ECONOMIC BUBBLE: IS THE STOCK MARKET TOO VOLATILE TO BE REGARDED AS EFFICIENT?

A case study of the German stock market

Thesis presented by
Ervin MUSASA MBALAKA

Supervisor
Pr. Johannes JOHNEN (UCL/UNamur)

Supervisor
Pr. Leonor MODESTO (UCP)

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and

Mestrado em Economia (UCP)

Ecole d'économie de Louvain/UCL • Place Montesquieu 3 • 1348 Louvain-la-Neuve / Belgium
Département des Sciences économiques/UNamur • Rempart de la Vierge 8 • 5000 Namur / Belgium
Universidade Católica Portuguesa • Palma de Cima 1640-023 • Lisboa / Portugal

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Table of Contents

INTRODUCTION

The recent financial events stir up the curiosity of many enthusiasts about the current state of the stock market, or even the markets in general. The media constantly wonders whether the stock market is efficient, whether we are witnessing the formation of a speculative bubble, etc. We have also been caught by those questions and our thesis is an attempt to answer to some of them. When we've had our first contact with that topic, we were primarily interested in speculative bubble. And we also knew that it is one of the many events that are materialized through excessive volatility in the stock market. Therefore, we decided to direct our research toward the market volatility.

Our thesis is divided in two main parts. The first part reviews the literature related to the mainstream financial theories. The first chapter defines the efficient market hypothesis, also known by its acronym "EMH", according to FAMA (1965). We decompose the definition to explain the stock prices generating process through the present value model. We essentially attempt to introduce the idea that each asset has an intrinsic value, and its prices needs to match it in the purpose of achieving an equilibrium state in the market. Then we explain how that equilibrium, efficiency is achieved through the optimal exploitation of the information set. The concept of arbitrage and the EMH's views about anomalies such as excessive market volatility and speculative bubble will be discussed as they eventually introduce us to the alternative theories. Once we finish with the market efficiency, we start summarizing the literature concerning the rational speculative bubble which provides an interesting insight not considered by the EMH. Thereafter, we direct our interest towards the behavioral literature that attempts to provide explanations of the irrational speculative bubble and the mechanisms encouraging their formation in the stock market through insights borrowed from other social sciences. We eventually mention some behavioral factors that might contribute to the general overreaction in the market.

The second part of our thesis is an empirical analysis that attempts to answer to our research question: Is the stock market too volatile to be efficient? We are interested in the largest German stock market and its main index, the DAX. We decide to resort to SHILLER's (1981) early work because it gave birth to an important literature, the excess volatility and then the behavioral critique that has contested the hegemony of the EMH in the academic field ever since. We initially resume the theoretical framework he relied on for his empirical work. Afterwards, we present our data and extensively explain how we have derived the variables needed to implement his methodology. The methodological part is divided between 2 chapters. Indeed, the first focuses on regression tests whereas the second one on variance-bound tests, which ultimately help us to answer our research question. The last chapter reviews the discussions about the methodological issues raised by different supporters of the EMH. We finally discuss the reliability of the variance-bound tests to detect market volatility, and by extension, speculative bubble.

As we are interested in analyzing the market as an aggregate of investors, we don't focus on individual speculative asset and don't plan to analyze individual stock price behavior. Throughout our thesis, we openly take an intuitive approach when we develop the ideas underlying our topic. We want to remind our reader that although the topic discusses about a financial model, we present our subject on a more generalist perspective first and foremost. Hence, we avoid resorting to too technical terms that may eventually confuse our reader. We also purposely avoid speaking on subjects involving advanced knowledge in finance such as risk management. Our main goal is to demonstrate how the market, as an aggregate of participants, displays too much volatility and may be subject to speculative bubble while making our points well understood by an economist, regardless of his or her background.

PART I: LITERATURE REVIEW

Chapter 1: Efficient market theory

In this first chapter, we introduce the main concepts defended by the market efficiency theory. This chapter is essential to understand the rest of the thesis. Indeed, the second chapter is an answer to the theory and the whole second part develops more extensively the expressions we present here. We essentially take the EMH definition: “the asset prices always fully reflect all the information available” FAMA (1970). We briefly analyze its meaning. Indeed, its key terms, "prices" and "information", are extensively explained. Eventually, we close the chapter with the implications those terms have on the market participants’ behavior, the interpretation of volatility and speculative bubble.[1]

Paragraph 1.1: Stock price

As stated in the introduction, we want to provide an intuitive explanation of the price formation. Therefore, we resort to a simple efficient market model. Here we introduce the present value model that relates the price to the future stream of dividends. Moreover, this model will be useful for the volatility test that we will conduct in the second part. We present the price formation in two steps based on ORLEAN’s (2004) publication. First, every asset has a fundamental or intrinsic value. Its value is calculated when the market is certain about the future. The fundamental value is therefore the sum of the discounted stream of future dividends.

$$FV_t = \frac{D_{t+1}}{1+r} + \frac{D_{t+2}}{(1+r)^2} + \cdots + \frac{D_{t+n}}{(1+r)^n} + \cdots \tag{1.1}$$

Where FV_t denotes the fundamental value at time t, D_{t+k} represents the dividend distributed at time $t+k$ and r is a constant discount rate. The model (1.1) assumes that the future dividends are determined under certainty. However, they are not known before the moment they are effectively distributed in the reality. As the uncertainty is a key component in our world, the future dividends are thus random variables. But we can still estimate them and therefore the fundamental value. Hence, the future dividends are expected conditionally to all information currently available. In the next paragraph, we will be a little more specific about that information.

The uncertainty surrounding the future dividends defines our second step. Furthermore, SHILLER (1988, p.16) argues prices are the primary means of communication between the participants as they need to agree upon them if they want to trade assets. In fact, in a market uncertain about its future, the price on which the participants agree to trade may be different from its intrinsic value. We

[1] We interchangeably use the substantives “market participants” and “investors” throughout the thesis. It refers to the same type of individuals in our context.

know that the participants behave rationally. To better understand our point, we refer to them individually. A rational participant sells his asset whenever its market price happens to be above or equal to its intrinsic value. Inversely, he purchases an asset whenever its market price happens to be below or equal its intrinsic value. The market is the aggregate of participants willing to trade assets. Through the mechanism and the coordination of the supply and the demand for assets across the market, the rational behavior of its participants leads to a rational estimation of the fundamental value given all the information currently available, namely the price.

$$P_t = E(FV_t|\Phi_t) = E_t(FV_t) \quad (1.2)$$

Where P_t denotes the market price of an asset and Φ_t the information set currently available. The equilibrium displayed in expression (1.2) is one of the key aspects of the efficient market model. Therefore, the equilibrium prices on which the participants trade the assets turn out to match their fundamental value. This equilibrium state is sustained when the market fully exploits the information set currently available and instantaneously integrates latest information that eventually affects the future dividends. Indeed, the participants constantly readjust their conditional expectations of the future dividends and this explains the movement of the prices through time according to FAMA (1965). Moreover, the upcoming information is unpredictable as BODIE et AL. (2014, p.350) argue. They also state that even if the participants were able to predict it, it would already be reflected in the prices.

Paragraph 1.2: Information subset

In the first paragraph, we have presented the price formation of an asset and pointed out the reasons behind its movements through time. We have explained that the EMH asserts that the inflow of new information is responsible for its movements. This paragraph focuses on the information that induces those movements. Indeed, FAMA (1970) presents three version of the EMH. Each of them is characterized by the type of information the participants rely on when they estimate market prices.

- The weak form of efficiency states that prices, profits and any market-related information from the past are integrated in the current prices;
- The semi-strong form of efficiency states that, in addition of the historical data, any public announcement related to the company or the macroeconomic events are reflected in the current prices;
- The strong form of efficiency simply indicates that any information, public or private, is included in the current prices.

We write three sections that briefly develops each version. We briefly discuss their differences and their relevancy in the real world. In general, FAMA (1970, p.388) asserts that there is no robust evidence against the weak and semi-strong forms of the hypothesis whereas the third one is a strong assumption that we cannot take it literally for granted.

Section 1.2.1: Weak form

Our second part will focus on the validity of this form. It asserts that all the available quantitative data such as the historical prices, returns and macroeconomic data (interest rates for instance) are already integrated in the prices.

Its most important implication is the impossibility to derive a higher return than the market on the base of that information. In fact, any active investment strategy that purposely seeks to outperform the market fails in its attempt to “beat the market”. MALKIEL (2003 b) argues that a passive investment strategy is rational because it maximizes the return of an asset. The buy-and-hold is a prime example of such strategy. It consists of acquiring an asset and holding it until, at least, the following period so its price, or dividend, grows at a rate provided by the market. Its main advantage is obviously a provision of regular stream of returns at the highest rate possible according to EMH, the market return. In the real world, investing on an index fund based on several sizeable institutions such as the DAX is considered as a passive investment strategy for instance.

On the other side, we have the trading which is an active investment strategy. The technical analysis, which is entirely based on past prices behavior, is an example of trading. It estimates the future prices by the probabilistic assumption that they are determined through a continuous succession of short-to-medium trends that repeat themselves across time. The repetition of those patterns makes the prices predictable to an extent, which is a violation of the EMH. BODIE et AL. (2014, p.355) argues that this strategy doesn’t outperform the market due the lack of consistent outperformances empirically speaking. Furthermore, the revelation of such technique to the public fades its relevancy as competing forces ultimately intervene to prevent a deviation of the prices from their equilibrium level. BARBER and ODEAN (2000) extensively argue that even if the gross return from such strategy happens to “beat the market”, the transaction costs implied by the strategy gives a lower net profit relative to the market profit.

Section 1.2.2: Semi-strong form

Under this form, the information subset encompasses all the events the stock price may adjust to such as stock split, publication of financial reports, and so forth. Any public announcement is essentially reflected in the prices besides the historical quantitative information that we find again in the weak form.

Under that version, it is impossible for an investor to outperform the market based on the analysis of fundamentals, might they be macroeconomics or market-related. In fact, BODIE et AL. (2014, p.356) argues that the investor likely seeks his source on a platform consultable by the public, with no cost involved. As the public can easily reach out that information, it means that it is already spread across the market and thus reflected in the prices. Hence, it is impossible to outperform the market. To close this section, FAMA (1970, p.409) asserts that the semi-strong form is empirically consistent in a sense where the market integrates the new public information such as stock splits, FED announcements and annual earnings from few seconds to couple of days at most. All the aforementioned announcements are among the most important ones and, so they have a sizeable effect on the prices.

Section 1.2.3: Strong form

The third version of the EMH states that all types of information, whether public or not, are already reflected in the prices. Theoretically, it implies that an investor with a monopoly access to information does not profit from that strategy. The prime example of such strategy is the "inside trading". Nonetheless, it has been demonstrated over time by FAMA (1970, p.409) and others that the "inside trading" may effectively generate a return significantly superior to the market. It is therefore superior to the strategy recommended by the EMH. Therefore, we safely assert that the strong form is repeatedly violated a lot of times.

Paragraph 1.3: Arbitrage

The arbitrage is an important condition of the theory and it is also extensively discussed in our second chapter. It essentially states that the profit opportunities are fully exploited by a category of investors. We base the following developments on ORLEAN (2004, p.242). We already know that by adopting a rational behavior, the market participants estimate correctly the prices, and thus the market is regarded as efficient. The competition among many participants within a market encourages the assets to be exchanged at their equilibrium prices, which correspond to their intrinsic value.

Nonetheless, the theory doesn't deny the existence of irrational participants. By "irrational", the theory explicitly means any behavior that doesn't adopt the optimal strategy to maximize an asset's return. In fact, the theory suggests that the principle of buying a stock at a relatively low price only to purposely sell it at a much higher price is not a profitable strategy in the long run. The literature has repeatedly demonstrated that passive strategies remain the most profitable one under normal market conditions FAMA (1970, p.387). Despite that fact, the irrational participants constantly seek to "beat the market".

The theory suggests that the presence of irrational participants within a market proves its consistency. We have different elements that favor its argument. First, the law of large number prevents those participants to benefit greatly from their strategy. In fact, the market is a pool where every participant enters with the expectation of getting the highest return possible from their investments. As the market is composed of both rational and irrational participants, the latter must compete against the former, who usually outnumber them. Therefore, the irrational participants’ strategies and their executions have a small impact in the valuation of the market.

Second, those irrational participants must compete against some of the most rational participants. Even when the latter don’t constitute the majority, they usually outlast the former. Indeed, one of the fundamental axioms of the free market is the free entrance and exit of its participants MANKIW et AL. (1998, pp.12-14). It is rational to conceive that the individuals who decide to leave the market are the ones who either altogether lose their investment or believe that there are alternative opportunities they deem more profitable than the market, and hence they choose to leave the market. Ultimately, the rational participant lasts longer because he constantly seeks to apply the optimal strategy that maximizes his returns. Hence, he manages to grow his capital base and his influence on the market in the long run ORLEAN (2004).

Furthermore, the rational participants have the power to adjust the prices to their fundamental value. If the irrational participants induce the fluctuations of the prices around their intrinsic value, the rational ones spot the financial opportunity and profit from it by adopting a contrarian strategy. Hence, those participants are called the “arbitrageurs”. We now provide an intuitive example. An irrational participant, by definition, would buy (sell short) overvalued (undervalued) assets whereas a rational participant would sell short (buy) those overvalued (undervalued) assets in reaction to the irrational participant’s strategy. Adding his behavior to other rational participants' behavior, the magnitude of their reaction decreases (increases) the prices in such way they eventually reconcile with their equilibrium level. Hence, their capital base, influence in the market and knowledge of the market valuation ultimately prevent the prices to significantly deviate from their intrinsic value on an aggregate level ORLEAN (2004).

Finally, the irrational participants tend to operate their transactions only with each other, isolated from the others SHLEIFER (2000, pp.4-5). The transactions with their rational counterparts are very limited as the latter is not interested to trade with the former. In fact, the rational participants would rather base their estimation upon the fundamental value of an asset while maximizing their profit opportunities whereas the irrational ones, as explained earlier, seek to maximize theirs regardless to its fundamental value. Hence, the irrational participants are encouraged to make transactions with each other and to trade with prices different than their rational counterparts.

Nonetheless, this has two consequences. First, that partitioning prevents their transactions to have a sizeable impact on the market and therefore on the listed prices. The irrational investors pay their isolation from the mainstream transactions. Second, their strategies cancel out each other in the long run as their pricing policy doesn't correspond to the market's policy. The incurring losses force them to eventually leave the market. We are therefore aware that the EMH assumes the market will always be composed of a certain number of irrational participants even though they leave it faster than their rational counterparts. The existence of such cycle implies that new irrational participants replace the former ones. Nonetheless, those new participants will eventually leave the market as their strategies will also turn out to be unprofitable and so forth TVERSKY and KAHNEMAN (1986, p.36).

Paragraph 1.4: EMH views on market volatility and bubbles

This paragraph basically introduces us gradually to our next chapter. We focus on certain "anomalies" that may provide excessive returns. A market anomaly is an event that suddenly causes a reevaluation of the prices. A known example of anomalies is commonly known as the "market crash" that usually follows a speculative bubble. The EMH views such anomalies as exogenous shocks.

As stated above, the event preceding a market crash is the "speculative bubble" in certain cases. However, it is not regarded as such by the EMH. Indeed, a continuous and rapid increase of the prices through time is just a reaction to a succession of information that are newly integrated in the prices. Therefore, the continuous deviation of the market prices from their intrinsic value is not conceivable as the information always guarantee that their equilibrium sustains, it has just shifted to a new level MALKIEL (2003 a, p.22).

The EMH regards the "market crash" or "financial crisis" through the same lens. Indeed, the sharp decline of the prices is just a result of successive pessimistic information that has just flowed into the market. The EMH asserts the prices always match their intrinsic level as the information is fully exploited. As we have just stated above, the theory therefore implies a dynamic variation of the fundamental value to explain the sudden change in the market prices and de facto denies the existence of a "speculative bubble" SHILLER (1988, p.12).

Chapter 2: Alternatives to EMH

In the continuity of the first chapter, we introduce some theories that attempt to explain the prices behavior in a fashion that is not captured by the efficient market theory. Indeed, those alternatives theories attempt to provide new explanations regarding the formation of speculative bubbles. They fall into two ramifications: rational and irrational bubble. We remind our reader that this chapter is interesting to understand another potential source of volatility in the stock market.

Paragraph 2.1: Rational bubble

BLANCHARD and WATSON (1982) introduce the model of rational bubble affecting the prices. By "rational bubble", we mean that the deviations of the prices from their fundamental value are due to the rationality of the market participants. In fact, they argue that the market prices include a bubble component besides their fundamental value.

$$P_t = FV + B_t \qquad (2.1)$$

Where B_t denotes the bubble element. A bubble is sustainable if the participants expect it to grow over time.

$$E_t(B_{t+1}) = (1 + i)B_t \qquad (2.2)$$

Where i denotes the growth rate of the bubble. We therefore notice that a speculative bubble may take form thanks to the rational participants. In fact, Grossman and Stiglitz (1980) assert that the rationality may be centered on the observable prices instead of their not so observable fundamental value. Indeed, they find out that the information that affects the prices may be costly and therefore it is rational for the participants to turn their attention towards the prices instead. Blanchard and Watson demonstrate that the absence of arbitrage cannot be the only condition that hinders the prices to deviate significantly from their fundamental value. As we have already explained in the last chapter, the rational participants are encouraged to sell short an asset whenever its price is above its intrinsic value. However, this is not the only rational behavior they may adopt under that circumstance. Indeed, it is also rational for them to hold the asset while expecting its value to soar over time. It eventually enables him to realize a capital gain. The argument is especially relevant when the market is composed of "generational participants". In fact, this enables them to project their time horizon into infinity. Hence, a bubble is subject to take form partially due to that reason BLANCHARD and WATSON (1982, p.8).

The rational bubble is also likely to take form in markets or sectors where it is difficult to assess the fundamentals. The IT sector, where a sizeable portion of the fundamental valuation relies on intangible assets, or the commodities markets, where gold is used for industrial and financial stability purpose are some prominent example. Furthermore, the rational bubble may influence the intrinsic value. In fact, it can either be entirely independent from the fundamental value as shown in expression (2.1) or it may also influence the latter BLANCHARD and WATSON (1982, pp.10-11).

To an extent, the bubble tends to have a “contagious” effect on other class of assets BLANCHARD and WATSON (1982, p.12). Indeed, a bubble that has already affected a market can expand to another one that has not witnessed excessive pricing yet. Many real effects can be observed. Blanchard and Watson argue that those effects mainly depend on the degree of substitutability of the assets and how demanded they or the money are by the investors. Ultimately, the market prices' equilibrium is much higher than in the past. We have just argued a case where a “speculative bubble” has some real effects on the economy while being rational. And this rational bubble may be materialized in the volatility observed in the market.

Paragraph 2.2: Behavioral literature

The behavioral literature, alongside the rational bubble theory, argues that excess volatility, and by extension “speculative bubble”, cannot only be explained by market fundamentals. It also takes form whenever there is a generalized manifestation of irrational behavior in the market. By “irrational behavior”, its supporters actually assert that the average human being is “less than fully-rational” STATMAN (2008, p.2). We remember that the arbitrage from the rational participants prevent the prices to deviate from their fundamental value.

Nonetheless, the behavioral literature argues that the arbitrage is actually risky, and hence limited, because of market imperfection. THALER and BARBERIS (2003, pp.1058-1061) find three factors that limit the arbitrage from the rational participants. First, any investment is fundamentally risky. Indeed, the risk of losing an investment is always present in an uncertain market as some factors are just beyond the control of the arbitrageur. For instance, a rational participant who is convinced that an asset is overpriced decides to short sell it. However, the asset's price may still rise the following day contrary to his expectations, and therefore incurs a loss to his portfolio.

Second, the gap between the price and its intrinsic value may widen in the short-run. This incurs an additional loss for him. He may eventually lose all his investment by the time the price reconciles with its intrinsic value. If the rational participant is a fund manager who is appointed by his client to maximize his portfolio return in the short-run, he may as well lose his job just because of a timing difference.

Third, the (psychological and financial) implementation cost limits the rational participants’ radius of action. In fact, SHILLER (2003, pp.98-100) extensively resumes that short-selling is costlier than purchasing. This cost prevents the rational participants to venture into it as much as they would like or need to, which eventually limits their profit opportunities. Therefore, their arbitraging attempts don’t guarantee them to profit from the mispricing caused by their irrational counterparts, and hence, reconcile the prices with their intrinsic value DE LONG et AL. (1990).

We have just shown that arbitrage does not systematically prevent asset mispricing. This means that the irrational participants' actions may outdo their counterparts' ones, and hence, significantly influence the market. In the following sections, we focus on the main factors that may encourage them to shift the prices away from their fundamental value, and hence, increase the market volatility, and maybe induce a "speculative bubble". We carefully remind our reader that market irrationality is not the result of a sole bias. Indeed, we assert that the overreaction of the participants, and therefore, the market, is rather due to the combination of many of them SHILLER (1988, p.2). They may work in coordination with each other to affect significantly the market. Therefore, they influence the market when a sizeable group of individuals, the irrational participants in our case, tends to adopt them. We want to focus on the factors that may affect a single individual. We already consider social interactions that might amplify the market volatility such as "herding behaviors" for instance. Hence, we decide to not develop them extensively in our thesis.

Section 2.2.1: Information processing

This section resumes the category of factors that may spurt the market volatility because of an inefficient information processing. In fact, individuals are likely to have unbalanced attention and outweigh probabilities on certain events at the expense of others. This eventually affect their decision-making processes, which may have a sizeable impact on the stock market.

Individuals are likely to commit **forecast errors**. KAHNEMAN and TVERSKY (1973) find out that they tend to prioritize recent experiences over older ones when attempting to predict the future. Based on that discovery, DE BONDT and THALER (1990) asserts that it may be a source of participants' overreaction. In fact, even the most rational ones are prone to make extreme predictions regarding future prices. In our case, an upward trend in the latest prices may notify the participants that their future levels are expected to sustain the growth in the detriment of plausible alternative outcomes. Hence, it is recommended to buy more assets if we expect those prices to go upward in the immediate future. Therefore, we argue that the forecast errors eventually drive the prices away from their fundamental value. It violates the EMH assumption that rational participants equally weigh their latest and older information when they estimate the prices.

Individuals tend to be **overconfident**. ROSS (1987, pp.140-144) asserts that its root comes from the tendency to partially neglect the uncertainty component when an individual analyzes a situation in its fullest. Despite the abundant empirical evidence that it is extremely difficult to “beat” the market, most of the participants still opt for an active investment strategy BARBER and ODEAN (2001, p.263). Indeed, BODIE et AL. (2014, p.390) find out that the buy-and-hold strategy only accounts for 15 percent of the strategies implemented in the US mutual fund sector. BARBER and ODEAN (2000) argue that households tend to trade much more than to invest into a passive fund. SHILLER (1998, p.27) argues that a combination of overconfidence and anchoring effect partially explain the high-volume trade in the stock market.[2] Indeed, that frequency demonstrates that a sizeable portion of individuals tends to perceive their beliefs as predictors of their future successes. Thus, they believe their ambitions de facto superior to others’ ambitions. Furthermore, those judgements are collectively formed as the participants nurture their own beliefs from the same information set. If we allow those collective judgements to vary over time, we argue a case where they actually drift the prices away from their fundamental value.

Individuals tend to be **conservative**. BODIE et AL. (2013, p. 390) argue that participants have slower reaction time than the EMH suggests when a new evidence or information flows into the market. Indeed, they do not want their current beliefs and perspective of the world to be challenged. Hence, they tend to underreact to new information regarding an event that eventually affects the market. There is also a case where participants are too reactive to the latest information. They therefore overreact. For the former case, we argue that positive information may drive up the fundamental value but the participants' underreaction forces the prices to join it gradually over time, which causes market volatility. For the latter case, the overreactions just influence the prices whereas the intrinsic value don’t necessarily vary.

The **representativeness** bias is the last we mention in this section. It frequently happens that individuals personally infer a pattern occurring within a sample to an entire population. In fact, the lack of consideration towards the sample size infers quick, and often wrong, conclusions while that pattern may be the fruit of pure coincidence KAHNEMAN and TVERSKY (1972). In finance, an uncorrelated succession of points in a chart during a determined period may be misinterpreted by the investors. BODIE et AL. (2014, p.391) argue that those individuals “extrapolate those apparent trends too far into the future”. This partially explains the formation of “speculative bubble”. Indeed, the participants may massively buy assets which in turn swell the price run-up due to unrealistic expectations, and move market prices further from their fundamental value. Ultimately, the accumulated gap closes up as the market corrects the mispricing.

[2] An example of “anchoring effect” is when an individual provides a numerical estimation based on external influences such as other individuals' suggestions

Section 2.2.2: Behavioral biases

Last section has shown some examples where the information is not perfectly processed. Nonetheless, some biases may occur even when the information processing is perfect. Indeed, individuals are still able to make irrational decisions. This section resumes a category of factors that relates individuals' interpretations of risk to the market volatility.

The first one is **framing** bias. KAHNEMAN and TVERSKY (1973, p.12) introduce the framing as a specific presentation of choice problem that connects with the norms, habits and expectations of the decision maker. Indeed, an individual can make two different decisions depending on how a problem has been introduced to him. In our case, the framing of an investment and the risk involved may influence the participant's decision-making process. BODIE ET AL. (2014, p.391) argue that "individuals may act risk averse in terms of gain but risk seeking in terms of losses" based on the way those risks are framed. Hence, participants may invest in (risky) assets they would never invest if they were fully rational. Those investments eventually induce a mispricing that could be avoided if they were fully rational.

Mental accounting is a specific case of framing. In our case, it means that an individual tends to arbitrarily segregate his resources into different mental compartments and the decisions, and risks involved, he makes depend on which mental compartment he wants to use. In fact, each compartment has its specific objective and thus its own approach to risk STATMAN (2008, p.3). In one compartment, such as a fund for his children's education, he makes risk-averse decisions whereas in another one, such as equity fund, he makes risk-lover decisions. Hence, he is not afraid to lose money into risky investments and has tendency to trade excessively as he also expects to outperform the market. The adoption of such behavior by the aggregate of participants eventually affects the stock market. SHLEIFER (1986) argues that mental accounting partially describes the predisposition for stock prices to suddenly increase whenever a stock is added to a US stock market index, which is a straightforward evidence of mispricing. Indeed, its incorporation doesn't affect the fundamental value of the stock.

Regret avoidance is another bias that influences market volatility. Participants strive to avoid bad feelings related to their decisions. And as they have decided to pick an investment that has eventually turned out to be a losing one, their bad feeling is materialized through regret. Furthermore, the effective selling of their losing investment permanently confirms that their decision was a mistake they committed on their own, and hence, it amplifies the feeling of regret. Therefore, they decide to hold onto their losing assets as much as possible, and thus, defer its selling while their values keep bombing SHEFRIN and STATMAN

(1985). On the other side, those participants accelerate the selling when those assets are winning so they don't not feel any remorse once those assets become losing investments. The volume trade might be an indicator of the magnitude of this bias SHILLER (1998, p.12). Those behaviors challenge the EMH.

Section 2.2.3: Affect

The literature suggests that an owner has a particular affection for the object he owns. Indeed, an object calls upon good or bad feeling regardless of its market value. In the economic world, BODIE et AL. (2014, pp.292-293) argue that participants regard some companies with positive affect because of the way they are perceived by the public for instance. Their high market valuation despite an objective lack of profitable activities may be explained through this behavior, which sustains such level of prices. As the demand for their stocks soars, their prices turn out to be much higher than their fundamentals indicate. Therefore, those stocks display high volatility.

PART II: EMPIRICAL ANALYSIS

Chapter 3: Theoretical framework

This chapter develops more extensively our present value model (1.2). SHILLER (1981 a) shows it offers many opportunities to test for market volatility. Indeed, we first derive an inequality based on the relationship between the actual prices and their corresponding fundamental value, that we will rather call here "perfect-foresight price" or "ex-post rational price". From the basic present value model, we will introduce an alternative version of the model which will allow us to derive additional inequalities.

Paragraph 3.1: Efficient markets present value model

We start our chapter by explaining extensively model (1.1). In fact, we have combined it with equation (1.2) to develop a present value model consistent with the efficient market hypothesis. As explained in the first chapter, the prices are the summation of the discounted future dividends expected by the market.

$$P_t = \sum_{k=0}^{\infty} \gamma^{k+1} E_t D_{t+k} \tag{3.1}$$

Where P_t is the real price and D_t is the real dividend discounted by a constant real discount factor γ which includes the real discount rate r.[3] We expect those future dividends conditionally to all information currently available. Hence, they may still change over time because model (3.1) states that the expected future dividends are random variables. The market prices movements are thus explained by that condition. SHILLER (1981 a) develops model (3.1) extensively. In fact, he adapts the model by considering the long-term growth rate of the prices and the inflation. Hence, he introduces the present value model with real detrended variables.

$$p_t = \sum_{k=0}^{\infty} \bar{\gamma}^{k+1} E_t d_{t+k} \tag{3.2}$$

Where p_t is the real detrended prices, d_t is the real detrended dividend and $\bar{\gamma}$ is the product of the long run growth factor, λ, and the constant real discount factor discount factor, γ. Thereafter, model (3.2) allows us to compare the actual prices

[3]Discount factor formula: $\gamma = \frac{1}{1+r}$

and the perfect-foresight ones, and eventually to derive the variance-bound inequalities.[4][5] The subsequent chapters will exclusively treat those variables. For the remaining of our thesis, the terms "prices" and "dividends" actually refer to real detrended prices and dividends.

Paragraph 3.2: Forecasting

We have suggested in our first chapter that the prices of an asset are the conditional expectations of its fundamental value. Hence, we can also argue that prices are the optimal forecasts of the fundamental value. In this chapter and the second part overall, we resort to the terms “perfect-foresight” and “ex-post rational” price instead of the “fundamental value” but we inform our reader that those terms are interchangeable. SHILLER (1981 a, p.425) derives the perfect-foresight pricing model with the same logic ORLEAN (2004, pp.242-243) derives model (1.1).

$$p_t^* = \sum_{k=0}^{\infty} \bar{\gamma}^{k+1} d_{t+k} \tag{3.3}$$

Where p_t^* are the perfect-foresight prices. It resumes the price an asset must have under certainty. Hence, it is equivalent to the fundamental value (1.1) developed in chapter 1. To show an example of the difference between p_t^* and p_t, SHILLER (1981 a, p.422) plot two figures of their evolution over time.

Figure 3.1 resumes the Standard and Poor's 500 index past performances while Figure 3.2 resumes the Dow Jones Industrial Average past performances.

[4] SHILLER (1981 a, p.424) also argues that $\bar{\gamma} = \frac{1+g}{1-r}$

[5] $\lambda = (1+g)$ where g is the growth rate of the prices over time

Figure 3. 1

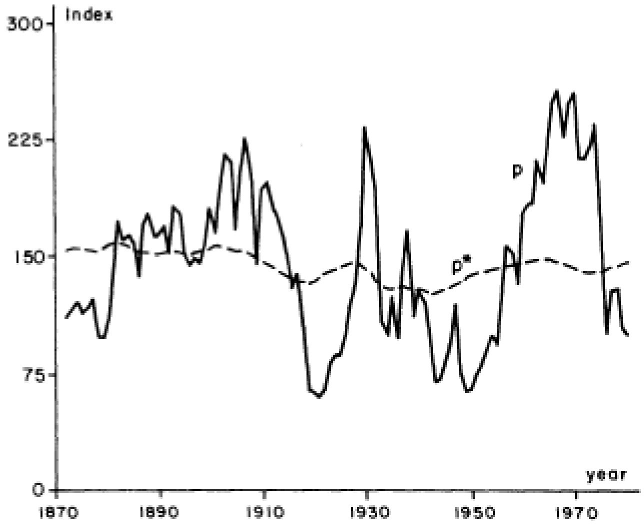
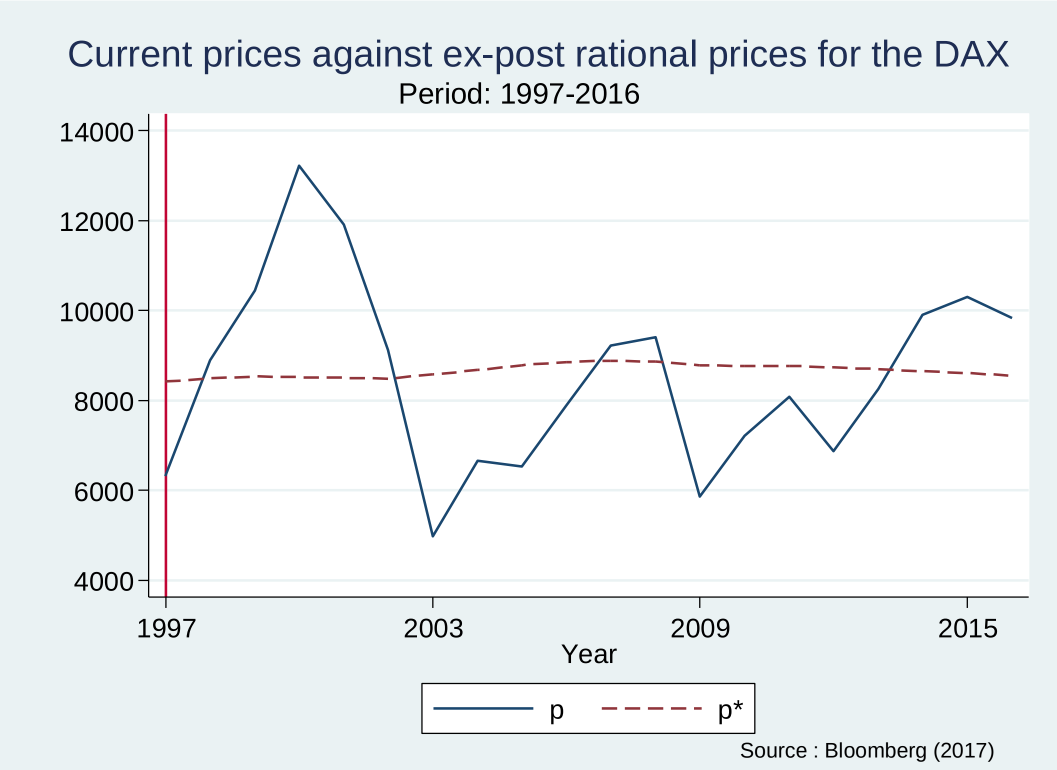


Figure 3. 2

We also display Figure 3.3 based on the stock market index of our choice, the DAX.

Figure 3. 3



Figures 3.1-3.3 are extensively discussed in chapter 6. The difference between actual prices p_t and its "ex-post rational" counterpart p_t^* can be intuitively explained. SHILLER (1981 a, p.426) argues that p_t^* is only observable at the periods following time t because of the impossibility to observe the realized future dividends that compose it. However, the market efficiency argues that the actual prices p_t are the best estimations of the level p_t^* might attain at t. As stated in chapter 1, those estimations are possible thanks to all the information available at that moment. As prices are function of expected future dividends, p_t is therefore the rational forecast of p_t^*.

$$p_t = E_t(p_t^*) \qquad (3.4)$$

Equation (3.4) is equivalent to equation (1.2). The only difference is that SHILLER (1981 a, p.422) designed (3.4) as a testable model whereas (1.2) was not. The rational forecast encompasses a variable denoted as the forecast error which is basically the difference between p_t^* and p_t.

$$u_t = p_t^* - p_t \tag{3.5}$$

The forecast error u_t essentially encompasses the exogenous events that are not included in the forecast of p_t^*. We have explained in the first chapter that those events are unpredictable. Hence, the market under uncertainty cannot take them into account while estimating the future dividends. The term "exogenous events" can also be dubbed as "noises", "exogenous shocks" or simply "shocks".

Coming back to our present value model, SHILLER (1981 a, p.422) deduces that the rational forecast of p_t^* allows him to derive a more classical expression of equation (3.5).

$$p_t^* = p_t + u_t \tag{3.6}$$

Equation (3.6) is the first model we estimate in chapter 5. Furthermore, it allows SHILLER (1981 a, p.422) to derive his first variance-bound inequality. In both cases, the independence of the forecast error u_t is crucial for the consistency of the model. Indeed, the movements of p_t must not correspond to the movements of the forecast error u_t at any degree. Hence, their covariance must be equal to zero otherwise the model is simply untestable.

$$cov(p_t, u_t) = 0 \tag{3.7}$$

Expression (3.7) states the independence condition. SHILLER (1981 a, p.422) argues that if it is violated, a relationship must exist between p_t and u_t. In fact, it means that the forecast can be improved and therefore p_t is not the optimal forecast of p_t^*.

Paragraph 3.3: First variance-bound

Last paragraph, we have insisted on the non-violation of the independence condition (3.7). This paragraph focuses on the implication of condition (3.7) which is essentially the implementation of the first variance-bound by SHILLER (1981 a, p.422). First, the independence assumption implies for expression (3.6) that the variance of the dependent variable, p_t^*, is equal to the sum of the variance of the independent variable, p_t, and the variance of the error term, u_t. [6]

$$Var(p_t^*) = Var(p_t) + Var(u_t) \tag{3.8}$$

Equation (3.8), in its turn, implies that the variance of the dependent variable, p_t^*, has a greater value than the variance of the independent variable, p_t. Hence, Shiller derives an inequality of the variances.

$$Var(p_t^*) \geq Var(p_t) \tag{3.9}$$

Expression (3.8) therefore implies that the volatility of the independent variable, p_t, is smaller than the one of his counterpart, p_t. The standard deviation is an easier metric to interpret that relationship. Hence, the volatility, and thus the standard deviation, of the actual market prices, p_t, must be lower than the one from the perfect-foresight prices, p_t^*.

$$\sigma(p_t) \leq \sigma(p_t^*) \tag{3.10}$$

Inequality (3.10) is the first variance-bound derived. We will test it on the DAX's past performances in chapter 6.

[6] The original expression is $Var(p_t^*) = Var(p_t) + Var(u_t) + 2cov(p_t, u_t)$ but the independence condition (3.1) states that $cov(p_t, u_t) = 0$

Paragraph 3.4: Alternative writing of the present value model

We will later discover that present value model (3.1) actually violates a condition that hinders its empirical estimation.[7] Shiller therefore introduces an alternative present value model that solves for that shortcoming. We simply refer to this model as the alternative model. Its advantage lies on the possibility to extensively develops the limits set by present value model (3.1) SHILLER (1981 a, p.423). SHILLER (1981 a, pp.425-426) derives a model that considers the innovations in variables. It means that the conditional expectations over a variable X_{t+k} can evolve between two periods because new market-related information has flowed in since.

$$\delta_t p_t = \sum_{k=0}^{\infty} \bar{\gamma}^{k+1} \delta_t \, d_{t+k} \tag{3.11}$$

$$where\ \delta_t \equiv E_t - E_{t-1}$$

The sign δ_t is denoted as the "innovations operator" and it is the main characteristic that distinguishes model (3.11) from model (3.1). It is important to not confuse the innovations in prices $\delta_t p_t$ with the difference in prices Δp_t even though Shiller's analysis and ours show that they approximatively have the same values.[8] The alternative model has several implications. First, the innovations in price, $\delta_t p_t$, are identifiable yet not predictable. Second, it relates the innovations in prices to the innovations in dividends. However, the latter remains unobservable as they remain random variables. Finally, the alternative model allows us to derive two additional inequalities. In fact, SHILLER (1981 a, p.423) argues that those inequalities strengthen the validity of the results provided by the first inequality. We will extensively develop their consequences in chapter 6. The next two sections will focus on the development of those two inequalities.

Section 3.4.1: Second variance-bound

SHILLER (1981 a, pp.426-427) develops this inequality in response to the shortcomings of (3.1). In fact, he discovers that the error term u_t is serially correlated. This is a violation of the classical linear assumptions and therefore the present value model cannot be empirically tested. However, he argues that the innovations in price $\delta_t p_t$ is not serially correlated, and therefore testable. In fact, he re-uses expression (3.5) and plugs model (3.2) and model (3.3) into their respective spots. After some rearrangements, he gets an equation relating the error term to the innovations in prices.

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[7] The present value model has a component that actually violates one of the Gauss-Markov assumptions. This will be developed extensively in our next chapter

[8] $\Delta p_t \equiv p_t - p_{t-1}$ which denotes the difference in prices

$$u_t = \sum_{k=1}^{\infty} \bar{\gamma}^k \delta_{t+k} p_{t+k} \tag{3.12}$$

We observe in expression (3.12) that the error term is the summation of the discounted innovations in prices. Furthermore, we observe that if we subtract (3.12) by the discounted future error term, the remainder is the discounted future innovations in price.

$$u_t - \bar{\gamma} u_{t+1} = \bar{\gamma} \delta_{t+1} p_{t+1} \tag{3.13}$$

Expression (3.13) means that the transformed error term is actually the discounted future innovations in price at t+1. LEROY and PORTER (1981, p.560) and SHILLER (1981 a, p.426) assert that while the error term is serially correlated, $\delta_t p_t$ is not. Hence, it is possible to estimate the alternative model and observe whether the empirical results are consistent with the theory. Therefore, alternative model (3.11) allows us to operate a regression test in chapter 5. Based on expression (3.13), Shiller decides to regress $u_t - \bar{\gamma} u_{t+1}$ on the variables known at time t.

$$\delta_{t+1} p_{t+1} = p_t + e_t \tag{3.14}$$

Where e_t encompasses all the unobserved factors that occurs at time t. $\delta_{t+1} p_{t+1}$ is obtained when we divide (3.13) by $\bar{\gamma}$. Being a transformation of the error term, the future innovations in price $\delta_{t+1} p_{t+1}$ must not be correlated with the actual prices p_t. This amounts to argue that $\delta_{t+1} p_{t+1}$ cannot be forecasted which is consistent with EMH statement. Under that configuration, the market is efficient.

$$cov(\delta_{t+1} p_{t+1}, p_t) = 0 \tag{3.15}$$

Now that the alternative model is specified, SHILLER (1981 a, p.427) focuses on the innovations in dividends. Indeed, that variable allows him to derive the second inequality. He especially focuses on the effect that innovations in dividends $\delta_t d_t$ may have on the actual dividends d_t. Hence, he derives three conditions that make the derivation of the second variance-bound possible. First, the innovations in price are not serially correlated. We have already developed the reasons above. Second, the dividends are assumed to be stationary. In fact, Shiller argues that by detrending exponentially the real dividend series, it appears to follow a stochastic stationary process.[9] We extensively discuss this argument in chapter 7. Third, the innovations in dividend $\delta_t d_t$ must have a non-zero variance. This makes sense as a constant $\delta_t d_t$ implies that the innovations in prices $\delta_t p_t$ is also constant over time in present value model (3.11). Therefore, the latter fails to explain the market prices behavior. The realization of those three conditions makes the maximization of $\delta_t p_t$ possible. Eventually, the maximization of $\delta_t p_t$ subject to the dividend condition provides us the second variance bound.[10] [11]

$$\sigma(\delta_t p_t) \leq \sigma(d_t)/\sqrt{\bar{r}_2} \tag{3.16}$$

$$where\ \bar{r}_2 = (1+\bar{r})^2 - 1$$

The two-period discount rate $\bar{r}_2$ is approximatively worth twice the one-period discount rate $\bar{r}$. Our second variance-bound (3.16) may be intuitively explained. The maximum of the variance of $\delta_t p_t$ is reached whenever the information regarding the future dividends are progressively and smoothly revealed until the moment the latter are effectively issued SHILLER (1981 a, p.427) This therefore explains the market price unpredictability. Indeed, the innovations in the prices are not forecastable because the future dividends (at $t+1$ for instance) are distributed during the period where all the information regarding them are fully revealed. Hence, the theory is consistent with the market price movements.

Section 3.4.2: Third variance-bound

Last section, SHILLER (1981 a, pp.427-428) has demonstrated that maximizing the variance of $\delta_t p_t$ provides us another inequality consistent with the market efficiency theory. In addition, it is possible to derive another inequality with a different approach.

This time, Shiller maximizes the prices difference Δp_t. We have stated in the last section that p_t is also assumed to follow a stationary process like d_t. Moreover, it must not be correlated with $\delta_{t+1} p_{t+1}$ such that condition (3.15) is satisfied. With those two conditions satisfied, the variance of Δp_t is well defined.

$$var(\Delta p_t) = 2var(p_t) - 2cov(p_{t,}\, p_{t+1}) \tag{3.17}$$

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[9] By real term, we mean that the inflation is removed from the series

[10] The dividend condition is related to the second and third condition. Indeed, the variance of the dividend must be equal to the sum of the variance of the innovations in dividend: $var(d) = \sum_{k=0}^{\infty} var(\delta d_k)$. The stationarity condition guarantees that the variance of the innovations in dividend is independent of the time variable t.

[11] SHILLER (1981 a, p.426) states that $\delta_t p_t = \Delta p_t + d_{t-1} - \bar{r} p_{t-1}$

In equation (3.17), we see that the variance is function of $cov(p_{t,}\, p_{t+1})$. We know that $cov(p_{t,}\, p_{t+1})$ is related to $cov(p_{t,}\, \delta_{t+1}p_{t+1})$.[12] The satisfaction of condition (3.15) allows for the following rearrangement.

$$cov(p_t, p_{t+1}) = \frac{var(p_t)}{\bar{\gamma}} - cov(d_t, p_t) \tag{3.18}$$

Once we plug (3.18) into the (3.17), we obtain expression (3.19) that we must maximize.

$$var(\Delta p_t) = 2(1 - \frac{1}{\bar{\gamma}})var(p_t) - 2\rho_{dp}\sqrt{var(d_t)}\sqrt{var(p_t)} \tag{3.19}$$

Where ρ_{dp} is the correlation coefficient between d_t and p_t. Like $var(d_t)$, it is a given variable. Hence, we obtain our third and last variance-bound after maximizing the equation (3.19) with respect to $var(p_t)$ and rearranging the first order condition.

$$\sigma(\Delta p_t) \leq \sigma(d_t)/\sqrt{2\bar{r}} \tag{3.20}$$

Inequality (3.20) provides us an intuitive explanation. In fact, a smooth and regular distribution of the dividend ensures the maximization of the variance of the prices first-difference, Δp. This implies that a very abrupt and irregular distribution of the dividends threatens the variability of the market prices and hence threatens the consistency of the model with the market prices behavior. It is important to note that the stationarity assumption however implies that the dividends distribution must not be too smooth. Indeed, an extremely smooth distribution of the dividends may merge with the distribution of a constant amount of dividends each period, which violate the consistency of the present value model.

[12] Indeed, $cov(p_{t,}\, \delta_{t+1}p_{t+1}) = cov(p_{t,}\, p_{t+1}) + cov(d_t, p_t) - var(p_t)/\bar{\gamma} = 0$ see the working paper version of SHILLER (1981 a, p.11)

We now have derived three inequalities, (3.10), (3.16) and (3.20), from the standard present value models (3.2) and (3.11). The theoretical framework therefore allows us to conduct an empirical research thereafter.

Chapter 4: Data

This chapter essentially covers everything related to the data and variables we will use in the subsequent chapters. We first explain the sources used to recover the raw data. Thereafter, we transform those nominal variables to obtain the variables presented throughout the first chapter. Eventually, we proceed to a quantitative and qualitative summary of our main variables, the prices, its ex-post rational counterpart and the dividends, in order to put them in perspective before our empirical analysis. From now on, we will refer to the fundamental price p_t^* as the ex-post rational price due to the methodology we resort to derive it.

Paragraph 4.1: Data recollection

We have extracted our main data, nominal prices and dividends, through BLOOMBERG TERMINAL. The reason behind our choice for the index is justified by COWLES (1938, p.2). He argues that one of the purposes of the index is to “represent […] what would have happened to an investor’s fund if he had bought […] all stocks quoted in the stock market”. In our context, we replace the quote “all stocks” by the most valuable stocks of the stock market.[13] In fact, we have turned our choice towards the main German stock market index, namely the DAX for several reasons.[14]

First, its portfolio encompasses the 30 largest capitalized and liquid German companies.[15][16] Their stock price movements, either individually or collectively, have a sizeable effect on the German stock market. Indeed, those stocks are the most actively traded in the highest segment of the Frankfurt Stock Exchange.

Second, we have not found in the literature an empirical work already treating this stock market. Therefore, we see it as an opportunity to add an original contribution to the literature.

Third, the DAX is one of the largest indexes in the world next to the already renowned American SP500, the British FTSE or the Japanese Nikkei. Hence, it is safe to assume that its behavior is somewhat representative of the world stock markets prices behavior. Indeed, a negative impact on the German stock market might have a sizeable effect to the world prices.

Fourth, the Frankfurt Stock Exchange is an established stock market. It is monitored by the German legislators who strive to effectively ensure the transparency and the fairness regarding the reported prices. This implies that those are less likely to be manipulated by a certain group of individuals who receives

[13] Also known as blue chip stocks
[14] DAX stands for "Deutscher AktienindeX"
[15] Source: BLOOMBERG [online]
[16] Source: YAHOO FINANCE [online]

privileged information regarding the future prices and eventually takes advantage of them for its own benefit. Hence, the strict regulation regarding this stock market has helped us in our choice HAUCK (2015).

And finally, the fifth reason is directly related to the first one. Indeed, its stock composition remains relatively constant over time. In fact, SHILLER (1981 a, p.432) argues that an index composed of a small number of large-sized companies has the advantage of remaining relatively constant whereas the one including a much larger number of companies tends to have a high rate of turnover such as the Standard and Poor's 500.[17][18]

Following the example set by Shiller, we have extracted the available data covering every closing price expressed in local currency, euro, for the month of January, I_t. Thereafter, we have computed the average January closing price for each year. For the dividends, we have extracted the 12-month dividends per share expressed in local currency. The average January closing prices series starts at 1960. However, we haven't been able to extract any dividend data before 1997. Hence, the years covered in our analysis goes from 1997 to 2016. The number of observations mounts up to 20. We have extracted both series in their nominal values and thus have adjusted them to inflation in order to derive the real level of each series. This had been made possible thanks to the producer price index series from the OECD database with its base year set at 2010.[19][20][21]

On a qualitative note, our historical series cover different events that affected the German economy at some point. Observing the real values allow us to observe the real impact of those events on the index. We therefore decide to display figure 4.1, so we can illustrate the different events that have occurred at that time.

[17] It means that for a given time, the index changes its composition quite frequently.
[18] Source: MORNINGSTAR INC. [online]
[19] Indeed, the values were changing depending on the currency we were setting
[20] Source: OECD [online]
[21] In chapter 7, we will analyze the prices series that goes down to 1960 and use the wholesale price index provided by the World Bank to derive the real prices.

Figure 4. 1

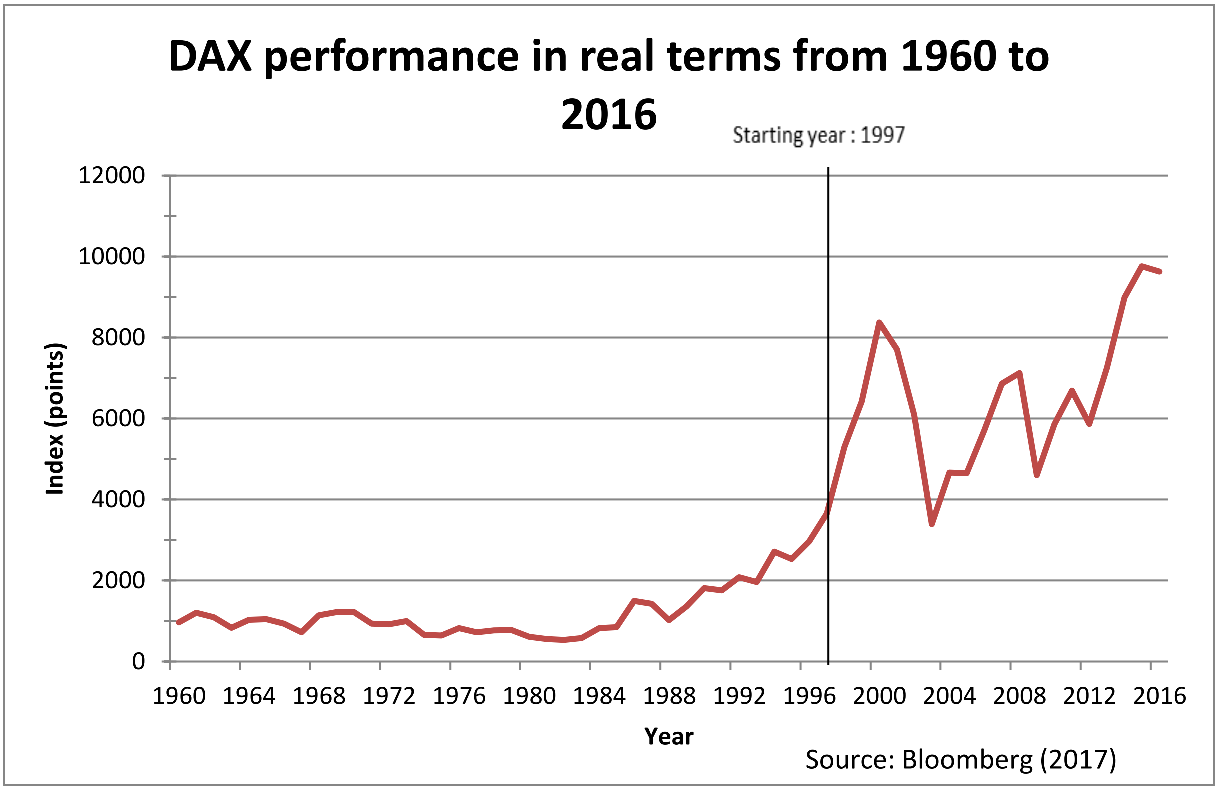


Figure 4.1 starts at 1960 although our starting point is set at 1997. We see a line partitioning figure 4.1 in two. In fact, the right side is the data we will analyze while the left one is the part of the dataset we are not able to work with before chapter 7.

We observe that the index has started to display a lot of variations around our starting point. Indeed, our starting date, 1997, coincides with the increasing global attention towards the IT sector during the late 1990's to the early 2000's. At that time, the German stock market was welcoming a high number of new investors with grandiose expectations concerning their returns on investment. Thus, the stock market underwent to an asset price bubble. For instance, the IPO of the former public company Deutsche Telekom in 1996 had helped to popularize the investment in the stock market. By 2000, their stocks were very popular among new investors. Hence, a boost in the index valuation occurred. Overall, the increasing demand for numerous stock companies from new investors, especially Deutsche Telekom, has contributed to increase the aggregate demand just before 2000. Many other factors have encouraged the investment in risky and speculative assets during that time.[22][23] At that time, the then-peak record was reached in March 2000 by crossing the nominal value of 8000 points BORCHERS (2010).

[22] Source: DEUTSCHE TELEKOM [online]
[23] Source: WIKIPEDIA [online]

Afterwards the investors started to notice that their expectations were effectively too high. This explains the decrease by more than 50 percent of the index valuation between 2000 and 2002. It is also the sharpest of the whole series.

Thereafter, a second market expansion had followed with an all-time nominal, but not real, peak in 2007. It was abruptly stopped by the worldwide financial crisis that eventually led to the "Great Recession". This downwards effect was sizeable up until 2012. By coupling that effect with the European debt crisis that worsened around 2011, the index performance persisted in its negative spiral at that time THE LOCAL (2012). However, from 2013 and onwards the index has totally recovered its pre-crisis level and has steadily reached new all-time heights on a yearly basis.

Based on our data, the real dividends tend to adopt the same pattern than the real prices although that the European debt crisis did not seem to affect them significantly.

Paragraph 4.2: Data transformations

After obtaining the nominal prices and dividends from BLOOMBERG TERMINAL, we have operated several transformations in order to obtain the main variables we have introduced in chapter 3.

Section 4.2.1: Real prices and dividends

We denote the price series, I_t, which simply represents the nominal prices. We also have the dividend series, div_t, which represents the nominals dividends. The real prices, P_t, is the product of the nominal value and the ratio of the inflation index at the base year, 2010, and the year corresponding the observation. The real dividends, D_t, was obtained through the same procedure.

$$P_t = I_t * \frac{\pi_b}{\pi_t} \quad and \quad D_t = div_t * \frac{\pi_b}{\pi_t} \tag{4.1}$$

Once we have obtained our real variables, we have focused on the exponential detrending of those variables.

Section 4.2.2: Detrended real variables

The tendency we wanted to remove from our observations was the exponential long run growth factor. To compare the movements of the current real prices to our **ex-post rational prices**, it was a necessary endeavor. SHILLER (1981 a, p.432) first estimated the trend by regressing of the logarithm of the real prices against an intercept and time trend.

$$ln(P_t) = a + bt + \varepsilon_t \tag{4.2}$$

From expression (4.2), we have obtained the estimate $\hat{b} \approx 0{,}0294$ and it was significant at any level of confidence. We stated the price series increased every year by an average rate of approximatively 2,94 percent. Afterwards, he sets expression (4.3).

$$\lambda = e^b \tag{4.3}$$

Formula (4.3) was very useful to derive the long run growth rate, g. Indeed, the equation linking the growth rate and the upper equation is expression (4.4).

$$\lambda^{t-T} = (1+g)^{t-T} \tag{4.4}$$

Where T is the base year, which 1997 in our sample. We have also observed that g, which is our annual growth rate, is equal to 2,98 percent. Once we have obtained the long-run growth rate, we could detrend our real variables by dividing them with (4.4).

$$p_t = \frac{P_t}{\lambda^{t-T}} = \frac{P_t}{(1+g)^{t-T}} \quad and \quad d_t = \frac{D_t}{\lambda^{t-T}} = \frac{D_t}{(1+g)^{t-T}} \tag{4.5}$$

After obtaining the real detrended price p_t, and the real detrended dividend d_t, our next step was to scale them up so that the final year's price, p_{2016}, is equal to the final year's nominal price, I_{2016} so we have multiplied the detrended real prices and dividends series by 1,8. Now, we have obtained the variables, p_t and d_t, we will use in different tests in our next two chapters.

Paragraph 4.3: Discount rate

We want to explain how SHILLER (1981 a, p.424) has developed his discount rate for the efficient market model. Indeed, we have developed in chapter 3 the present value model (3.3). This equation displays a constant real discount factor, $\bar{\gamma}$, that includes a discount rate, $\bar{r}$.

$$\bar{\gamma} = \frac{1}{1+\bar{r}} \tag{4.6}$$

We must remember that $\bar{\gamma} = \lambda\gamma$. Thus, the real discount rate r in model (3.1) is different from the real discount rate $\bar{r}$ in models (3.2) and (3.3) as the latter were adjusted to the long run growth factor while the former was not. Shiller has eventually found out that $\bar{r}$ is equal to the division of the expected value of the detrended real dividend, $E(d_t)$, by the expected value of the detrended real price, $E(p_t)$. In other words, the sample mean of the detrended real dividend is divided by the sample mean of the real price.

$$\bar{r} = \frac{E(d_t)}{E(p_t)} \tag{4.7}$$

After calculating equation (4.7) with our data, we have found that $\bar{r}$ = 2,78 percent. Now that we have obtained p_t, d_t and $\bar{r}$, we plan to obtain the ex-post rational prices, p_t^*.

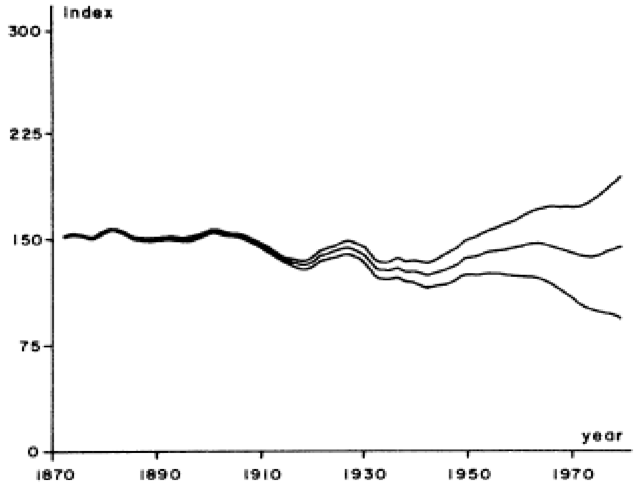
Paragraph 4.4: Ex-post rational prices

We have already described in the first chapter the relationship between the current real prices and the ex-post rational prices. Their relation is expressed in expression (3.4) where we find the present value model (3.3). It is important to note that each observed p_t^* always includes an unobservable factor that eventually affects the realized dividend. We have obtained p_t^* by proceeding recursively from our terminal year, which is 2016 here, to our starting year.

$$p_t^* = \bar{\gamma}(p_{t+1}^* + d_t) \tag{4.8}$$

We observe that the weight of the terminal value is smothered whenever we move upwards. The terminal date is determined as the sample average of the detrended real prices p_t. The choice of equation (4.8) is justified by the guarantee that p_t^* will not display therefore excessive variance due to a time component. Indeed, the use of another formula may likely give a trend, either upwards or downwards, to our p_t^* series as SHILLER (1981 a, p.425) shows in the following chart.

Figure 4. 2



In figure 4.2, Shiller aims to show the different trajectories p_t^* may take if we use another terminal condition. In fact, we clearly observe from figure 4.2 that resorting to an alternative terminal condition may provide different outcomes. Hence, our choice implies that the variation of our ex-post series is not influenced by the trend and our variance is finite.

Paragraph 4.5: Definitions and summary statistics

In this paragraph, we essentially present several quantitative statistics in order to, first, put in perspective the coefficients we want to estimate in the next chapter, and second, emphasize our units of measurement WOOLDRIDGE (2014, p.549). Hence, we first present a table with the definitions for the different variables we have introduced in this second part. Thereafter, we introduce a table comparing our data with the ones Shiller has worked with. And lastly, we put summary statistics directly related with the empirical work we plan to undertake in the next chapter.

We know that a lot of variables have been used here and therefore we introduce a table covering the main ones. It will be easier for our reader to understand their respective role in our empirical work and have an overview of the developed concepts. The following table comes directly from SHILLER (1981 a, p.425).

Table 4. 1: Definitions of the principal symbols

γ	Real discount factor for series before detrending
$\bar{\gamma}$	Real discount factor for detrended series
D_t	Real dividend accruing to stock index (before detrending)
d_t	Real detrended dividend
Δ	First difference operator
δ_t	Innovations operator
E	Unconditional mathematical expectations operator
E_t	Mathematical expectations operator conditional on information at time t
λ	Trend factor for price and dividend series
P_t	Real stock price index (before detrending)
p_t	Real detrended stock price index
p_t^*	Ex post rational price index
r	One-period real discount rate for series before detrending
$\bar{r}$	Real discount rate for detrended series
$\bar{r}_2$	Two-period real discount rate for detrended series
t	Time (year)
T	Base year for detrending and for producer price index

Further, we have also drawn a table comparing some sample statistics with the data sets SHILLER (1981 a, p.431), Modified Dow Jones and Standard and Poor's 500, use for his own analysis. The figures are expressed in units.

Table 4. 2: Comparison of sample statistics between our empirical analysis and SHILLER's (1981, p.432)

	DAX	Modified Dow Industrial	Standard and Poor's
Sample period	1997-2016	1928-1979	1871-1979
1) $E(p)$ $E(d)$	8 545,1 237,38	982,6 44,76	145,5 6,989
2) $\bar{r}$ $\bar{r}_2$	0,0278 0,0563	0,0456 0,0932	0,0480 0,0984
3) $b = ln\lambda$ $\hat{\sigma}(b)$	0,0294 (0,0099)	0,0188 (1,0035)[24]	0,0148 (0,0011)
4) $corr(p, p^*)$ $\sigma(d)$	-0,3048 59,458	0,1626 9,828	0,3918 1,481

We notice that there are significant differences between his dataset and ours. First, he had the possibility to observe much more years than us. His shortest sample consists of 52 observations whereas our unique sample of 20 observations.

Secondly, the sample means of our reported prices and dividends displays higher values overall. Several reasons may rise for this significant gap. His analysis doesn't go beyond 1979 while ours only starts almost twenty years after. We observe that in the middle of the 1980's and onwards, both American indices have regularly reached new nominal heights whereas their performances were marginally bullish before that period. As Shiller's analysis happens to cover the pre-1980 periods, the sample mean is obviously smaller compared to the level those indexes have reached afterwards.[25] This mainly explains the relative smaller figures in the four categories as the second depends on the means, the third on the exponential long-run growth rate of the prices and the fourth on the prices and its ex post rational counterpart which, itself, is function of the actual dividends.

Lastly, we don't observe the same stock market. However, several studies have pointed out an increasing correlation between different stock markets across the globe, especially the largest ones. This is generally attributed to an only increasing globalization of the capital and goods around the globe through the recent times KUPIEC (1991) and SONG et AL. (2011). Hence, the bull and bear movements we've witnessed in the DAX correlate positively with the movements of its American counterparts. Unfortunately, we don't observe the same periods as Shiller and therefore our figures are significantly different.

[24] The figure has been reported as such although we question its validity.
[25] Source: YAHOO FINANCE [online]

Summary statistics of the main variables are useful for our following interpretations. The values are all expressed in units and therefore we plan to interpret our coefficient estimates as such. As those units are expressed in points, we therefore refer to a variation of those variables in points.

Table 4. 3: Summary statistics of our main variables

Number of observations	Variable	Mean (in points)	Std. Dev. (in points)	Min (in points)	Max (in points)
20	p_t	8 545.097	2 089.647	4 971.179	13 226.4
	p_t^*	8 654.662	143.0998	8 415.12	8 883.398
	d_t	237.3786	60.1144	132.2765	323.0098

Table 4.3 provides some interesting insights. We see that the mean of the actual prices and its ex-post counterpart are comparable even though their sample standard deviation really differs. This is partly explained by the fact that the extreme levels of the actual prices are around 8000 points apart from each other while the extreme levels of the ex-post rational prices are around 400 points apart from each other. We reserve the extensive analysis of those statistics for chapter 7.

The dividend series obviously has a smaller mean than the other variables as it is theoretically a component of them. It also has a smaller variance than both and its extreme values are around 200 points apart from each other.

We have eventually obtained all the variables needed to conduct our tests in the next two chapters. We have also described the data in order to explain the context behind the lately historical performances of the DAX. From now on, we can focus on the methodology underlying our empirical results.

Chapter 5: Regression tests

In this chapter, our methodology consists of testing the relationship shown in model (3.6) by estimating it with econometrics. We later find out that one of the properties required to estimate (3.6) is violated and therefore we decide to focus on the relationship displayed in model (3.14) that solves for the violated property. We eventually report our empirical results by comparing them to Shiller's results and discuss their implications.

Paragraph 5.1: First model

Our first paragraph is focused on the estimation of model (3.6) with our dataset. Hence, we restate it in a standard econometric form.

$$p_t^* = \beta_0 + \beta_1 p_t + u_t \tag{5.1}$$

Expression (5.1) is the model for the population and we are interested in the partial effect that the actual price p_t might have on the ex-post rational price p_t^*. This partial effect is embodied by the parameter β_1. We obviously don't, and never will, know the true value of β_1 because we are unable to observe the entire population. However, we can set a benchmark that we use as a null hypothesis. Hence, CAMPBELL et AL. (1997, p.276) states the null hypothesis must be $\beta_1$equal to unity.

$$H_0: \beta_1 = 1 \tag{5.2}$$

The null hypothesis (5.2) therefore states that variation of p_t has a full effect on p_t^* on a population level. Otherwise, the alternative hypothesis essentially states that p_t^* has a disproportionate relationship with p_t.

Even though we do not know the value of β_1 at the population level, we can resort to our sample by estimating the value it may take. In fact, SHILLER (1981 a, p.426) suggests that we resort to OLS estimation for our model.[26] Hence, we resort to $\hat{\beta}_1$ as an OLS estimator of β_1. But before we test our hypothesis, we must be certain that the classical linear model assumptions are satisfied for model (5.1) WOOLDRIDGE (2014, pp.279-286). Indeed, the satisfaction of those assumptions guarantees us an unbiased and efficient estimator that helps us to infer a relationship even with a small sample. As Shiller mainly focuses on some specific properties of the model, we decide to just focus on the exogeneity of p_t, which is the subject of our first section, and the serial correlation of u_t, which is the subject of our second section. We have verified on our own that nothing indicates any violation of the other assumptions, and therefore they would add little value to our thesis if we discuss them.[27] For the properties we will discuss, we start each section with their respective definition provided by WOOLDRIDGE (2014, pp.310-313) and resort to verify their validity with the appropriate tests.

[26] OLS estimation stands for ordinary least squares estimation

[27] SHILLER (1981 b, p.3) adds that the scale factor affecting $p_t$and p_t^* removes the heteroscedasticity of u_t

Table 5. 1: Definition of the exogeneity of the regressor WOOLDRIDGE (2014, p.)

For each t, the expected value of the error u_t, given the explanatory variable for all time periods, is zero. Mathematically, $E(u_t \vert p_t) = 0, t = 1, 2, \dots, n$.

Table 5.1's statement is equivalent to the independence condition stated in equation (3.7). This assumption implies that error term at time t is uncorrelated with its contemporary explanatory variable WOOLDRIDGE (2014, pp.280-281). Indeed, it resumes that the error term must not vary alongside the independent variable across the population. Hence, this is the reason behind the use of the terms "independent" and "exogenous variable". Being an unobservable variable, u_t is replaced in our analysis by the OLS residual term, $\hat{u}_t$. A clever way to observe the validity of this property is to plot of a graph of their relationship. In fact, we resort to a scatter plot of $\hat{u}_t$ against p_t. We also add a trend line resuming their relationship and their coefficient of determination to observe if the variation of the total sample in $\hat{u}_t$ is partially explained by p_t.

Figure 5. 1

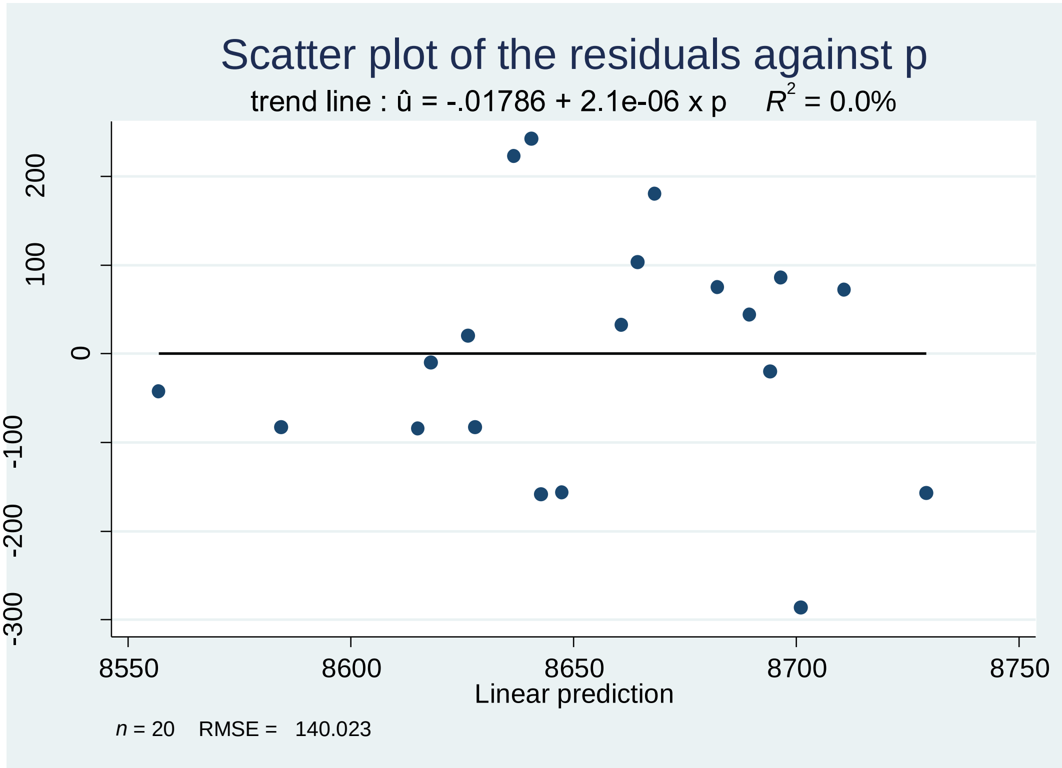


Figure 5.1 displays the different points of those variables scattered around a trend line. Visually, they are quite scattered around the graph and it is not simple to deduce an overall trend by only looking at them. Furthermore, the trend line equation is $\hat{u}_t = -0{,}018$, which can be approximated to zero. The slope is so small that we also approximate it to zero. Moreover, our decision is also strengthened by our coefficient of determination. It shows that $R^2 = 0{,}00$ percent, which means that the variation of the residuals in the sample is not explained at all by p_t. Hence, p_t is a strictly exogenous variable. When we compare the results to the theory developed in chapter 3, it also confirms that the actual prices are the rational forecasts of the ex-post price as stated in expression (3.4). Hence, p_t is an independent variable. The assumption also implies that $\hat{u}_t$ must not be correlated with the lag variables of p_t (p_{t-1}, etc.). On a theoretical basis, our results combined with the validity of the two first classical assumptions states that our OLS estimate $\hat{\beta}_1$ is unbiased. To conclude our point, the assumption is valid, and we can therefore move onto the next section.[28][29]

Section 5.1.2: Serial correlation of the error term

Table 5. 2: Definition of the serial correlation of the error term WOOLDRIDGE (2014, p.283)

Conditional on p_t, the errors in two different time periods are uncorrelated: $Corr(u_t, u_s \mid p_t) = 0$ for all $t \neq s$.

After our analysis for the independency of p_t, we decide to focus on the serial correlation of the error term. The last section has focused on the correlation of the error term to its contemporary regressor and we have not found an apparent relationship between them. Here, the serial correlation essentially means that a variable is correlated to itself across time. In other words, the current level of a variable depends on its past values. In our case, we want to know whether u_t is significantly influenced by its lagged value u_{t-1}. We therefore model a relationship with a white noise of zero mean and constant variance.

$$u_t = \rho u_{t-1} + \varepsilon_t \qquad with\ \varepsilon_t \sim N(0, \sigma^2) \tag{5.3}$$

[28] The two first properties are the linearity and the absence of multicollinearity in the regressors.
[29] However, the fact that the sum of the residuals is equal to zero is non-negligible. Indeed, the sum implies that the residuals are not independent and therefore the scatter plot approximates the relationship between the forecast error and the current prices. But we remain confident in our assessment of the zero-conditional mean. Source: THE UNIVERSITY OF TEXAS AT AUSTIN [online]

Where ε_t is i.i.d. with mean zero and a constant variable.[30] We go by the assumption that this relationship doesn't exist and, hence, our null hypothesis states that the autocorrelation coefficient ρ across the population is not significantly different from zero.

$$H_0: \rho \;= 0 \qquad (5.4)$$

Now that we have defined our model for the population in (5.3), we can estimate it with our sample. To make it happen, we replace once again the error term by the residual term $\hat{u}$. We choose to proceed to a portmanteau test.[31] The results show us that the p-value according to the Q-statistics is 0,00 percent.[32] Hence, we must reject the null hypothesis and infer a positive serial correlation for our error term.[33]

Shiller turns out to face the same problem than us with model (5.3). The presence of a serially correlated error term hinders us to estimate model (5.1). Although we have concluded that our estimate is unbiased, its standard error isn't. Hence, it is not efficient. Therefore, we cannot estimate the model with our sample and discuss of a relationship between p_t and p_t^*, and thus verify whether the actual prices are forecastable.

Paragraph 5.2: Second model

As stated in section 5.1.2, we cannot test the model (5.1) because of its misspecification. Indeed, the serial correlation of the error term has made for us impossible to infer a relationship between p_t and p_t^*. However, we can test another model that corrects the shortcoming. As explained in chapter 3, we resort to a transformed model in such way we obtain a testable model. Hence, we resort to the model (3.14) developed in that chapter and rewrite it as a standard econometric model.

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[30] Here, "i.i.d." stands for an identical and independent distribution of the noises. The "N" in equation (5.3) stands for normal distribution HAMILTON, 1994, p.43)

[31] A portmanteau test basically means that the null hypothesis is well-specified whereas the alternative one is loosely specified. Therefore a rejection of the null hypothesis doesn't necessarily infer that the variable is characterized by a specific pattern. Here our portmanteau test is also known as the Ljung-Box test

[32] "The p-value is the minimum level of significance at which the null hypothesis is rejected" WOOLDRIDGE (2014, p.577)

[33] We reject the null hypothesis at the level of significance of 5 percent

$$\delta_{t+1}p_{t+1} = \beta_0^* + \beta_1^* p_t + e_t \qquad (5.5)$$

In chapter 3, we have suggested that there is no apparent relationship between the $\delta_{t+1}p_{t+1}$ and p_t. In fact, our null hypothesis (5.6) embodies that statement. It states that the parameter is equal to zero.

$$H_0\colon \beta_1^* = 0 \qquad (5.6)$$

Our model suggests that there is no relationship between the $\delta_{t+1}p_{t+1}$ and p_t at a population level. It states that the parameter is not statistically different from zero. The alternative hypothesis states that our parameter is significantly different from zero. With the help of our sample, we estimate that relationship with a GLS estimator β_1^*.[34] The particularity of this procedure is that we don't plan to focus on the error term for this model, e_t. WOOLDRIDGE (2014, p.226) argues that the transformed model (5.5) already satisfies the classical assumptions satisfied in the first model (5.1). In fact, we are only interested to see whether $\delta_{t+1}p_{t+1}$ actually solves for the serial correlation. Therefore, the section 5.2.1 aims to answer our main question. Section 5.2.2 provides the results for our GLS estimation and compares them to Shiller's results.

Section 5.2.1: Serial correlation of the innovations

In the last paragraph, we have discovered that the error term u_t displays serial correlation. We want to know whether it is still the case with our transformed variable $\delta_{t+1}p_{t+1}$. Indeed, the relationship between both variables is displayed in equation (3.13). In our case, we have computed the estimated $\delta_{t+1}p_{t+1}$ with the residual term $\hat{u}$ instead of u_t. Our serial correlation model is like model (5.3) although we henceforth deal with the transformed variable.

$$\delta_{t+1}p_{t+1} = \rho\delta_t p_t + \varepsilon_t \qquad with\ \varepsilon_t \sim N(0, \sigma^2) \qquad (5.7)$$

Where ε_t is i.i.d. with mean zero and a constant variable. We resort once again to a portmanteau test. Hence, our null hypothesis is the autocorrelation coefficient ρ is not significantly different from zero at any time. We find out a more satisfying result. Indeed, the portmanteau test provides us a p-value of 0,09. Hence, we fail

[34] GLS stands for generalized least square

to reject the null hypothesis.[35] Therefore, the transformed variable $\delta_t p_t$ turns out to not be serially correlated as argued by Shiller and LeRoy and Porter.

Section 5.2.2: GLS estimation results

In section 5.2.1, we have solved for the serial autocorrelation through our second model (5.5). When we merge that with the other classical assumptions already satisfied in the first model, we can therefore report our GLS estimates and compare them to SHILLER (1981 a, p.432).

Table 5. 3: Comparison of the generalized least square estimation between our empirical analysis and Shiller's

Dataset	DAX	Modified Dow Jones	Standard's and Poor
Sample period	1997-2016	1928-1979	1871-1979
$\hat{\beta}_1^*$ (standard error)	0,0211 (0,0073)	-0,2382 (0,0910)[36]	-0,1576 (0,0482)[37]
t	2,89	-2,618	-3,271
R^2	0,3171	0,0831	0,1048

Table 5.3 provides us some interesting results. First, a relationship between the future innovations in price and the actual price actually exists. Indeed, the covariance of both variables is a component of the GLS estimate $\hat{\beta}_1^*$. Furthermore, our coefficient is statistically significant.[38] SHILLER (1981 a, p.432) argues that those results also suggest that the prices can be forecasted. Hence, that finding totally goes against the market efficiency theory as condition (3.15) is violated. In the chapter 6, we will see that this existence of this relationship is confirmed by our third variance-bound result (3.20).

Our second point is that our estimate shows a positive relationship between both variables whereas Shiller's estimates show a rather negative relationship. In fact, this difference may be summarized by table 4.2. The correlation between DAX prices and its ex-post counterpart is negative whereas Shiller's correlations were positive. As the future innovations in price result from the transformation of the residuals and that those derives from the regression of p_t^* by p_t, we wonder whether the difference in the signs is due to that relationship.

[35] We do not reject the null hypothesis at the significance level of 0,05

[36] SHILLER (1981 a) did not provide the standard errors of his coefficients. So, we have proceeded to a simple division of $\hat{\beta}_1^*$ by the t-ratio linked as $t_{\hat{\beta}_1^*} = \frac{\hat{\beta}_1^* - 0}{\hat{\sigma}_{\hat{\beta}_1^*}}$. The zero term is the restriction imposed by our null hypothesis (5.6).

[37] See footnote 37

[38] We do not reject the null hypothesis at the level of confidence of 5 percent

Nevertheless, we must stress the difference between the statistical and the economic significance of an estimator. As WOOLDRIDGE (2014, pp.111-114) argues, an estimator is statistically significant whenever its t-test is larger than a certain level of significance. In our case, the t-test computed is statistically significant at most levels. Nonetheless, he also argues that the magnitude of the estimate determines its economic significance. Here, the magnitude of our estimate mounts to 0,02 which is small and close enough from zero. Hence, we discuss the economic importance of p_t to explain $\delta_{t+1}p_{t+1}$. Economically, we may argue a case where condition (3.15) holds whereas it is not the case statistically.

Furthermore, we will explain in our next chapter why the variance-bound is a more suitable test for the efficient market model validity than the regression tests we have conducted in this chapter.

Chapter 6: Variance-bound tests

Last chapter, we have proceeded to an estimation of our models with our dataset and compared them with Shiller's results. The latter argues that, despite the conclusive results we have obtained, the regression tests may have some shortcomings compared to the variance-bound tests. First, our results have reported a low coefficient of determination. In fact, the regression might not respond well to data misalignment which eventually translates into a relatively low R^2. Second, we deal with a number of observations that is quite small. It implies that our regression test is powerful only with very large samples. Hence, SHILLER (1981 a + b, p.433 + p.6) argues that the variance-bound test is a better indicator to assess the validity of the present value model defined at (3.1) as they are not affected by those shortcomings.

Before we display our results, we want to remind our reader that the consistency of inequality (3.10) lies on the validity of the independence assumption, which has been confirmed in section 5.1.1. Hence, the actual prices are the rational forecasts of its ex-post counterpart. Inequalities (3.16) and (3.20) have been derived to consider the periodic evolution in the expectations surrounding the actual prices and the variability of the dividends. The joint result of those three inequalities determines our research question: is the German market too volatile to be regarded as efficient? The next table displays the results and compares them to the ones SHILLER (1981 a, p.431) obtains.

Table 6. 1: Comparison of the variance-bound tests results between our empirical analysis and SHILLER's (1981, p.431)

	DAX (in points)	Modified Dow Jones (in points)	Standard and Poor's (in points)
Sample period	1997-2016	1928-1979	1871-1979
Elements of inequalities[39]			
First inequality: (3.10)			
$\sigma(p_t)$ $\sigma(p_t^*)$	2 089,65 143,1	355,9 26,9	50,12 8,968
Second inequality: (3.16)			
$\sigma(\Delta p_t + d_{t-1} - \bar{r}p_{t-1})$ $\sigma(d_t)/\sqrt{\bar{r}_2}$	2 006,81 250,52	242,1 32,20	25,57 4,721
Third inequality: (3.20)			
$\sigma(\Delta p_t)$ $\sigma(d_t)/\sqrt{2\bar{r}}$	1 986,77 252,25	239,5 32,56	25,24 4,777

Table 6.1 provides us interesting elements that help us to answer our research question. First, we observe that all the inequalities are clearly violated for our dataset as well as for Shiller's. The magnitude of those violations is also interesting because they are also comparable to Shiller's. Indeed, ours range between seven for the smallest ratio and fourteen for the largest one. His magnitude ranges between five and thirteen. Hence, we both observe a clear rejection of those inequalities for the three stock markets and notice a pattern.

Moreover, we also take a closer look at figures 3.3. As stated earlier, we have plotted p_t and p_t^* against the time with our sample. We observe that p_t^* follow a very stable trend throughout the sample whereas p_t revolves up and down around that trend. Shiller's figures 3.1- 3.2 display similar features. He infers that the stability displayed by p_t^* proves that the aggregate stock market prices, embodied by p_t, is excessively volatile.

Second, we have argued earlier that our first inequality (3.10) holds because p_t is an optimal forecast. Despite that, the inequality is clearly violated. The proportion of this violation despite the reconciliation of the theoretical and the empirical forecast arguments lead us to conclude that the market is effectively too volatile according to the market

[39] Our table is designed in such way that for each inequality, the formula above is lower or equal to the formula below according to the market efficiency hypothesis.

efficiency theory. Indeed, this violation is not due to the possible existence of a relationship between p_t and u_t.

Third, we have observed in our regression test that a relationship between the actual prices and the future innovations in price actually exists. That result is reinforced by the violation of inequalities (3.16) and (3.20). As our price series appears to be stationary, the relationship between $\delta_{t+1}p_{t+1}$ and p_t therefore needs to be considered. Indeed, we have argued in our third chapter that inequality (3.20) holds if there is no relationship between those variables as stated in condition (3.15). Nonetheless, our research provides us opposite results. The violation of the third inequality (3.20) combined with the significant relationship between $\delta_{t+1}p_{t+1}$ and p_t goes against one of the most important EMH assumptions SHILLER (1981 a, p.423). We remember that in our literature review, the EMH has stated that the prices behavior is not predictable.[40] Indeed, only the inflow of new information explains the prices behavior. Yet, we have discussed its rejection through the regression test.[41] Therefore, to an extent at least, we argue that the prices behavior is predictable.

We remind our readers that those inequalities are derived with respect to the assumptions provided by the EMH. Nonetheless, their systematic violations reveal that the market efficiency theory as it is defined in our thesis fails to provide a satisfying explanation of such volatility from the stock prices, and by extension the market prices behavior. Indeed, the new information influencing the expected future dividends don't seem to totally explain their behaviors. In hindsight, SHILLER (1998, p.23) argues there is a repeating cycle in which the prices appear to overreact to the news about fundamentals only to be progressively corrected by the market participants. Besides providing the clear evidence that the German stock market is too volatile, we have also provided some elements that question the non-predictability of the prices behavior. Ever since, Shiller has opened an ongoing debate that has eventually overseen the birth of alternative theories attempting to provide more consistent answers regarding market volatility. The rational bubble theory and the behavioral critique as introduced in our literature review are one of them. But before concluding on those terms, we will explore in our next chapter that some elements constituting Shiller's arguments may be contested. In fact, they question the robustness of the methodology he relies on to derive those conclusions.

[40] The EMH in its purest form states that despite some subsequent evidences that they may be predictable to an extent.

[41] Yet we also have briefly discussed its economic significance.

Chapter 7: Discussions of the variance-bound methodology

The results we have provided in the last chapter strongly suggest that the German market is not efficient when we rely on an efficient market model. However, the methodology derived to draw those partial conclusions may violate some important properties from the economic theory and hence, our results may turn out to be invalid. In the following paragraphs, we mention the main elements that question the methodology Shiller have resorted to derive those bounds: short sample bias, assumption stationarity and the terminal condition for the fundamental value. Finally, we question the reliability of those volatility tests to detect speculative bubble.

Paragraph 7.1: Short sample bias

Throughout the second part, we have reminded several times that our sample is rather small due to numerous reasons. We have done it on purpose. In fact, we have suspected that our number of observations would have a significant impact not only on the regression tests, but on the variance-bound tests too. FLAVIN (1983) extensively developed the issue. She pointed out that the variance-bound test tends to be violated because of the bias induced by resorting to short samples. At the time, she criticized Shiller to use only 105 observations. To illustrate her point, she reviewed the first inequality and analyzed the spread between both variances of p_t^* and p_t respectively.

$$D = V^* - V \qquad (7.1)$$

Where V^* is the variance of the ex-post rational prices p_t^* and V is the variance of the actual prices p_t. D is the spread between them and can be described as the net variance. She subsequently described that resorting to short samples contributes to push more downwards V^* than V. In other words, the former variance is more downwardly biased than the latter and hence, the rejection of the inequality. This may be the reason behind such small value for variance of p_t^* compared to the other one in our first inequality (3.10). Therefore, a plausible solution here is to implement the test on a much larger dataset. However, the lack of abundance of historical data in our case implies that we may implement the test in a future where the sample will be large enough.

For inequalities (3.16) and (3.20), FLAVIN (1983) identified the same problem regarding the variance of the dividend and suggested that an estimation of the relative bias induced by the sample might help to correct for its downwards bias.

Paragraph 7.2: Stationarity of the dividend series

The stationarity of the main variables is one of the key assumptions when one's implementing a variance-bound test. It especially concerns the stationarity of the dividends because all the price-related variables are function of them according to the theory. Indeed, LEROY and PORTER (1981, p.569) state that the heavy dependence of model (3.1) on the stationarity assumption may be its most serious limitation. Hence, the generating process of the dividend directly involves the generating process of the prices. We have explained in chapter 4 that once the series are expressed in real terms and detrended from their long-run growth path, SHILLER (1981 b) has argued that they appear to follow a stationary process around a mean.[42] We have therefore supposed the same for our series. Indeed, figure 3.3 displays the evolution through time of our prices p_t (without the mean line) but they seem to remain bounded. This assumption is very important because it has allowed Shiller to set forth that the variance-bounds are unconditional. However, several economists discussed it. KLEIDON (1986) started the controversy by arguing that the consensus among the (financial) economists is that dividend series actually follow non-stationary processes. He went even more specific by arguing that they follow a random walk.[43] It therefore means that the unconditional variance would depend on a time component, and thus it is not finite.[44] Although we can still derive the conditional variance, the suggestion of "unconditional variance" in Shiller's publication seriously threatens the robustness of the variance-bound methodology.

MARSH and MERTON (1986) also strongly suspected the validity of the stationarity assumption. They firstly based their argument on the policy undertaken by a public company management concerning the distribution of the dividends.[45] Although no optimal model prevails, they used the work of LITNER (1956) who identified a common pattern among the managers. The amount distributed each period actually depends of the company's historical and future performance in the stock market. To be more explicit, he argued that the managers usually base their permanent earnings on the stock market performance. They afterwards derive a long-run growth path where the dividends are expected to be distributed very smoothly. However, only an exogenous shock might affect the dividend and have a permanent effect. Hence, his argument reconciles with the random walk hypothesis. Later on, SHILLER (2003, p.87) assessed his statement and said that under this circumstance, the prices are expected to vary quicker than the dividends, hence the difference in the plots between p_t and p_t^*.

Furthermore, KLEIDON (1986, p.975) also added that managers may implement a policy where they decide to retain the dividends in the short-term and put them in a longer-term investment instead. Hence, they may expect to recoup much higher dividends in a further horizon.

On their side, FLOOD et AL. (1994, p.116) argued that the time series of the dividends fails to capture the dynamics of the expectations surrounding them. These are some examples to explain the reason behind the supposedly extreme smoothness of the dividend series. Overall, they support MARSH and MERTON's point that the extreme smoothness of the dividend series hinders it to be stationary. We remember in section

[42] SHILLER (1981 b, pp.6-7) states that the definition of our terminal condition implies a stationary process for our price series.

[43] Random walk is essentially when the current level of a variable has deviated from its origin only because of the summation of past shocks. The shocks being random in nature, the variable cannot follow a stationary process as the variable doesn't revert to its mean afterwards.

[44] See HAMILTON (1994, p.44)

[45] By public company, we mean a company whose shares are publicly traded in the stock market.

3.4.2 that SHILLER (1981 a) explained that the extreme case of a smooth series is when it merges with a constant series, which cannot be considered for our present value models.

FLOOD et AL. (1994, p.122) considered whether an analysis of the return series offers more guarantee of being stationary than the variables expressed in level such as the price and the dividend. Indeed, the returns usually offer more guarantee to remain within arbitrary bounds whereas the prices and dividends are more subject to take explosive value over time, and thus, have more likelihood to violate a given bound and never revert from it.

For his defense, SHILLER (2003) later argued that, at that time, it was a common assumption among economists to believe that dividends oscillate around a known trend. But the different arguments we have presented here encourages us to verify whether our dividend series, and by extension our price series, is effectively stationary. Concretely, we want to observe whether the dividend process has an autoregressive estimate that is sufficiently close to 1 to have the same observable implications than a random walk HAMILTON (1994, p.446). With the same dataset used to derive expression (4.5), we decide to perform an Augmented Dickey-Fuller test with the existence of a unit root as a null hypothesis.[46] In other words, we test whether the autocorrelation coefficient ρ is equal to one. A rejection of the null hypothesis implies that the process has stationary properties.[47] As we use the real detrended dividend d_t, we don't need to specify a model with a time trend. However, as KLEIDON (1983) suggested, we use the log-level of d_t as the dividends may display very high positive value. Our specification test follows a simple autoregressive model with a drift.[48]

$$\ln(d_t) = \mu + \rho\ln(d_{t-1}) + \varepsilon_t \qquad with\ \varepsilon_t \sim N(0, \sigma^2) \tag{7.2}$$

We assume that the error term ε_t is a i.i.d. white noise with zero mean and constant variance.

[46] In our case, a unit root means that the series follow a nonstationary process.
[47] Indeed, the stationary properties are that its two moments, mean and variance, are well defined
[48] We use a drift as the series' origin is not set at zero.

Table 7. 1: Dickey-Fuller test to detect the actual process of the dividend series

Number of observations = 19				
----------- Z(t) has t-distribution -----------				
	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	**-1,666**	-2,567	- 1,740	-1,333

Table 7.1 allows us to compare our test statistics to different critical values, and therefore interpret them. We observe that we successfully reject the non-stationarity hypothesis for our dividend series when the level of significance is at 10 percent. Indeed, the statistical test has a lower value than the critical value at 10 percent.[49] Moreover, our interpretation of the test is reinforced as the p-value computed for this test mounts to 0,057.[50] However, it also means that we fail to reject the null hypothesis at the significance levels of 1 and 5 percent respectively.[51] Therefore, we cannot completely refute the arguments developed above either when it comes to our dividend series.

We also observe the process of our price series. We argue that it is relevant to use extended series (from 1960 to 2016). In a similar fashion than for the dividends, we model an autoregression of order one for p_t.

$$\ln(p_t) = \mu + \rho\ln(p_{t-1}) + \varepsilon_t \qquad with\ \varepsilon_t \sim N(0, \sigma^2) \tag{7.3}$$

With $\rho = 1$ as the null hypothesis. ε_t is i.i.d. with mean zero and a constant variable. The following table shows the Dickey-Fuller test for our sample.

Table 7. 2: Dickey-Fuller test to detect the actual process of the extended price series

Number of observations = 56				
----------- Z(t) has t-distribution -----------				
	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	**-2,147**	-2,397	-1,674	-1,297

[49] First difference process means that the initial nonstationary process is integrated of order 1 in order to become stationary

[50] This means that the null hypothesis is rejected whenever the level of significance is above 5,7 percent

[51] We reject the null hypothesis at the level of significance of 1 and 5 percent though.

Table 7.2 provides the results. We don't fail to reject the null hypothesis at the level of significance of 1 percent whereas we reject it at both levels of 5 and 10 percent. Moreover, the p-value for our test mounts to 0,018, which only confirms our analysis.

By interpreting our results for model (7.3), we see that, at those levels, the prices series process has the same observable implications than a random walk. Indeed, a shock on the prices will never disappear from our system as the price series is just a summation of shocks. On the other side, at the level of significance of 1 percent, the price series has similar implications than a stationary process. Indeed, after several years, a shock on the prices will eventually die away as time goes on, and we come back to the mean of the process. This interpretation is also valid for the dividend series we have tested in model (7.2).

As stated earlier, the market efficiency theory asserts that the properties of the dividend process determine the ones for the price series. On the other side, we have been able to observe the behavior of the actual prices with a much longer sample. However, we have not come to a conclusive answer as, depending on the level of significance we test our hypothesis, both dividend and price series display stationary and non-stationary characteristics. Hence, our results are not significant. One plausible solution to clear up the discussion might be to implement the test on a longer dataset for both series.

Paragraph 7.3: Terminal value

In paragraph 4.4, we have explained the formation of p_t^*. We have mainly explained that it is computed backwards with the terminal value as a base. We remind that SHILLER (1981 a) argues that the purpose was to provide a relevant comparison between p_t^* and the actual prices p_t. In fact, another terminal condition might have deviated significantly p_t^* due to the uncertainty as shown in figure 4.1. Hence, our terminal value p_{2016}^* is equal the sample mean of prices $E(p_t)$.

Nonetheless, our methodology is not exempt of criticism. First, FLAVIN (1983) argued that resorting to that terminal condition leads to an even stronger downwards bias of V^* in the first inequality (3.10). We insist on the term “even stronger” because we have already developed her opinion about the biased variances. She discovered that this terminal condition pushes the probability to reject the variance-bound test to a figure very close to 1. Because of that systematic rejection, she therefore argued that the variance-bound test is unable to detect a bubble.

FLOOD et AL. (1994, p.112) were also concerned by our terminal condition. Although they approved its theoretical relevance, they argued that obtaining the ex-post rational prices p_t^* through it is not a valid procedure as the actual p_t^* is in reality unobservable. We care to remind that p_t^* is also called the perfect-foresight price. Indeed, the choice of a terminal condition is completely arbitrary. Moreover, the terminal condition might be misspecified if the market was already too volatile during the analyzed period. For those reasons, we can only derive an estimate of the unobservable p_t^*, which is $\hat{p}_t^*$. They based their argument of the fact that p_t^* represents the price in the market if the future dividends were exactly predicted until the infinite, which is impossible to define in a world under uncertainty. Therefore, they concluded that the first inequality (3.10) was violated due to the model misspecifications (3.2). Furthermore, they argued that it doesn't provide any evidence of the existence of a bubble.

As we can observe, those two reviews suggested that the variance-bound test cannot detect the existence of a bubble. Our next paragraph will explore quickly the argument introduced by Flood and Hodrick and discuss the relationship between the volatility and the bubble in the variance bound literature.

Paragraph 7.4: Relationship between bubble and volatility in the variance bound test

As stated in the introduction and the first part of our thesis, we were initially interested in the speculative bubble and the denial of its existence by EMH. We have argued that a bubble is materialized through a visible and excessive volatility in the market prices of a sizeable portion of stocks. Hence, we have stated a joint hypothesis that the market may be excessively volatile because a bubble is taking form. We knew that Shiller implemented a test consistent with the market efficiency theory and its violation would indicate that the actual stock market was too volatile to be explained by the theory. And by our joint hypothesis, a bubble may currently exist in the market.

However, paragraph 7.4 has introduced the argument that the variance-bound test is unable to detect a bubble. FLOOD and HODRICK (1990, pp.94-96) directly assessed the link between the market volatility and the speculative bubble. They especially discussed the rational bubble theory we have covered in chapter 2.1. To demonstrate their point, they re-used expression (2.1). If a rational bubble is growing, it means that the actual prices are inflated compared to their fundamental value as used in the first chapter.

They mainly argue that the bubble component is actually included on both sides of inequality (3.10). Indeed, we remember in paragraph 2.1 that Blanchard and Watson argued a possible influence of the rational bubble on the fundamental value. Therefore, we cannot state a composite hypothesis involving the bubble and the volatility. It proves that the variance-bound test is not designed to test for the existence of a rational bubble. And therefore, an apparent high volatility in a stock market doesn't necessarily infer a speculative bubble in the same stock market.

CONCLUSION

Our thesis has aimed to bring some lighting on the efficient market theory by decomposing its main definition: “the asset prices fully reflect all the available information at any time” FAMA (1970), as stated in our introduction. Indeed, we have presented a simple efficient market model and explained the prices formation and behavior according to the theory. Afterwards, we have seen that information, which affects the future dividends, is a crucial component of the model as it generates the prices movement. We have also described the main property that maintains the prices aligned to their equilibrium level: the arbitrage from rational investors.

Thereafter, we have discussed the theory’s opinions on excessive volatility and speculative bubble. We wanted to compare those opinions with complementary or alternative theories to EMH that extensively focus on those events. Indeed, the rational bubble theory and the behavioral literature provide us a perspective quite different from the classical EMH: the former with the inclusion of an additional rational behavior regarding the prices run-up and the latter with psychological and sociological insights that create those events.

In the second part, we extensively resumed our initial present value model and derived several tests used to detect for the “excessive volatility” in the stock market. We have tested those inequalities with the largest German stock market index, as representative of the entire German stock market, and discovered that it is too volatile to be considered efficient by the EMH. Eventually, we have discussed about the robustness of the variance-bound methodology and conclude that the several elements composing it may provide flawed results and, on the top of that, not indicate the presence of a speculative bubble in the market.

The main contribution of the EMH literature regarding the prices behavior remains that, although the market may display an important level of volatility or even incorporate elements that eventually form a speculative bubble, it is effectively difficult to profit from those potential sources of inefficiency BODIE et AL. (2014, p.375). Indeed, we have shown throughout the first part a constant reality about the stock market: a trading strategy almost never provides an excess return relative to the market. Nonetheless, its main drawback is that all its aspects may only work in an ideal world. In fact, it seems from our observations that the market prices don’t necessarily move only because of the impact of additional information on future dividends. We cannot set forth that the alternative theories presented are undisputedly better but some of their elements need to be extensively developed.

Despite the limitations provided by the variance-bound tests and FAMA’s (1991, p.1575) claims that the EMH is untestable, Shiller has had the merit to open the doors for subsequent theories that has ever since attempted to explain the prices behavior in the market. Some of those endeavors eventually gave birth to what is known today as the behavioral finance. Its approach takes a different route than the EMH as it provides some relatively new insights regarding market volatility but still, its psychological and sociological aspects make hard to formalize it into a model that truly revolutionize the economic theory as no fundamental principle seems to emanate from them SHILLER (2003, p.100). Although many researchers have frequently identified excessive volatility in the market, the reasons advanced for such level of volatility still belong to the realm of speculation up to this day. Hence, the researchers strive to find a model consistent enough to be part of the economic theory while convincingly explains the prices movements we witness in the world.

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