks.

differences in terms of speed of ICT diffusion or the diffusion time-path shape, new technologies have quickly spread in all the economies regardless of their economic performance or institutional framework. Nonetheless, ICT has been gaining in popularity in all the countries and so it can be recognized as extremely successful technology that has profoundly affected not only telecommunication markets but has also given rise to enormous structural shifts in financial markets, enabling, for instance, the introduction of financial innovations whose development is highly subjected to sophisticated technological solutions.

Next, we analysed the development of ETF markets using descriptive statistics and diffusion models. In the two Asia-Pacific economies the development of ETF markets occurred in the time period considered and predictions using diffusion models indicate that this trend can be expected to continue, especially in South Korea. In the two CEE countries the level of ETF market development was very low and no significant changes are expected in the future unless the market environment is deeply transformed (which cannot be predicted). The trajectory of ETF market development in the more advanced European economies differed considerably. In Spain and Germany the ETF market share remained very low and no meaningful predictions could be reached using diffusion models. In France and Italy significant development of ETF markets was identified and the predictions indicate a potential for further growth – in France at a rate comparable to the Asia-Pacific economies. The analysis of the UK market for ETFs was limited due to a lack of data on competing products but a stable growth of the ETF market in this country is indicated. Graphical evidence on the ETF markets shows that ETF diffusion patterns in some countries may be described as a logistic growth trajectory – characteristic phases of the S-shaped path can be distinguished, which justifies the application of diffusion models.

The final step in our research was an identification and examination of the role of ICT in the development of ETF markets (as discussed in the theoretical section). We used both panel and country-specific regressions. Estimates of panel models indicated that random effects models were to be preferred. In the case of the best fitted models the regression coefficients (showing the impact of ICT on ETF markets) are positive and statistically significant. However, apart from the pooled OLS model, the R^2 of the remaining models is between 0.20 and 0.27, which suggests that only 20-27% of the change in the value of ETFs can be explained by changes in ICT (measured in terms of Internet Users). In most cases country-specific estimates confirm a positive relationship between ETFs and ICT. The results of our analysis prove that the development of ETF markets was influenced to some extent by adoption of ICT.

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Appendix

TABLE A-1 ABOUT HERE

FIGURE A-1 ABOUT HERE

FIGURE A-2 ABOUT HERE

FIGURE A-3 ABOUT HERE

TABLE A-2 ABOUT HERE

Figure and Table Legends

Fig. 1. S-shaped diffusion trajectory. Theoretical specification. Source: Lechman (2015).

Fig. 2. ICT diffusion trajectories in the countries selected. 1998-2014. Source: Authors` elaboration. Y-axis: the share of the country`s population with access to ICT.

Fig. 3. ETFs, stock index options, stock index futures and total index financial instruments – diffusion trajectories. 2004-2015 (monthly time series). Values in USD millions. Source: Authors` elaboration.

Fig. 4. ETFs, stock index options and stock index futures – share of total turnover of index financial instruments. 2004-2015 (monthly time series). Source: Authors` elaboration. Note: left-hand Y axis – ETF share of total index financial instruments; right-hand Y axis – stock index options and stock index futures share of total index financial instruments.

Fig. 5. Share of ETFs of total turnover of index financial instruments versus turnover value in USD millions. 2004-2015 (monthly time series). Source: Authors` elaboration. Note: nonparametric graphical approximation applied (lowess).

Fig. 6. Exchange traded funds versus ICT penetration rates. 2004-2015 (annual time series). Source: Authors` elaboration. Note: nonparametric graphical approximation is applied. The United Kingdom is excluded from the ETF share.

Fig. 7. Shares of exchange traded funds versus Internet Users. 2004-2015 (annual time series). Source: Authors` elaboration. Note: nonparametric graphical approximation; default bandwidth. X axis: Internet user penetration rate (raw data). Y axis: ETF share (raw data).

Fig.A-1. Number of ETFs in the countries selected (2004-2015). Source: Authors` calculations.

Fig.A-2. Current and predicted ETF diffusion patterns. Source: Authors` elaboration. Note: graphs and forecasts prepared using IIASA software.

Fig.A-3. Value of ETF turnover versus ETF market shares in the countries examined. 2004-2015. Source: Authors` elaboration.

Table 1. Main differences between ETFs and stock index futures. Source: own compilation based on Madhavan, et al. (2014), Arnold and Lesné (2015), BlackRock (2015) and CME Group (2016).

Table 2. ICT summary statistics for the countries selected. 1990-2014. Annual data. Source: Authors` calculations. For Fixed Broadband Subscriptions, time series are available from 1998 onwards.

Table 3. Summary statistics for exchange traded funds, stock index options, stock index futures and total index financial instruments. Monthly data for 2004-2015. Source: Authors` calculations. Note: the United Kingdom is excluded from the calculations. For ETFs, the periods of analysis are: Japan, 2004m1-2015m12; South Korea, 2004m1-2015m12; Poland, 2010m9-2015m12; Hungary, 2007m1-2015m12; Italy, 2004m1-2015m12; Spain, 2006m7-2015m12; Germany, 2004m1-2015m12; and France, 2004m1-2015m12. The number of ETFs varies across time periods and countries – see Fig. 1 in the Appendix.

Table 4. Diffusion of exchange traded funds (as share of total turnover of index financial instruments). Logistic growth model estimates. 2004-2015 (monthly time series). Source: Authors` estimations. Note: Poland – data from 2010m9; Hungary – data from 2005m1; Spain – data from 2006m7.

Table 5. Predicted ETFs diffusion patterns (as share of total turnover of index financial instruments). Source: Authors` estimations. Note: Hungary – outliers excluded. Italics = misspecifications.

Table 6. Panel regression estimates. ETF shares versus Internet Users. 2004-2015 (annual time series). Source: Authors` estimations. Note: for pooled OLS regression, constant included but not reported; for random effects regressions, constant term suppressed. Robust standard errors in square brackets below coefficients; the panel is balanced. Statistically significant results at the 5% level of significance in bold. United Kingdom is excluded.

Table A-1. Panel regression results. Internet Users (IU) and Fixed Broadband Subscriptions (FBS). Period 1998-2014. Source: Authors` estimations. Note: Constant included but not reported. [a] standard errors at 5% level of significance; [b] conventional SE; [c] Bootstrap SE (1000 replications).

Table A-2. ETF shares versus Internet Users. Country-specific models. 2004-2015 (annual time series). Source: Authors` estimations. Note: robust SE in square brackets below coefficients. Constants included but not reported. Statistically significant results in bold. The United Kingdom is excluded.

Figures and Tables

Fig. 1.

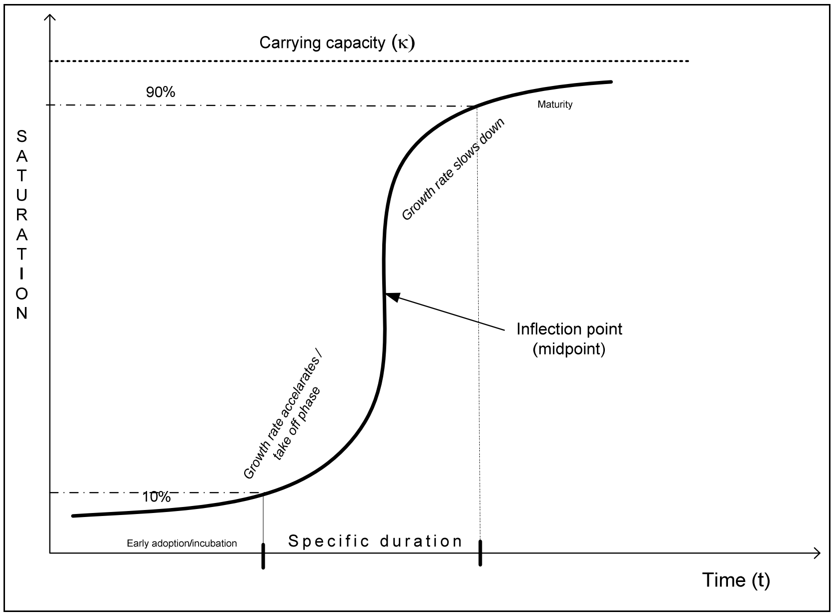


Fig.2.

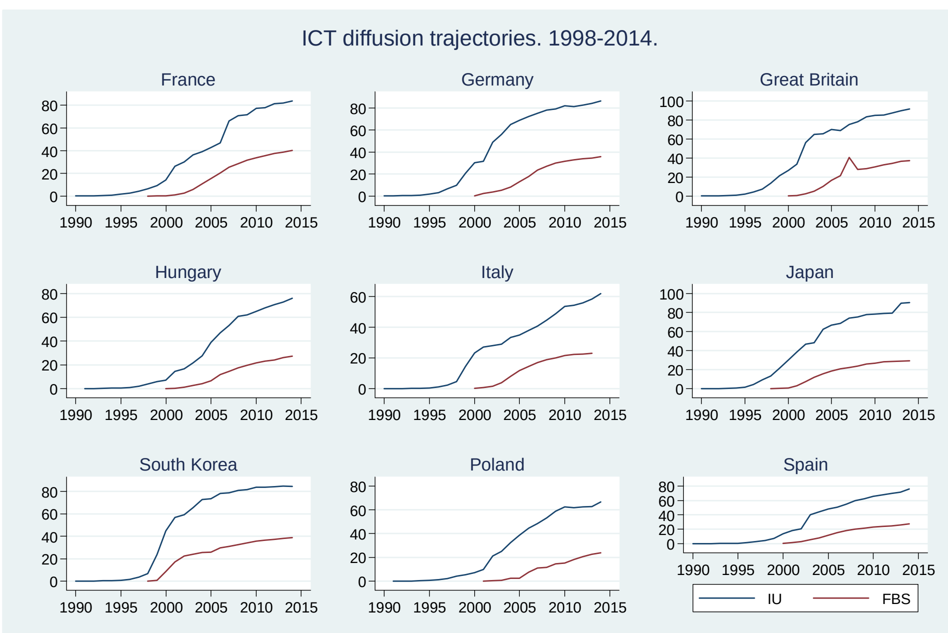
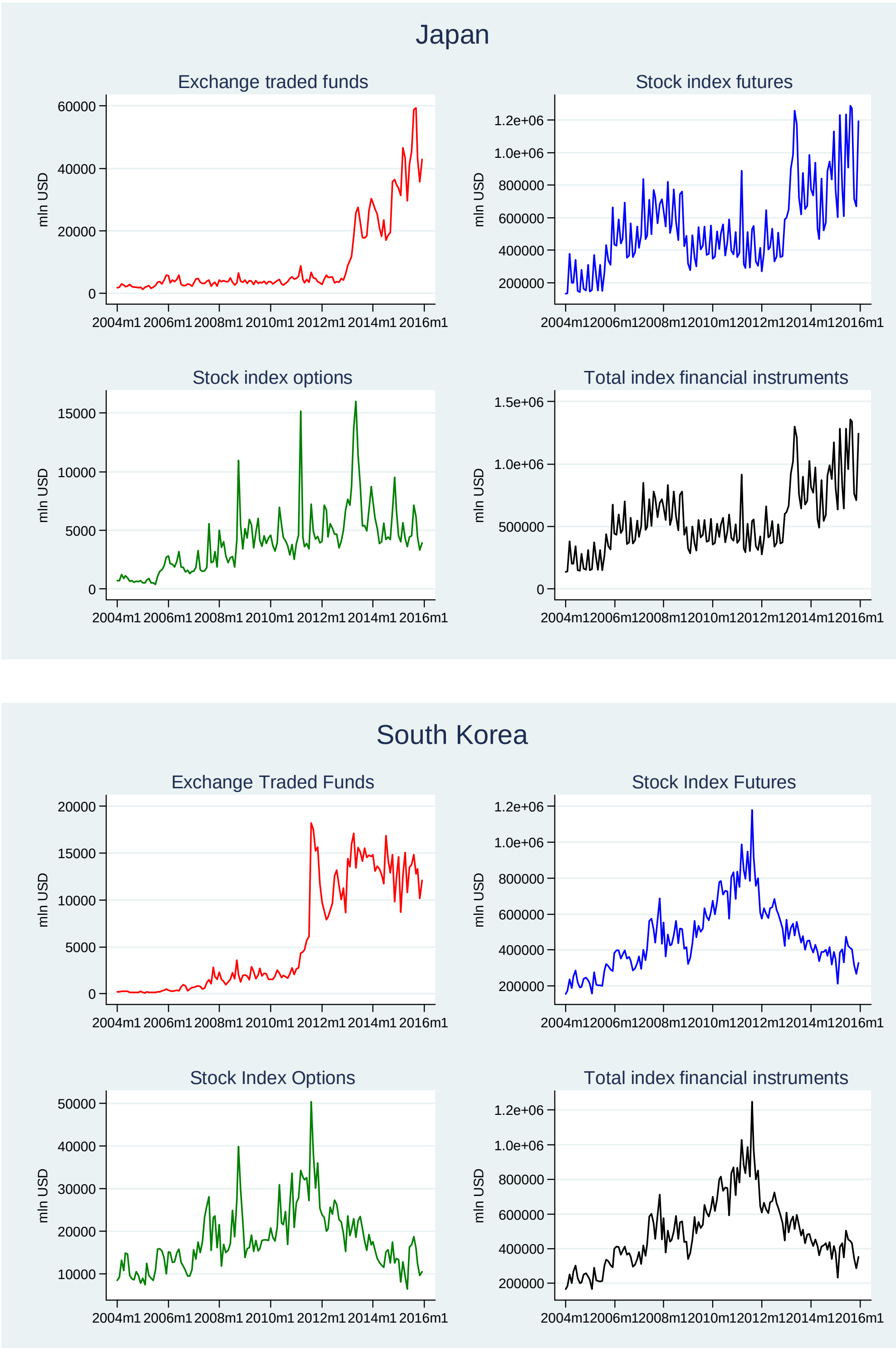
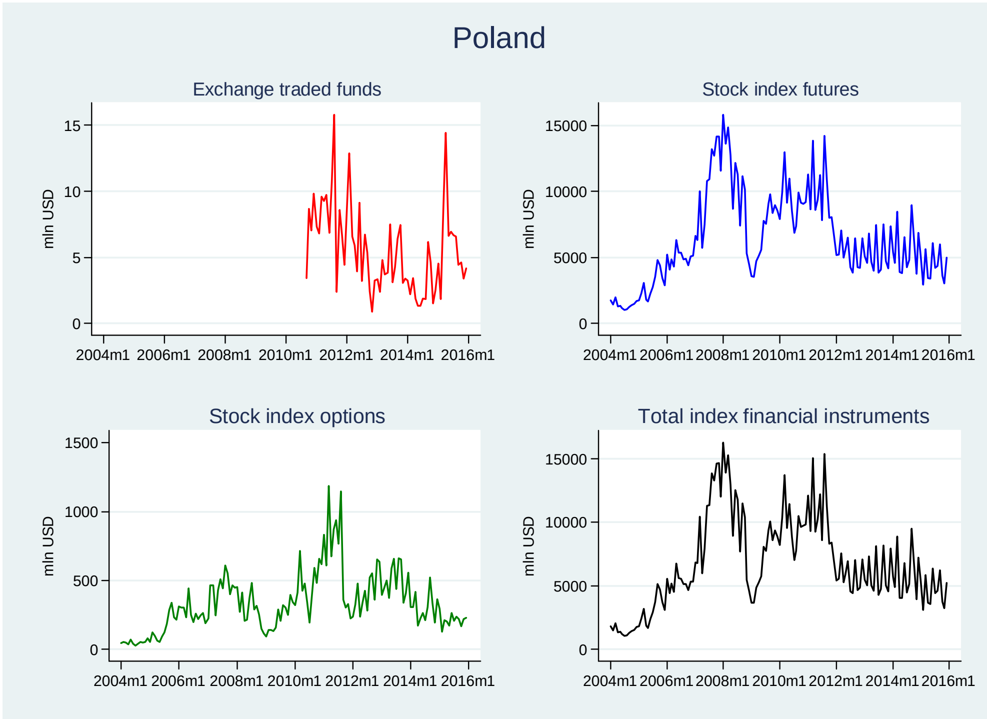


Fig. 3.


Japan
Exchange traded funds
Stock index futures
Stock index options
Total index financial instruments
mln USD
2004m1 2006m1 2008m1 2010m1 2012m1 2014m1 2016m1
South Korea
Exchange Traded Funds
Stock Index Futures
Stock Index Options
Total index financial instruments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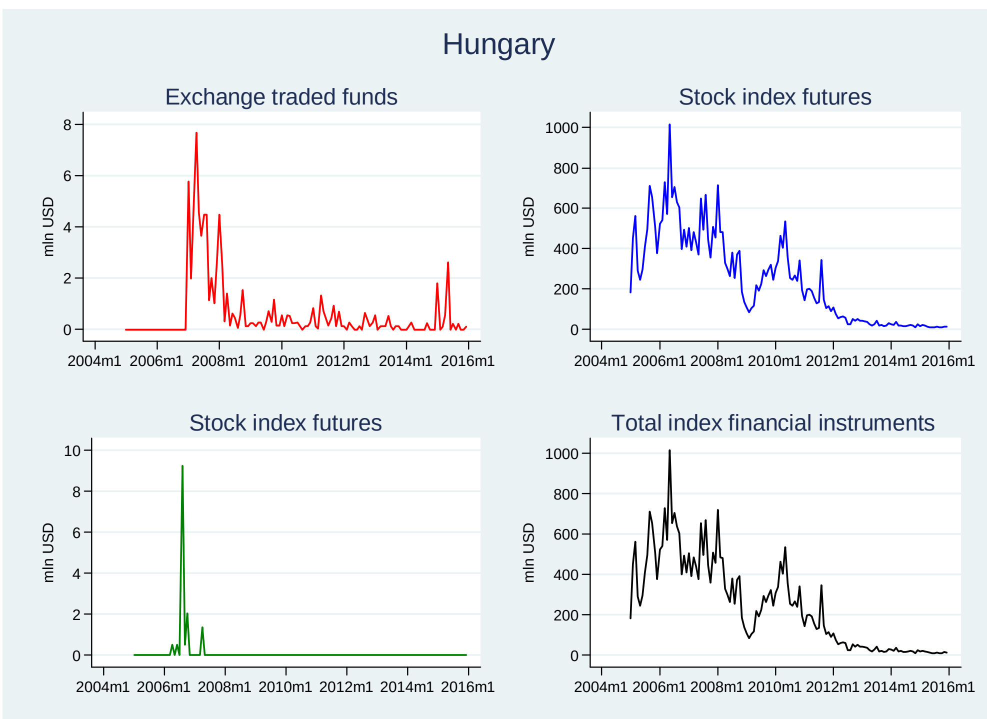
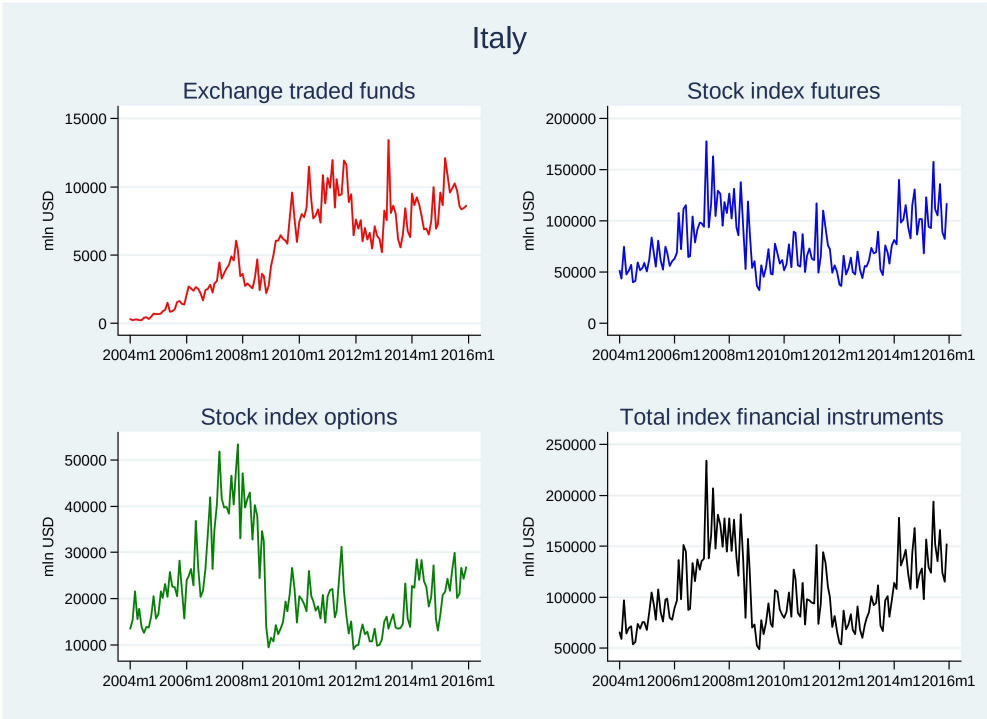
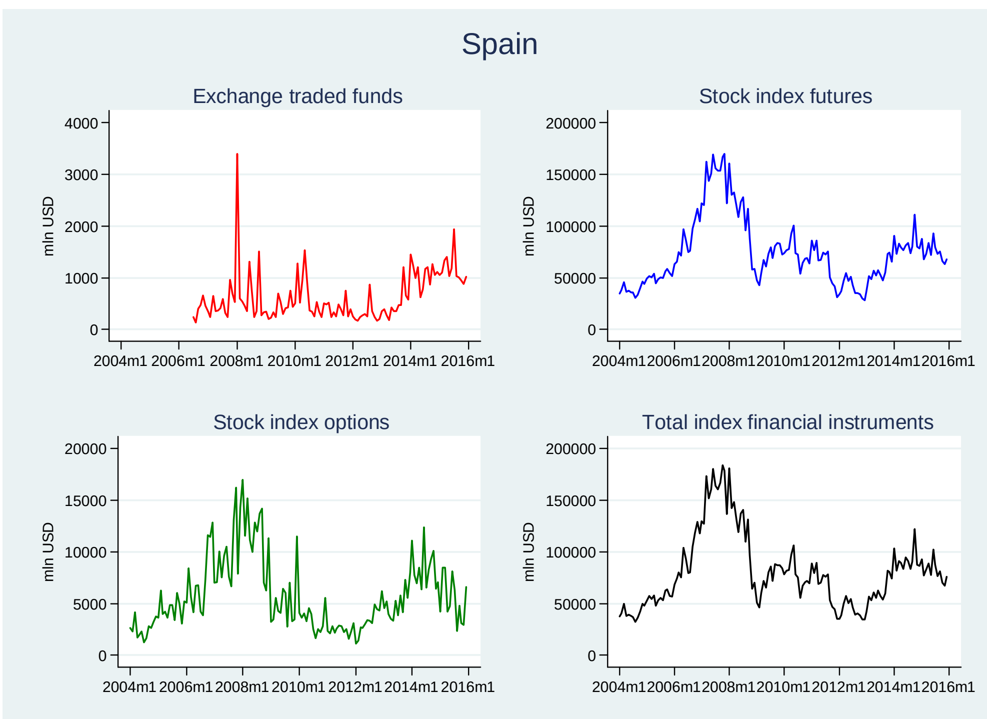
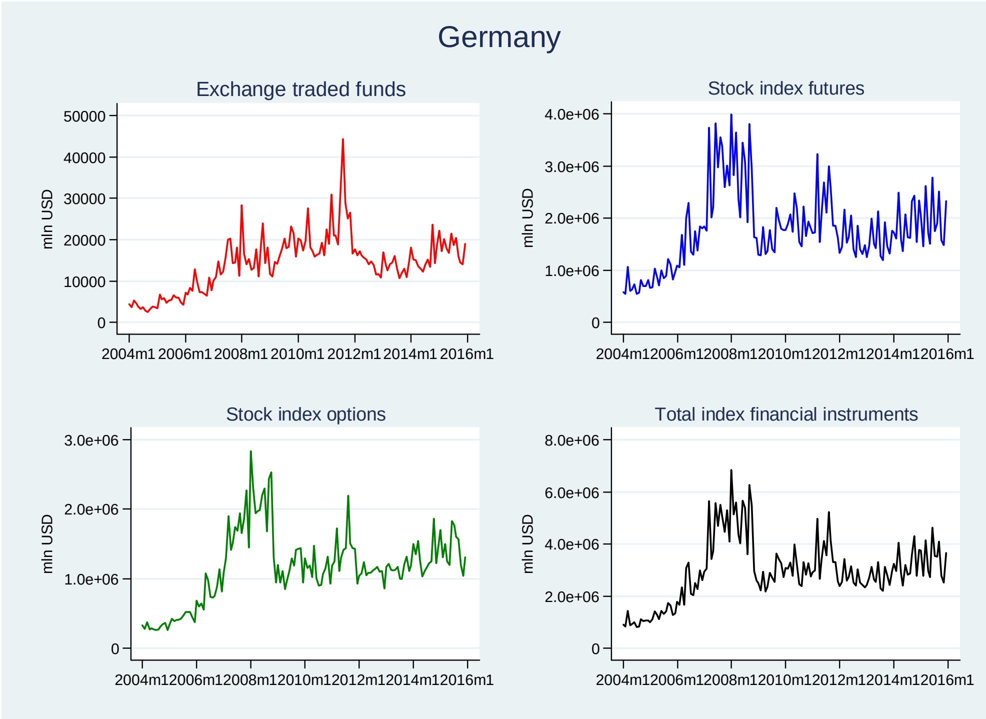
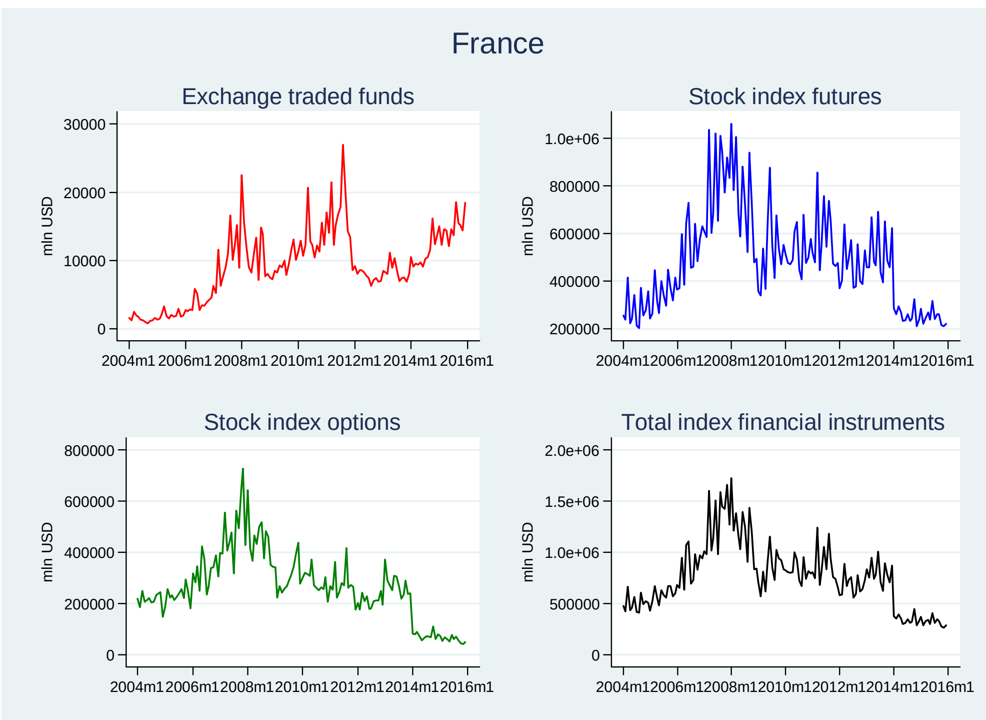
Exchange traded funds
Stock index futures
Stock index options
Total index financial instruments
mln USD
2004m1 2006m1 2008m1 2010m1 2012m1 2014m1 2016m1


Hungary
Exchange traded funds
Stock index futures
Stock index futures
Total index financial instruments
mln USD
2004m1 2006m1 2008m1 2010m1 2012m1 2014m1 2016m1


Italy
Exchange traded funds
Stock index futures
Stock index options
Total index financial instruments
mln USD
2004m1 2006m1 2008m1 2010m1 2012m1 2014m1 2016m1


Spain
Exchange traded funds
Stock index futures
Stock index options
Total index financial instruments
mln USD
2004m1 2006m1 2008m1 2010m1 2012m1 2014m1 2016m1


Germany
Exchange traded funds
Stock index futures
Stock index options
Total index financial instruments
mln USD
50000
40000
30000
20000
10000
0
4.0e+06
3.0e+06
2.0e+06
1.0e+06
8.0e+06
6.0e+06
4.0e+06
2.0e+06
2004m1 2006m1 2008m1 2010m1 2012m1 2014m1 2016m1


France
Exchange traded funds
Stock index futures
Stock index options
Total index financial instruments
mln USD
30000
20000
10000
0
1.0e+06
800000
600000
400000
200000
2.0e+06
1.5e+06
1.0e+06
500000
2004m1 2006m1 2008m1 2010m1 2012m1 2014m1 2016m1

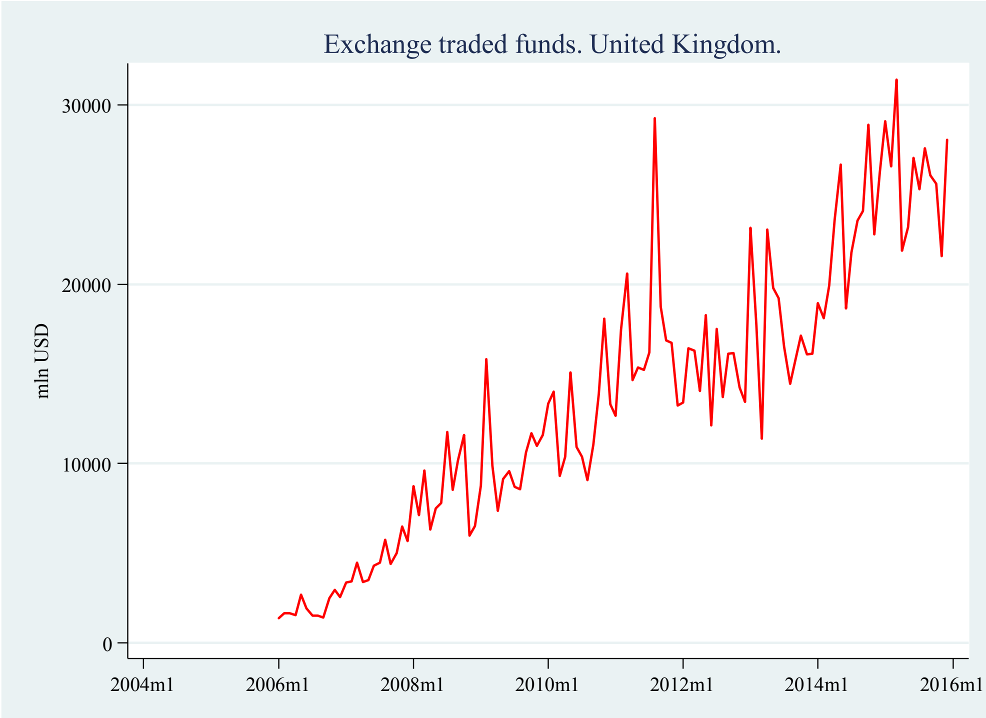

Exchange traded funds. United Kingdom.
mln USD
30000
20000
10000
0
2004m1
2006m1
2008m1
2010m1
2012m1
2014m1
2016m1

Fig. 4.

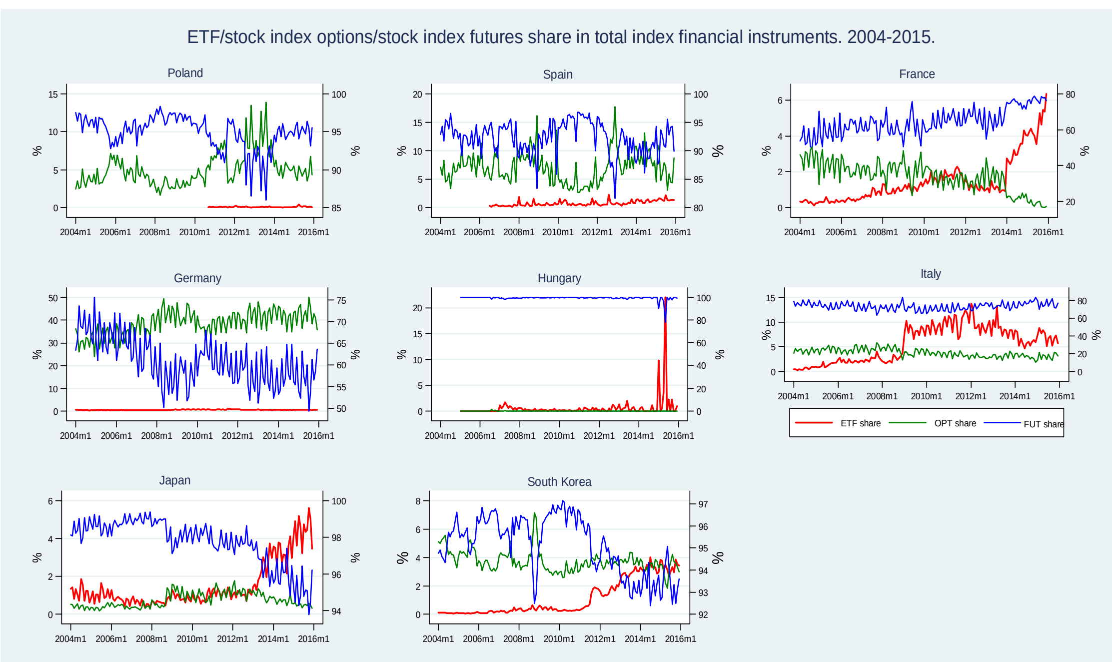

ETF/stock index options/stock index futures share in total index financial instruments. 2004-2015.
Poland
Spain
France
Germany
Hungary
Italy
Japan
South Korea
ETF share
OPT share
FUT share

Fig.5.

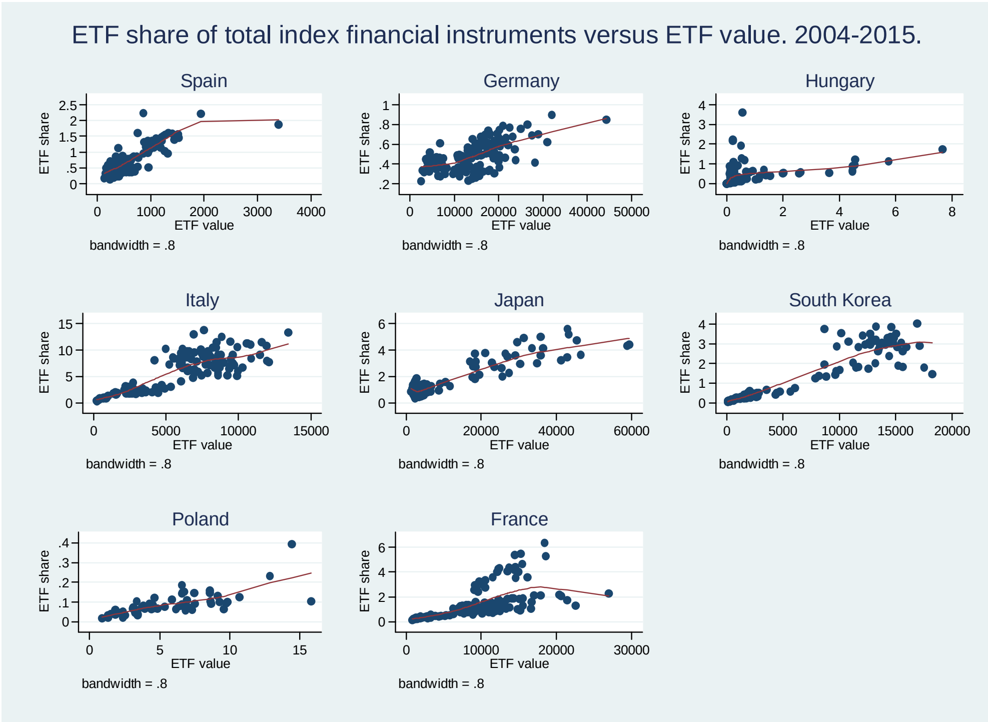

ETF share of total index financial instruments versus ETF value. 2004-2015.
Spain
Germany
Hungary
Italy
Japan
South Korea
Poland
France
ETF share
ETF value
bandwidth = .8

Fig.6.

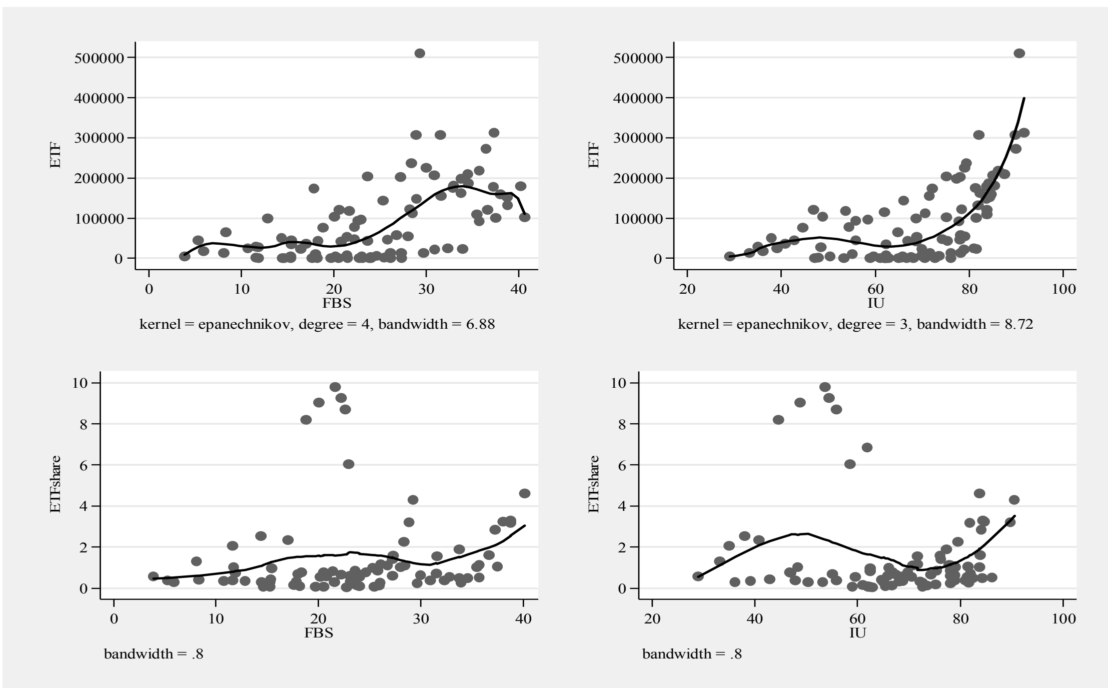

ETF
FBS
IU
kernel = epanechnikov, degree = 4, bandwidth = 6.88
kernel = epanechnikov, degree = 3, bandwidth = 8.72
ETFshare
bandwidth = .8

Fig.7.

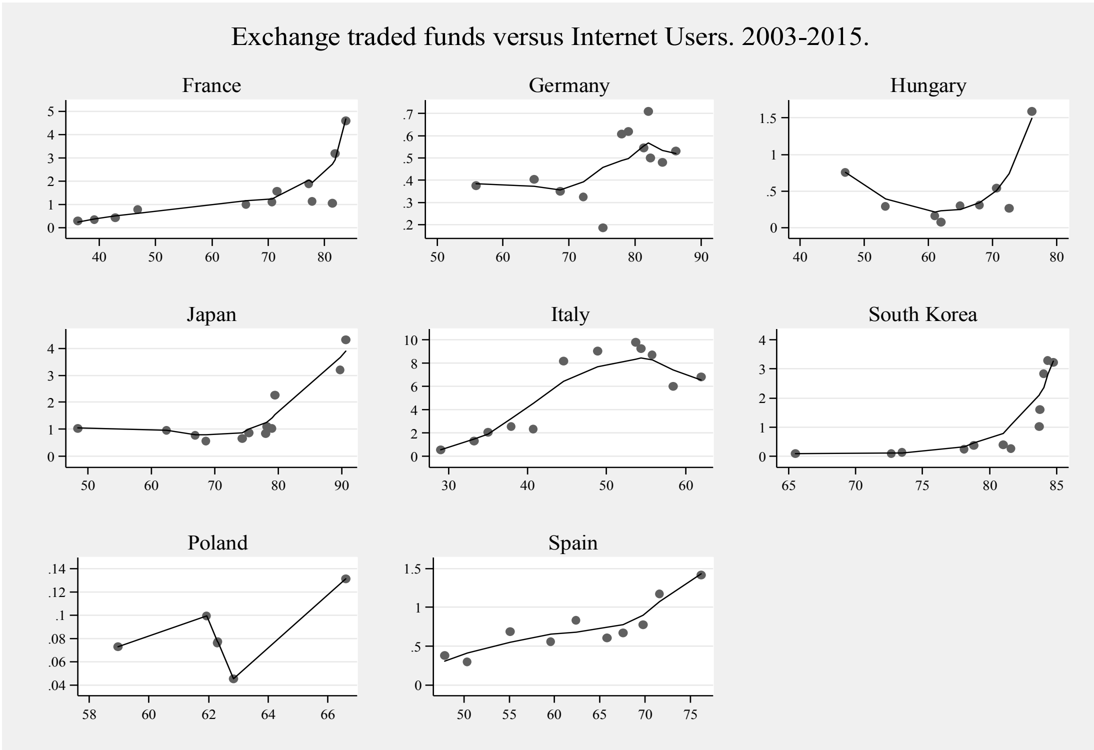

Exchange traded funds versus Internet Users. 2003-2015.
France
Germany
Hungary
Japan
Italy
South Korea
Poland
Spain

Fig.A-1

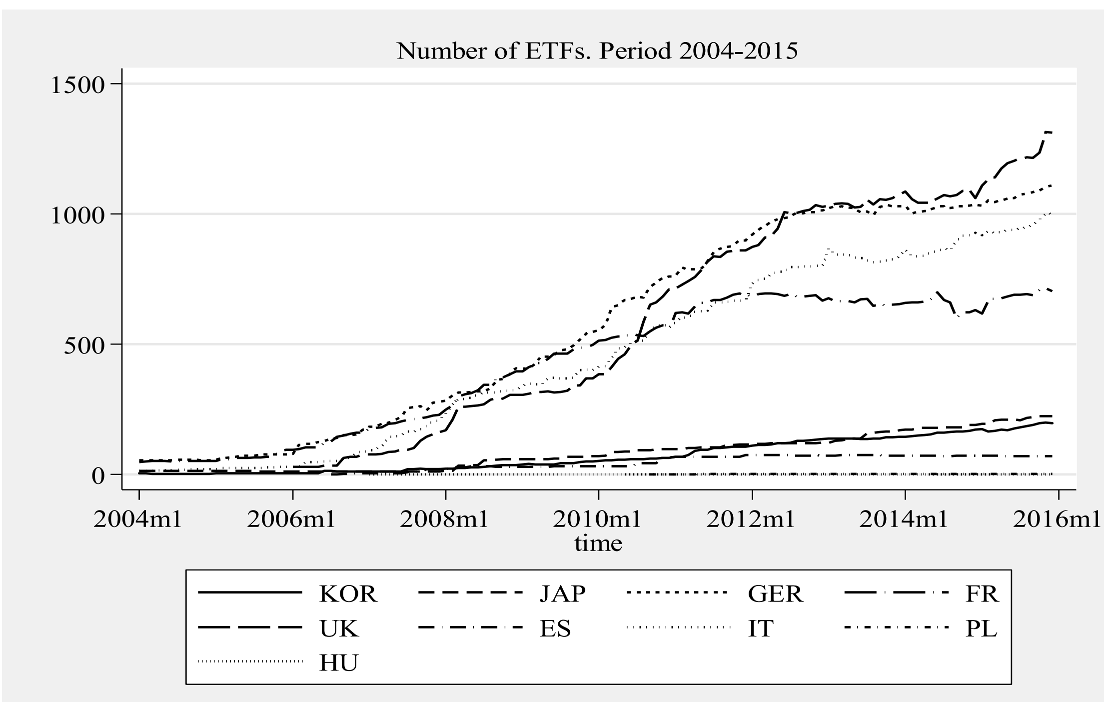
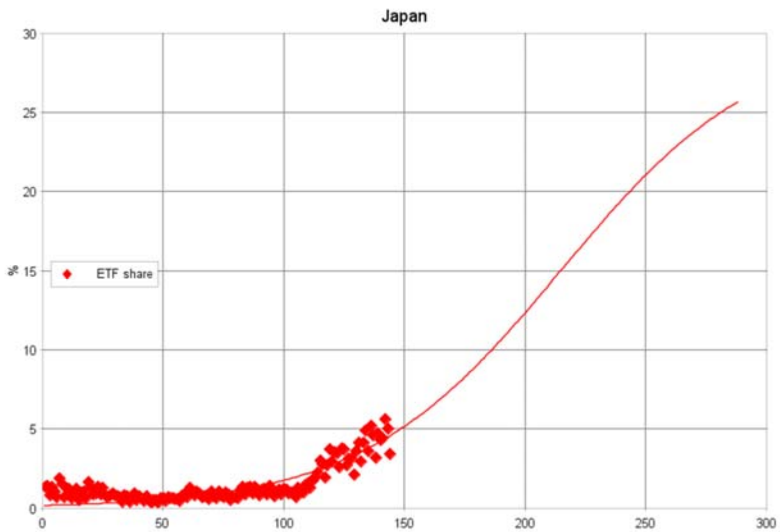
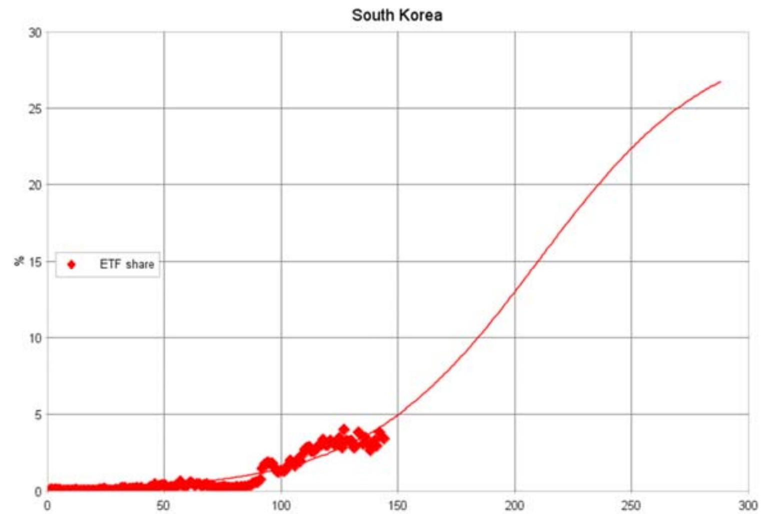
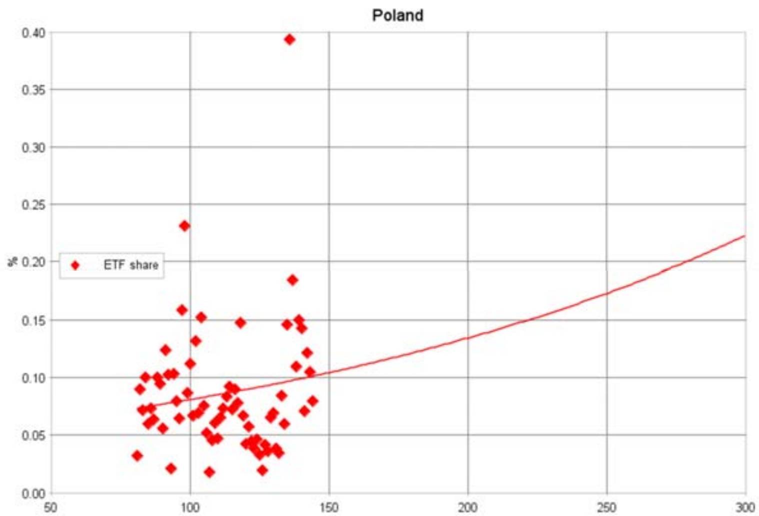
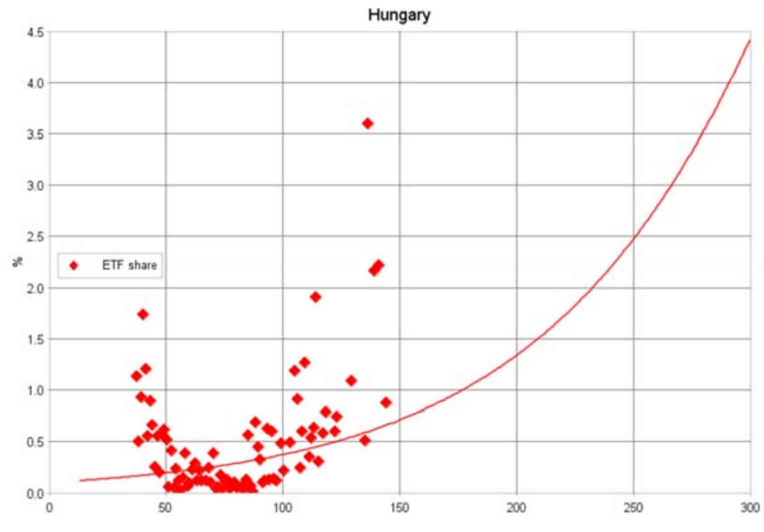

Number of ETFs. Period 2004-2015
time
KOR
JAP
GER
FR
UK
ES
IT
PL
HU

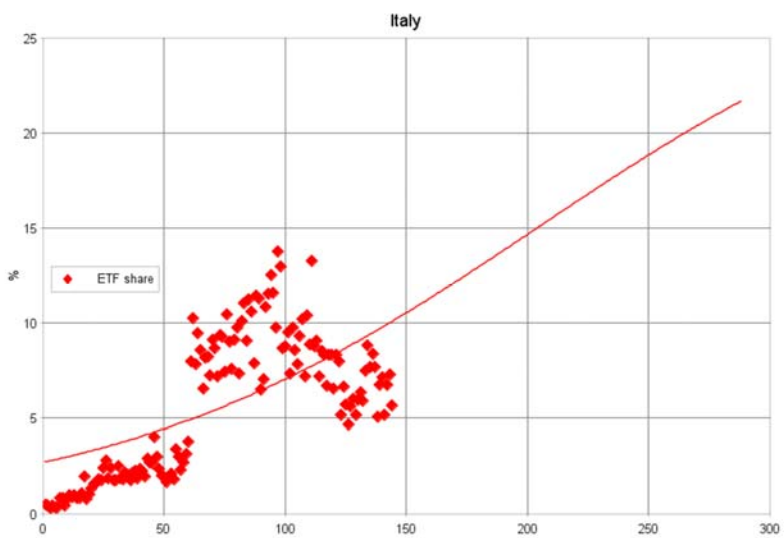
Fig.A- 2.

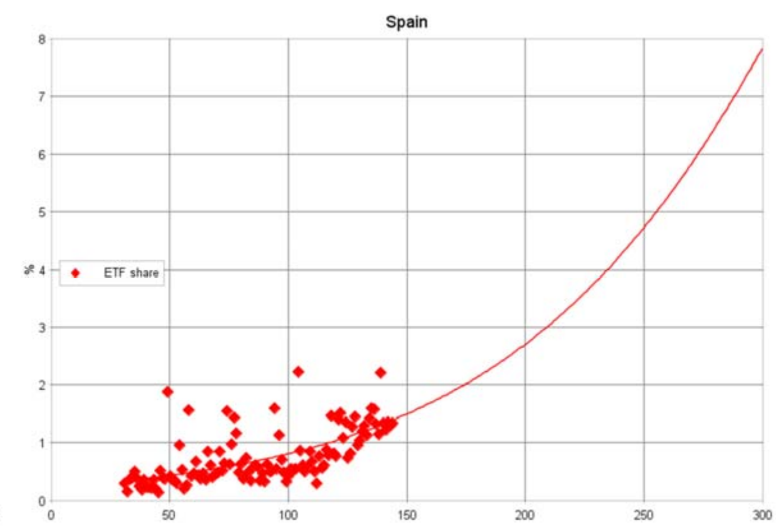

Japan
ETF share
%
0
5
10
15
20
25
30
0
50
100
150
200
250
300

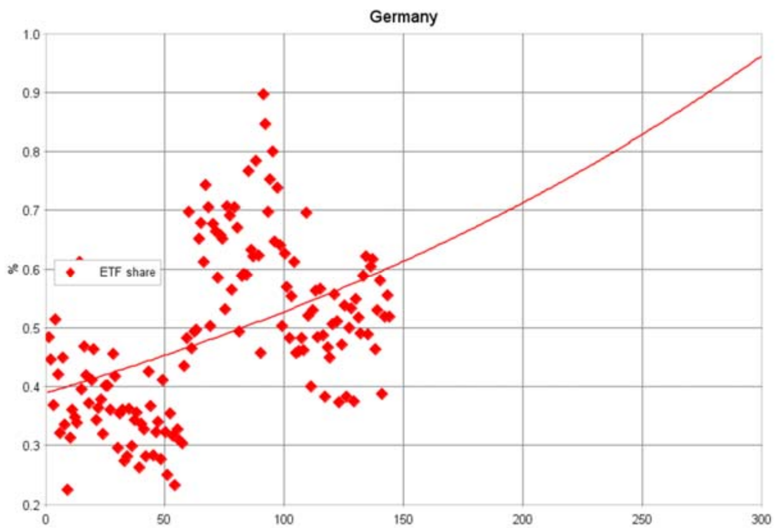

South Korea
ETF share
%
0
5
10
15
20
25
30
0
50
100
150
200
250
300


Poland
0.40
0.35
0.30
0.25
%
0.20
0.15
0.10
0.05
0.00
50
100
150
200
250
300
ETF share


Hungary
4.5
4.0
3.5
3.0
2.5
%
2.0
1.5
1.0
0.5
0.0
0
50
100
150
200
250
300
ETF share


Italy
25
20
15
%
10
5
0
0
50
100
150
200
250
300
ETF share


Spain
8
7
6
5
%
4
3
2
1
0
0
50
100
150
200
250
300
ETF share


Germany
ETF share
%
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
50
100
150
200
250
300

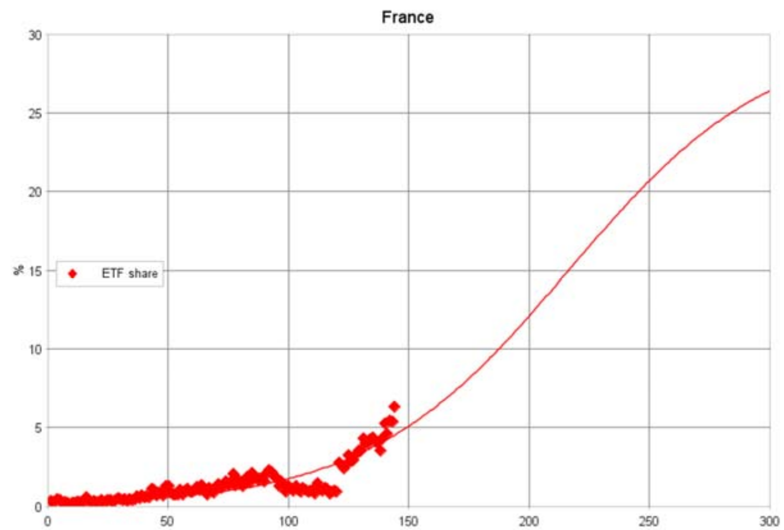

France
ETF share
%
30
25
20
15
10
5
0
0
50
100
150
200
250
300

Fig.A-3.

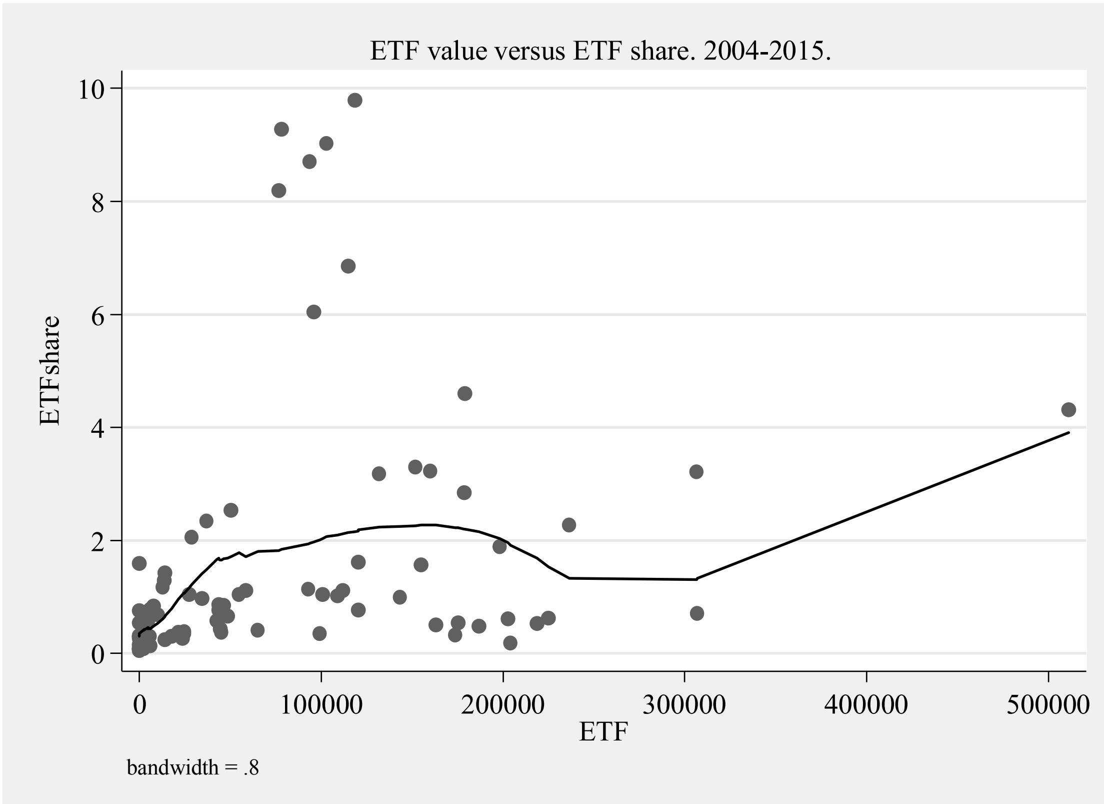

ETF value versus ETF share. 2004-2015.
ETFshare
0
2
4
6
8
10
0
100000
200000
300000
400000
500000
ETF
bandwidth = .8

Table 1.

Feature	**ETFs**	**Stock index futures**
Accessibility	Very high, due to small notional requirements. Operationally simple in most cases.	Small notional requirements. Operationally complicated (e.g. pricing).
Product range	Very broad. Many asset classes.	Most major equity indexes.
Required capital	Full upfront payment.	Only margin (a notional fraction of the investment needs to be posted).
Position management	Minimal (may include reinvestment of dividends).	Margin and cash flow management, contract rolling.
Maturity	Open-ended.	Predefined (usually one or three months).
Leverage	Only in the case of leveraged ETFs.	Available, usually very high.
Short sales of securities	May be limited (with the exception of special ETF classes, e.g. inverse ETFs).	Investors may use futures to obtain short exposure.

Positions in foreign assets	No need to manage foreign exchange component.	Foreign exchange management necessary.

Table 2.

Country	# of obs.	Mean	Std. dev.	Min. value	Max. value	Average annual growth rate (%)	Absolute change (in % points.)
Internet Users							
Hungary	24	29.8	29.1	.003	76.1	18.8	76.2
Poland	24	27.9	26.2	.005	66.6	18.3	66.6
Germany	25	42.5	34.9	.12	86.2	27.2	86.1
France	25	34.9	32.4	.05	83.6	30.7	83.7
Spain	25	31.2	29.1	.01	76.2	36.2	76.2
Italy	25	26.2	22.3	.02	61.9	34.1	61.9
United Kingdom	25	44.5	36.4	.08	91.6	28.9	91.6
Japan	25	42.3	34.3	.02	90.6	35.1	90.5
South Korea	25	45.9	36.7	.02	84.8	34.2	84.3

Fixed Broadband Subscriptions							
Hungary	15	13.3	10.1	.03	27.3	47.9	27.3
Poland	14	10.8	8.7	.03	23.8	47.9	23.8
Germany	15	20.0	13.3	.32	35.8	33.8	35.4
France	17	19.3	15.6	.02	40.2	46.7	40.1
Spain	15	15.3	9.7	.18	27.3	35.5	27.1
Italy	14	13.3	8.8	.20	22.9	35.7	29.7
United Kingdom	15	21.8	14.7	.08	40.7	43.1	37.3
Japan	17	17.1	11.06	.02	29.3	44.0	29.3
South Korea	17	25.7	12.5	.03	38.8	44.7	38.7

Table 3.

	Japan				South Korea			
	Turnover on Local Stock Exchanges (in million USD)							
	ETFs	Stock Index Options	Stock Index Futures	Total Index Financial Instruments	ETFs	Stock Index Options	Stock Index Futures	Total Index Financial Instruments
# obs.	144	144	144	144	144	144	144	144
Min	1,289.6 (2005m1)	405.2 (2005m1)	133,910.8 (2004m1)	136,450.2 (2004m1)	110.9 (2005m2)	6,344.9 (2015m5)	156,889.3 (2004m1)	165,203.7 (2005m2)
Max	59,382.1 (2015m9)	15,980.2 (2015m9)	1,288,211 (2015m8)	1,354,212 (2015m8)	18,215.9 (2011m8)	50,418.3 (2011m8)	1,179,588 (2011m8)	1,248,222 (2011m8)
Mean	10,100.3	4,052.9	539,579.5	553,732.8	5,666.7	18,134.1	470,849.9	494,650.7
Absolute change in value	41,092.6	3,223.1	1,059,989	1,104,304	11,884.9	2,038.2	172,817.1	186,740.2
Average monthly dynamic	102.232	101.2	101.5	101.5	102.9	100.1	100.5	100.5
	Share of Total Turnover of Index Financial Instruments on Local Stock Exchanges [%]							
	ETFs	Stock Index Options	Stock Index Futures	-	ETFs	Stock Index Options	Stock Index	-

							Futures	
# obs.	144	144	144	-	144	144	144	-
Min	.33 (2007m8)	.18 (2005m6)	93.7 (2015m10)	-	.06 (2005m5)	1.82 (2015m5)	92.3 (2014m7)	-
Max	5.6 (2015m10)	1.8 (2012m2)	99.4 (2007m12)	-	4.01 (2014m7)	7.14 (2008m10)	97.1 (2010m3)	-
Mean	1.5	.74	97.7	-	1.14	3.74	95.1	-
Absolute change in share (pp)	2.1	-0.204	-1.9	-	3.31	-2.13	-1.2	-
Average monthly dynamic	100.6	99.6	99.9	-	102.4	99.6	99.9	-
	Poland				**Hungary**			
	Turnover on Local Stock Exchanges (in million USD)							
	ETFs	Stock Index Options	Stock Index Futures	Total Index Financial Instruments	ETFs	Stock Index Options	Stock Index Futures	Total Index Financial Instruments
# obs.	64	144	144	144	132	132	132	132
Min	.90 (2012m11)	29.14 (2004m7)	1,041.05 (2004m7)	1,070.2 (2004m7)	0.0	0.0	9.2 (2015m5)	10.08 (2015m7)

Max	15.79 (2011m8)	1,187.1 (2011m3)	15,820.6 (2008m1)	16,274.5 (2008m1)	7.6 (2007m4)	9.2 (2006m8)	1,015.6 (2006m5)	1,015.6 (2006m5)
Mean	5.5	336.2	6,422.6	6,761.30	.60	.10	244.9	245.7
Absolute change in value	0.76	184.05	3,220.6	3,408.8	-5.6	0.0	-172.7	-0.25
Average monthly dynamic	100.3	101.1	100.7	100.7	48.6	66.8	97.9	97.9
	Share of Total Turnover of Index Financial Instruments on Local Stock Exchanges [%]							
	ETFs	Stock Index Options	Stock Index Futures	-	ETFs	Stock Index Options	Stock Index Futures	-
# obs.	64	144	144	-	132	132	132	-
Min	.02 (2012m11)	1.6 (2008m4)	86.01 (2008m4)	-	0.0 (multiple periods)	0.0 (multiple periods)	77.9 (2015m5)	-
Max	.39 (2015m4)	13.9 (2013m8)	98.4 (2013m8)	-	22.01 (2015m5)	1.4 (2006m8)	100 (multiple periods)	-
Mean	.08	5.05	94.9	-	.55	.02	99.4	-

Absolute change in share (pp)	0.05	1.9	-2.00	-	-0.25	0.0	-0.89	-
Average monthly dynamic	101.4	100.4	99.9	-	39.7	60.7	99.9	-
	Italy				**Spain**			
	Turnover on Local Stock Exchanges (in million USD)							
	ETFs	Stock Index Options	Stock Index Futures	Total Index Financial Instruments	ETFs	Stock Index Options	Stock Index Futures	Total Index Financial Instruments
# obs.	144	144	144	144	114	144	144	144
Min	246.4 (2004m5)	9,038.99 (2011m12)	32,881.4 (2009m2)	48,685.7 (2009m2)	131.2 (2012m8)	1134.1 (2012m1)	28,439.7 (2012m2)	32,317.4 (2004m8)
Max	13,435.2 (2015m3)	53,337.8 (2007m3)	178,067.9 (2007m3)	234,279.7 (2007m3)	3,397.5 (2008m1)	16,971.7 (2008m1)	169,693.3 (2007m11)	183,875.7 (2007m10)
Mean	5,669.7	22,329.0	78,508.4	106,507.1	630.5	5,764.6	74,557.7	80,821.5
Absolute change in value	8,306.9	13,222.2	64,909.3	86,438.5	779.1	3,950.7	33,361.5	38,333.1
Average	102.3	100.5	100.6	100.6	101.3	100.6	100.4	100.5

monthly dynamic								
	Share in Total Turnover of Index Financial Instruments on Local Stock Exchanges [%]							
	ETFs	Stock Index Options	Stock Index Futures	-	ETFs	Stock Index Options	Stock Index Futures	-
# obs.	144	144	144		114	144	144	-
Min	.27 (2004m3)	10.7 (2014m12)	63.6 (2007m10)		.14 (2007m9)	81.6 (2011m1)	81.6 (2012m12)	-
Max	13.7 (2012m1)	32.3 (2007m10)	83.3 (2014m12)		2.2 (2015m7)	96.8 (2012m12)	96.8 (2011m1)	-
Mean	5.6	20.9	73.4		.75	7.1	92.3	-
Absolute change in share (pp)	5.2	-3.07	-2.1		1.04	1.6	-2.9	-
Average monthly dynamic	101.7	99.8	99.9		101.3	100.1	99.9	-
	Germany				**France**			
	Turnover on Local Stock Exchanges (in million USD)							
	ETFs	Stock Index	Stock Index	Total Index	ETFs	Stock Index	Stock	Total Index

		Options	Futures	Financial Instruments		Options	Index Futures	Financial Instruments
# obs.	144	144	144	144	144	144	144	144
Min	2,549.1 (2004m9)	259,180.4 (2004m12)	550,142.9 (2004m2)	823,511.8 (2004m7)	810.6 (2004m9)	44,421.9 (2015m11)	204,785.8 (2004m8)	269,320.8 (2015m11)
Max	44,323.2 (2011m8)	2,830,918 (2008m1)	3,993,353 (2008m1)	6,852,531 (2008m1)	26,980.5 (2011m8)	726,885.4 (2007m11)	1,059,843 (2008m1)	1,725,926 (2008m1)
Mean	14,351.3	1,161,163	1,781,525	2,957,040	9,170.3	266,211.7	485,718.8	761,100.9
Absolute change in value	14,556.7	979,971.1	1,747,945	2,742,473	16,803.99	-168,972	-33,997.2	-186,165
Average monthly dynamic	101.0	100.9	100.9	100.9	101.7	98.9	99.9	99.6
	Share of Total Turnover of Index Financial Instruments on Local Stock Exchanges [%]							
	ETFs	Stock Index Options	Stock Index Futures	-	ETFs	Stock Index Options	Stock Index Futures	-
# obs.	144	144	144	-	144	144	144	-
Min	.22 (2004m9)	24.06 (2004m12)	49.4 (2015m7)	-	.13 (2004m9)	16.5 (2015m11)	49.5 (2004m8)	-

Max	.89 (2011m7)	50.06 (2015m7)	75.6 (2004m12)	-	6.4 (2015m12)	50.3 (2004m8)	78.7 (2015m5)	-
Mean	.48	38.6	60.9	-	1.4	33.9	64.5	-
Absolute change in share (pp)	0.03	-0.31	0.27	-	6.00	-28.7	22.7	-
Average monthly dynamic	100.0	99.9	100.0	-	102.0	99.3	100.2	-

Table 4.

	Logistic growth model estimates		
	Japan	**South Korea**	**Poland**
κ_i^{ETF} (ceiling/upper asymptote)	8,516,876	3.52	.087
Tm_i^{ETF} (β_i^{ETF}) (midpoint)	787.6	101.3	397,133.9
α_i^{ETF} (rate of diffusion)	.02	.09	-2,606.7
Δt_i^{ETF} (specific duration)	196.1	47.3	-.002
R^2 of the model	.77	.95	.00
# of obs.	144	144	64
	Hungary	**Italy**	**Spain**
κ_i^{ETF} (ceiling/upper asymptote)	97,207	8.56	500,100.2
Tm_i^{ETF} (β_i^{ETF}) (midpoint)	1,062	52.9	1,175,6.2
α_i^{ETF} (rate of diffusion)	.013	.113	.012
Δt_i^{ETF} (specific duration)	339.2	38.7	354.4
R^2 of the model	.075	.76	.411
# of obs.	130 (outliers excluded)	144	114
	Germany	**France**	
κ_i^{ETF} (ceiling/upper asymptote)	.585	7,755,333.6	
Tm_i^{ETF} (β_i^{ETF}) (midpoint)	-3.94	777.3	
α_i^{ETF} (rate of diffusion)	.026	.023	
Δt_i^{ETF} (specific duration)	169.8	194.2	
R^2 of the model	.27	.789	

# of obs.	144	144

Table 5.

κ_i^{ETF} **(upper asymptote) - fixed**	Tm_i^{ETF} **(midpoint) – refers to a specific date**	Δt_i^{ETF} **(specific duration) – number of months**	α_i^{ETF} **(rate of diffusion)**	**R^2 of the model**
	Japan			
5%	114.4 (2013m6)	111.1	.04	.72
7.5%	136.5 (2015m6)	137.2	.032	.75
10%	153.2 (2016m9)	151.7	.029	.76
15%	176.6 (2018m8)	166.4	.026	.77
20%	192.8 (2019m12)	173.8	.025	.77
25%	205.1 (2021m1)	178.3	.025	.77
30%	214.9 (2021m10)	181.2	.024	.77
	South Korea			
5%	116.1 (2013m8)	89.1	.049	.93
7.5%	137.7 (2015m5)	120.6	.036	.93
10%	153.5 (2016m9)	135.2	.032	.90
15%	175.2 (2018m7)	149.3	.029	.89
20%	190.0 (2019m10)	156.3	.028	.89
25%	201.2 (2020m9)	160.4	.027	.89
30%	210.1 (2021m6)	163.1	.027	.89
	Poland			
5%	*-229,626,799*	*-249,867,896*	*.00*	*.016*
7.5%	*981.7*	*857.4*	*.005*	*.018*

10%	*1,010.6*	*859.5*	*.005*	*.018*
15%	*-258,875,673*	*-220,949,493*	*.00*	*.016*
20%	*1,181,1*	*862.7*	*.005*	*.018*
25%	*1,225.8*	*863.3*	*.005*	*.018*
30%	*1,262.3*	*863.8*	*.005*	*.018*
	Hungary			
5%	282.4 (2027m6)	319.5	.014	.073
7.5%	318.3 (2030m6)	326.0	.013	.073
10%	343.2 (2032m7)	329.3	.013	.073
15%	377.4 (2035m5)	332.6	.013	.074
20%	401.2 (2037m5)	334.2	.013	.074
25%	419.4 (2038m11)	335.2	.013	.074
30%	434.2 (2040m2)	335.9	.013	.074
	Italy			
5%	*Already achieved*			
7.5%	*Already achieved*			
10%	*Already achieved*			
15%	100.24 (2012m4)	246.9	.018	.485
20%	141.7 (2015m9)	318.7	.014	.454
25%	175.7 (2018m7)	359.9	.012	.445
30%	204.1 (2020m12)	386.9	.011	.435
	Spain			
5%	211.4 (2021m7)	300.3	.015	.41
7.5%	252.4 (2024m12)	318.2	.014	.41
10%	280.6 (2027m4)	327.2	.013	.41
15%	318.9 (2030m6)	336.3	.013	.41
20%	345.4 (2032m9)	340.8	.013	.41

67

25%	365.6 (2034m5)	343.5	.013	.41
30%	381.7 (2035m9)	345.4	.013	.41
	Germany			
5%	*1,402.6*	*1,426.9*	*.003*	*.02*
7.5%	*892.6*	*1,349.1*	*.003*	*.02*
10%	*1,003.8*	*1,375.0*	*.003*	*.02*
15%	*1,156.0*	*1,401.0*	*.003*	*.02*
20%	*1,261.3*	*1,413.9*	*.003*	*.02*
25%	*1,341.7*	*1,421.7*	*.003*	*.02*
30%	*730.8*	*1,297.3*	*.003*	*.02*
	France			
5%	*Already achieved*			
7.5%	139.9 (2015m7)	157.6	.028	.73
10%	156.8 (2016m12)	165.6	.027	.75
15%	179.7 (2018m11)	174.5	.025	.76
20%	195.3 (2020m3)	179.2	.025	.77
25%	207.2 (2021m3)	182.1	.024	.77
30%	216.6 (2021m12)	184.0	.024	.77

Table 6.

$LnETFshare_{(i,y)}$										
	Pooled OLS(1)	Pooled OLS(2)	Pooled OLS(3)	RE (1)	RE(2)	RE(3)	G2SLS IV RE(1)	G2SLS IV RE(2)	G2SLS IV RE(3)	G2SLS IV RE(4)
$LnIU_{(i,y-1)}$	-0.1 [0.45]	-0.74 [12.5]	**489.2** **[194.8]**	**2.57** **[0.37]**	-0.19 [9.59]	**335.4** **[136.3]**	**2.03** **[0.66]**	-11.3 [14.5]	**614.4** **[235.1]**	**2.22** **[0.75]**
$(LnIU_{(i,y-1)})^2$		0.02 [1.58]	**-123.7** **[49.4]**		0.20 [1.21]	**-84.56** **[34.9]**		1.65 [1.82]	**-154.4** **[59.7]**	
$(LnIU_{(i,y-1)})^3$			**10.4** **[4.16]**			**7.11** **[2.99]**			**12.9** **[5.1]**	
LnETF		**0.21** **[0.04]**	**0.18** **[0.04]**		**0.41** **[0.14]**	**0.34** **[0.14]**	0.34 [0.20]	0.33 [0.20]	0.24 [0.18]	0.34 [0.21]
Ramsey Reset test (Prob>F) (for OVB)	0.00 (there are omitted variables)	0.00	0.00							
Breuch-Pagan test (prob>chi^2)				0.00 (random OK)	0.00	0.00	0.00			
R^2	0.00	0.34	0.37	0.00 (overall)	0.27 (overall)	0.27 (overall)	0.22 (overall)	0.23 (overall)	0.22 (overall)	0.22 (overall)
Rho				0.73	0.70	0.69	0.71	0.70	0.67	0.72

Instrument: $LnFBS_{(i,y-1)}$									No	Yes
Instrument: lagged $IU_{(i,y-1)}$							Yes	Yes	Yes	
Instrument: lagged $(LnIU_{(i,y-1)})^2$								Yes	Yes	
Instrument: lagged $(LnIU_{(i,y-1)})^3$									Yes	
Instrument: lagged LnETF							Yes	Yes	Yes	Yes
# of countries	8	8	8	8	8	8	8	8	8	8
# of observations	85	85	85	85	85	85	77	77	77	76

Table A-1.

	LnIU$_{(i,y)}$			
	Pooled OLS	FE	FE(IV)	FE(IV)
LnFBS$_{(i,y)}$	.30 (.009)[a]	.29 (.007)[a]	.31 (.011)[b]	.31 (.025)[c]
Hausman test (prob>chi^2)	-	.00	-	-
R-squared	.87	.91 (within)	.92 (within)	.92 (within)
Country-fixed effects	No	Yes	Yes	Yes
Instruments – lagged FBS	No	No	Yes	Yes
# of countries	9	9	9	9
# of observations	139	139	133	133

Source: Authors` estimations. Note: Constant included but not reported. [a] standard errors at 5% level of significance; [b] conventional SE; [c] Bootstrap SE (1000 replications).

Table A-2.

	LnETFshare					
	OLS	IV 2SLS	IV 2SLS	OLS	IV 2SLS	IV 2SLS
	France			Germany		
LnIU	**2.38** **[0.34]**	**2.38** **[0.34]**	**2.39** **[0.29]**	**1.27** **[0.47]**	**1.22** **[0.39]**	**1.21** **[0.41]**
R^2	0.78	0.78	0.78	0.19	0.19	0.19
Instrument: LnFBS	No	No	Yes	No	No	Yes
Instrument: lagged IU	No	Yes	No	No	Yes	No
# of observations	12	12	12	12	12	12
	Hungary			Italy		
LnIU	0.73 [2.42]	0.23 [1.97]	0.67 [2.05]	**3.41** **[0.52]**	**3.34** **[0.45]**	**4.15** **[0.41]**

R^2	0.01	0.00	0.01	0.81	0.81	0.84
Instrument: LnFBS	No	No	Yes	No	No	Yes
Instrument: lagged IU	No	Yes	No	No	Yes	No
# of observations	9	9	9	12	12	12
	Japan			South Korea		
LnIU	2.04 [1.29]	1.94 [1.07]	1.81 [1.02]	**14.8** **[3.55]**	**15.1** **[3.43]**	**17.1** **[3.46]**
R^2	0.29	0.29	0.29	0.72	0.72	0.70
Instrument: LnFBS	No	No	Yes	No	No	Yes
Instrument: lagged IU	No	Yes	No	No	Yes	No
# of observations	12	12	12	12	12	12
	Poland			Spain		
LnIU	4.24 [2.9]	2.00 [2.82]	0.86 [4.76]	**2.67** **[0.48]**	**2.58** **[0.44]**	**2.61** **[0.39]**
R^2	0.21	0.15	0.07	**0.76**	**0.76**	**0.76**
Instrument: LnFBS	No	No	Yes	No	No	Yes
Instrument: lagged IU	No	Yes	No	No	Yes	No
# of observations	6	6	6	10	10	10