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Inflation and corporate investment – a critical survey

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Abstract

The analysis of inflation's effect on investment can contribute to a deeper understanding of the benefits of a monetary policy oriented towards price stability. It can also help conduct such a policy effectively. We begin with a review of conclusions about the inflation-investment relationship that can be drawn from traditional monetary models with exogenous growth and no market imperfections. As these conclusions are ambiguous, models of this type could lead economic decision-makers to fail to take proper account of inflation's impact on investment. We then survey research which, contrary to monetary exogenous growth models, takes account of market imperfections such as the asymmetry of information, uncertainty and nominal rigidities in the tax system. The analysis of the significance of these imperfections for the direction and magnitude of the relationship between inflation and investment forms the bulk of the article. We highlight, on the one hand, the key assumptions of the particular theories (and whether they are in keeping with stylized facts), and, on the other hand, the difficulties that empirical research faces when trying to verify the conclusions from these theories. Finally, we offer some conclusions on the basis of the conducted survey.

Keywords: investment, inflation, monetary growth models, asymmetry of information, uncertainty, taxes

JEL: D81, D82, E22, E31, E44, E52, O42

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> "If there is anything in the world which ought to be stable it is money, the measure of everything which enters the channels of trade".
>
> Le Blanc (1690; quoted after Einaudi 1953, p. 233)

> "Policies that impede the accurate perception of real costs are ipso facto inimical to growth. Inflation is the most obvious, probably the most pervasive, and almost certainly the most noxious of such policies".
>
> Harberger (1998, p. 21)

1. Introductory remarks

Price stability is becoming the chief monetary-policy goal for an increasing number of central banks. In addition to dynamic inconsistency, the reason why the main monetary policy goal is formulated in this way is the conviction that inflation, at least above a certain level, impedes economic growth. It seems, however, that in economists' debates about inflation's impact on economic growth insufficient attention is paid to one of the channels of this impact, namely inflation's effect on corporate investment decisions. No consensus exists in the literature either about the magnitude or the precise mechanism of this impact. At the same time it is difficult to confirm empirically the significance of the impact on investment of those variables which according to major theories constitute investment's main determinants and which in consequence have an influence on the predictions formulated for the needs of monetary policy.

The analysis of inflation's effect on investment can contribute to a deeper understanding of the benefits of a monetary policy oriented towards price stability. It can also help conduct such a policy effectively. These are the two reasons, important from the perspective of both the theory and practice of monetary policy, why we have decided to take up this topic.

Several channels of inflation's impact on investment have been identified in the literature. What is surprising, however, is that, to the best of our knowledge, a comprehensive survey analyzing the conclusions from existing research on these mechanisms does not exist. There are surveys analyzing the impact of inflation on economic growth (e.g. Temple 2000) or surveys related to the specific topics relevant for the inflation-investment relationship (e.g. investment under uncertainty, see Carruth et al. 2000), however they do not contain a systematic and comprehensive analysis of the various mechanisms of inflation's impact on investment that are discussed in the literature. This article is an attempt to fill this gap. On the one hand, the operation of the particular mechanisms is outlined. Special attention is paid to the key assumptions of the various theories and to how they correspond to the stylized facts about relationships present in a real-world economy. On the other hand, the results of empirical research verifying the significance of the particular mechanisms of inflation's influence are presented. At the same time the difficulties with conducting such research are highlighted. The article consists of five sections (numbered 2 to 6).

In the second section, which is a point of departure for further discussion, we examine the conclusions from monetary exogenous growth models. The models discussed in this section assume a lack of market imperfections, such as the asymmetry of information, uncertainty or nominal rigidities in the tax system. The significance of these imperfections for the way in which inflation influences investment is discussed in the following sections.

The third section contains a survey of that line of research on the link between inflation and corporate investment which takes account of the asymmetry of information between the investor and the firm. This asymmetry can restrict access to capital for some firms and make it impossible for them to realize profitable investment projects. Inflation amplifies these negative effects.

In the fourth section we survey studies which take account of the fact that firms make decisions in the presence of uncertainty.

In the fifth section we discuss research in which inflation impacts corporate investment through tax laws.

The sixth section is a summary of the main conclusions from the surveyed research within the context of their relevance for monetary policy.

2. Inflation and investment in monetary growth models[1]

As the focus of this article is on the link between investment and inflation, in this section we concentrate on conclusions about this relationship that can be drawn from monetary exogenous growth models. On the one hand, given the various methods of introducing money into these models, they are sufficient tools to analyze fully inflation's effect on investment. In these models capital inputs are usually the only proximate cause of economic growth whose growth rate is not exogenously assumed but carefully analyzed. On the other hand, in contrast to some endogenous growth models, these models have analytic solutions.

The first exogenous growth model taking account of inflation's impact on investment was presented by Tobin (1965). He introduced into the neoclassical model money issued by the government in order to finance public expenditure. In the model capital inputs depend on the relation in which wealth (constant by assumption) is allocated between capital and real money balances. If the return on real money balances declines, a part of wealth is reallocated to capital. As the opportunity cost of holding wealth in the form of money is equal to the nominal interest rate, that is the sum of inflation and the marginal product of capital, a rise in inflation causes a decline in real money balances and an increase in capital.

In order for the portfolio composition effect to have an impact on the capital stock in line with Tobin's model, it is necessary to assume that the saving rate is independent of the inflation rate. Levhari and Patinkin (1968) have demonstrated that if the above assumption is relaxed and the saving rate is a function of the portfolio's assets' (money and capital) rates of return, the Tobin effect need not occur. On the other hand, Dornbusch and Frenkel (1973) have shown that if one assumes a positive impact of inflation on consumption, the Tobin effect is reversed.

[1] A detailed discussion of the models presented in this section can be found in Ciżkowicz, Hołda, Rzońca (2009).

One of the first attempts to eliminate the assumptions that formed the basis of the critique of Tobin's model was made by Sidrauski (1967). In the Ramsey-Cass-Koopmans model, in which the saving rate is endogenous, he introduced money directly into the household utility function. In the Money-in-Utility-Function (MIUF) models, the steady-state level of capital is independent of the inflation rate. But whether inflation has an impact on the level and the rate of capital accumulation outside of the steady-state depends on the form of the utility function (see Fischer 1979 or Asako 1983). The direction of inflation's potential impact can be determined by the risk aversion coefficient, which, depending on the values it takes, gives money and capital the features of substitute or complementary goods respectively.

The lack of capital inputs' dependence on inflation in the MIUF model is rather a special case than a rule for monetary growth models. In order for this dependence to arise it suffices to assume that leisure is another argument of the utility function, besides consumption and real money balances (Brock 1974). In a model modified in this way this relationship does not occur only in the case of a special form of the utility function (utility function separable with respect to money). Otherwise inflation has an impact on capital outlays, but the direction of this influence is ambiguous and depends on the assumed forms of the utility and production functions.

This problem can be partly (but only partly) eliminated by assuming that money is not an indirect but a direct source of utility allowing to lower transaction costs measured in units of consumption or units of labour input (see e.g. Brock 1974). In models based on this assumption, such as the Shopping-Costs (SC) or Shopping-Time (ST) models with elastic supply, the sign of the relationship between capital and inflation does not depend on assumptions about the signs of the partial derivatives, respectively, of the marginal utility of consumption and the marginal utility of leisure with respect to the real money stock. It does not depend on assumptions about relationships between these derivatives either. The same results can be obtained by imposing the Cash-in-Advance (CIA) constraint (Clower 1967; Grandmont, Younes 1972; Lucas 1980) on consumption (Gomme 1997). More on the equivalence between the MIUF, SC, ST and CIA concepts can be found, *inter alia*, in Wang and Yip (1992) and Zhang (2000).

Another modification which makes capital inputs dependent on inflation in the steady-state is the introduction of money into the production function (Fischer 1974). However, in Money-in-Production-Function models this relationship is still ambiguous. A rise in inflation lowers the steady-state level of capital if capital and money are complementary inputs in the production process and the production function exhibits decreasing returns to scale with respect to capital inputs and the money stock. Each of these assumptions is arbitrary. The assumptions necessary in order for inflation to have a negative or a positive impact on capital accumulation can be given a deeper interpretation through the introduction of transaction costs expressed in units of production. However, this does not eliminate the ambiguity regarding the direction of inflation's impact on capital accumulation.

A clearly negative dependence between capital and inflation can be obtained by introducing the CIA condition into exogenous growth models, where the CIA constraint must apply to purchases of investment goods (see e.g. Stockman 1981). In such a model, and similarly to MIPF models, the negative sign of inflation's impact on capital inputs is a consequence of the complementarity of money and capital (Orphanides, Solow 1990). Relaxing this assumption and narrowing the CIA constraint to purchases of consumption goods makes any impact of inflation on capital inputs (assuming inelastic labour supply) disappear (Abel 1985, 1987) – similarly to MIUF models and SC models with transaction costs expressed in units of consumption.

In summary, depending on the model a rise in inflation can either increase, decrease or leave capital inputs unchanged. It is difficult to indicate which of the presented approaches reflects best money's actual role in the economy because money is introduced into all these models based on *ad hoc* assumptions. Moreover, the direction of inflation's effect on capital accumulation, even within a single model, depends fully on the assumptions made, and it is difficult to verify empirically in an unambiguous manner whether these assumptions are valid.

A new and interesting approach to introducing money into growth models are monetary search models in which the point of departure is the exchange process itself, described by a mechanism of bilateral adjustments between the transaction counterparties. Such an approach allows a more realistic description, compared to the one based on *ad hoc* assumptions, of money's role as a good facilitating exchange and improving the efficiency of asset allocation in the economy (Kiyotaki, Wright 1989 and 1993; Trejos, Wright 1995; see also surveys by Rupert et al. 2000; Shi 2006). Most search-theoretic monetary models do not allow to analyze inflation's impact on capital accumulation because they do not include capital as a special good. The few exceptions are models proposed by Shi (1999) and Aruoba, Waller and Wright (2009). However, the level of analytical complexity of these models makes them insoluble even after including the basic relationships from other areas of macroeconomic theory (e.g. search models with capital are analyzed also by Menner (2005) Molico, Zhang (2006), but these authors provide numerical solutions only). As a result, also in the case of these models, the direction of inflation's impact on real variables, including its impact on investment, depends on assumptions that do not easily yield to unambiguous empirical verification (see e.g. Shi 2006, who makes a critical assessment of the conclusions of the model by Shi 1999). As a consequence they also do not allow to identify the most important channels through which inflation impacts capital accumulation.

3. Inflation – capital market – investment

The main conclusion from monetary growth models, i.e. the lack of an unambiguous relationship between investment and inflation, is contradictory to the results of most empirical research (to be discussed further in the article). This research usually indicates that inflation leads, at least from a certain level upwards, to lower productivity of investment. Although one can find studies according to which inflation, as long as it is low, does not have a statistically significant impact on economic performance, it is difficult to point to any solid research that would ascertain a positive relationship between economic performance and high inflation (see e.g. Levine, Renelt 1992; Fischer 1993; Barro 1995; Bruno, Easterly 1998; Li, Zou 2002; Fountas, Karanasos, Kim 2006).

A possible reason for the discrepancy between the model-based descriptions discussed in the previous section and stylized facts about the inflation-investment relationship is that monetary growth models assume far too simplistic a description of the conditions in which economic agents make decisions. A common feature of these models (with the exception of search-theoretic monetary models) is the assumption of no market imperfections. In the present section we discuss inflation's effect on corporate investment in the presence of one of the market imperfections, namely the asymmetry of information and its relevance for financial institutions.

3.1. The importance of information asymmetry

The existence of financial institutions is economically reasonable only when one relaxes the assumption of perfect information, characteristic of the neoclassical approach (the rationale for the existence of financial intermediaries is, of course, their ability to reduce transaction costs and the risk connected with investment, but Freixas and Rochet (1997) demonstrate that these functions lose their importance in the case of perfect information). Without relaxing the perfect information assumption, the capital structure of enterprises does not have an impact on their value (Modigliani, Miller 1958), and hence on their ability and propensity to invest. Under perfect information investment decisions depend on the relation between the market value of an investment and its replacement cost (Tobin 1969), however, they do not depend on financial variables, such as equity capital or cash-flow. Firms do not face quantitative constraints in their access to capital as long as they can cover the cost of capital. It is the cost of capital that determines the size of investment (Jorgenson 1963). However, such a description of financial market's functioning is inconsistent with empirical evidence. Smith (2003, p. 2), in his survey of financial intermediation's role in the economy, concludes for instance that models that ignore the financial system's role in the accumulation and allocation of capital lead to "fairly embarrassing results". Baddeley (2003, p. 104) maintains that "(…) there is a general consensus that q theory, on its own, does not provide a good empirical basis for the analysis of investment expenditure". According to Blanchard (1986, p. 153) "(…) it is well known that to get the user cost to appear at all in the investment equation, one has to display more than the usual amount of econometric ingenuity".

The asymmetry of information leads to three types of problems: adverse selection (Akerlof 1970), moral hazard (Jaffee, Russell 1976) and costly state verification (Townsend 1979; Gale, Hellwig 1985). These problems can, from a certain level of the interest rate, lower the expected rate of return on loans as they:

eliminate from the market potential borrowers who have the highest expected rates of return (the case of adverse selection – see e.g. Stiglitz, Weiss 1981),

increase the number of borrowers who do not comply with the loan agreement (the case of moral hazard – see e.g. Jaffee, Russell 1976; Bester, Hellwig 1987) or

increase the cost of actions that the bank must take against borrowers who do not fulfil their obligations (the case of costly state verification – see e.g. Williamson 1986 and 1987; Gale, Hellwig 1985).

The resulting incentives for lenders not to raise the interest rate above a certain level may in turn lead to equilibrium credit rationing. Alternatively, creditors may introduce non-price elements into loan covenants that will counteract the problems stemming from information asymmetry. These elements could include, e.g. the requirement of collateral (see e.g. Bester 1985) or the requirement of an economic agent's own contribution in financing the investment (see e.g. Leland, Pyle 1977; Greenwald, Stiglitz, Weiss 1984 or Bernanke, Gertler 1986). As a result, external funds become more expensive than own in-house funds (compare e.g. with Bernanke, Gertler, 1985). This is so even when the borrowed funds are fully collateralized because establishing collateral is also connected with a certain cost. Consequently, the firm's financial structure becomes an important factor determining the cost and availability of financing, and so determines the size of investment. An insufficient level of own in-house funds or too low a value of wealth can make it impossible for the firm to obtain external financing necessary to realize investment or make its cost too high in order for the investment to be profitable. (see e.g. Kaplan, Zingales, 1997). The financial structure of the firm becomes important in determining the availability of financing especially when an adverse shock hits the economy, as explained by the financial accelerator mechanism (Bernanke, Gertler, Gilchrist, 1996). This is due to the fact that an adverse shock leads to a fall in the prices of assets that firms hold on their balance sheets. These assets serve as collateral required by lenders due to their inability to properly assess firms' creditworthiness (inability caused by asymmetry of information). As the market value of firms' assets (net of their liabilities), i.e. their net worth, falls, their ability to borrow against these assets declines (financing conditions tighten). Firms borrow less, which limits their investment, which in turn reduces their economic activity. Dampened economic activity leads to further asset price declines, deteriorating balance sheets, tightening financing conditions and declining economic activity. Due to this financial accelerator mechanism, in which informational asymmetry plays a key role, the initial negative effect of the shock is amplified.

3.2. The interaction of inflation and information asymmetry – theoretical results

Even if fully anticipated, inflation exacerbates the consequences of information asymmetry and hampers the development of financial institutions.

First, inflation can lower the real rate of return on savings, which in turn intensifies adverse selection (Boyd, Choi, Smith 1996) or moral hazard (Azariadis, Smith 1996; Paal, Smith 2004; Gertler, Rogoff 1989). On the one hand, a fall in this rate discourages "natural" lenders from saving, i.e. creditors who have sufficient funds to undertake an investment, but who do not have access to equally efficient investment projects. On the other hand, it increases the risk that lenders will try to implement investments on their own and act as if they were borrowers – a role to which they have no predisposition. Boyd, Choi and Smith (1996) justify the assumption of inflation's negative impact on the real rate of return on savings by the fact that financial intermediaries are obliged to maintain required reserves against deposits, and nominal interest rates can be capped by law. At the same time this assumption is consistent with the results of numerous empirical studies (see e.g. Fama, Schwert 1979; Boudoukh, Richardson 1993, Pennacchi 1991; Barnes, Boyd, Smith 1999 and Boyd, Levine, Smith 2001). The relationship resulting from their model between the level of inflation and investment is non-linear. When inflation is sufficiently low the rate of return on savings is so high that adverse selection does not occur. Only after a rise in inflation above a certain threshold does the rate of return decline so much that it triggers adverse selection, influencing financial institutions' decisions about the scope of financing. But there is also another threshold within the interval in which inflation causes credit rationing. Above this threshold inflation becomes more variable, and, as a result, the variability of investment and of other economic-activity measures increases as well.

Second, inflation constitutes a tax imposed on the real value of firms' own funds (Boyd, Smith 1998; Huybens, Smith 1999). The size of these funds bears significance for the ability of firms to finance investment if, in response to the information asymmetry, financial institutions require borrowers to finance a part of the investment with their own funds. At higher inflation rates firms must rely to a larger extent on external financing if they want to realize the investment, but lower own funds limit their access to such financing. These negative effects will occur even when firms do not hold their own funds in cash but in other financial assets. The real rate of return on these assets diminishes with inflation growth, which is well-documented in the literature (see references in the previous paragraph). The level which, when exceeded makes inflation detrimental to investment may decline together with the growth of capital stock per employee (Boyd, Smith 1998). The higher this level is, the more important own funds can become as an instrument to ensure a satisfactory expected rate of return for the lender: on the one hand capital is characterized by diminishing marginal productivity, and, on the other hand, a higher capital stock per unit of labour widens the opportunities to accumulate sufficient own funds. Hamid and Singh (1992) demonstrate that countries with a higher per-capita income level are on average characterized by a higher share of own-financed fixed-asset investments in total investment.

Third, the fall in firms' own funds due to the inflation tax may deepen as a result of their own decisions (Smith, van Egteren 2005). On the one hand, the cost of maintaining a given amount of own funds rises together with inflation, but on the other hand, when inflation is more volatile a given level of own funds has a lesser influence on the probability of obtaining external finance. Both these effects encourage firms to lower the desired level of own funds, and exacerbate the negative effects of information asymmetry.

Fourth, inflation decreases not only the propensity but also the ability of enterprises to accumulate own funds because it lowers markups over unit cost (such an assumption is sufficient in order for the Smith and van Egteren (2005) model's conclusions to hold). In the literature there are at least three groups of models explaining such a relationship between markups and inflation.

Rotemberg (1983), Danziger (1988) and Benabou, Konieczny (1994) point to a significant role of the interaction of inflation and menu costs and the impact of this mechanism on the markup chosen by the firm when the profit-maximizing markup is known. Benabou and Konieczny (1994) demonstrate that models of this type can predict both a negative and a positive impact of inflation on the markup level, depending on the assumptions that describe the evolution of profit as a function of the markup. However, Russell, Evans and Preston (2002) point out that the assumptions needed to obtain a positive dependence between inflation and the markup level in models of this type are inconsistent with reality.

Benabou (1988; 1992a), Diamond (1993), Gali and Gertler (1999) and Head, Kumar and Lapham (2006) emphasize that inflation can lower the profit-maximizing markup directly if only the cost function and the demand function are endogenous and depend on the level of inflation. For instance, Benabou (1992a) argues that a rise in inflation may encourage buyers to make price comparisons more frequently than when inflation is low, which forces firms to reduce markups.

Chen and Russell (2002) and Russell, Evans and Preston (2002) focus on the case in which the profit-maximizing markup is unknown to the firm at the moment of price setting. In such conditions higher inflation increases the difficulties that the firm faces when choosing the appropriate markup level as well as the costs of coordinating price changes done by the firm with price changes in the market. The authors emphasize that the mechanism of inflation's impact on the markup level concerns not only the short term but also persists in the steady-state.

There are also models which indicate a reverse relationship, that is, a rise in the average markup obtained due to a rise in inflation. For instance, Ball and Romer (2003) as well as Tommasi

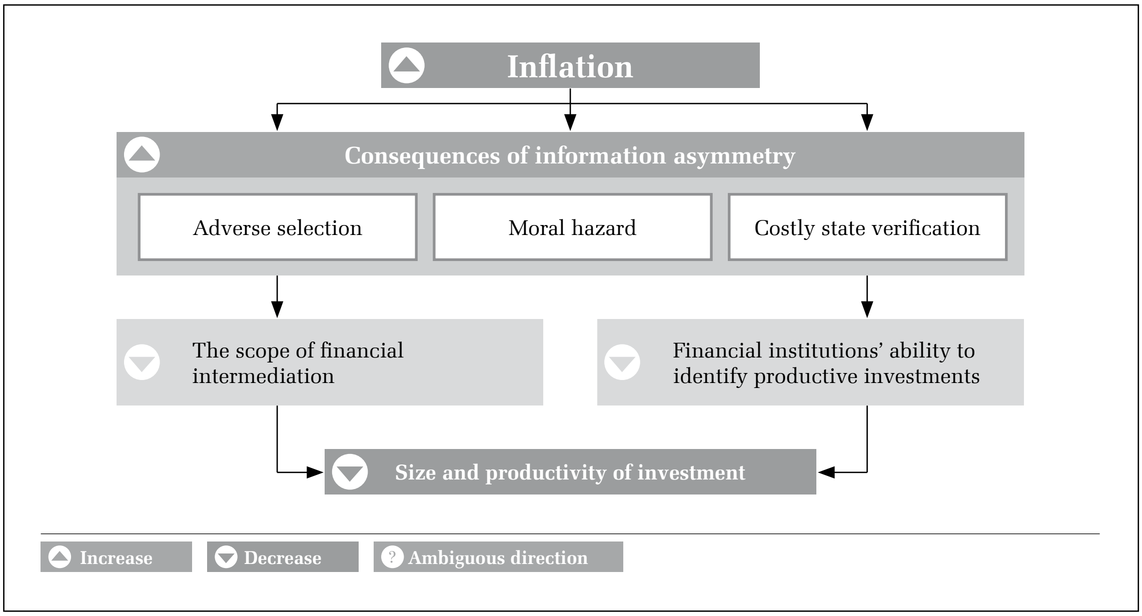
(1994) show that higher inflation increases relative price variability, which distorts the information about future prices that is contained in current prices. As a result, consumers have less complete and less accurate information, which allows firms to impose higher markups. Conclusions from models of this type do not find strong empirical support, however. A negative relationship between inflation and the markup level has been found *inter alia* by Benabou (1992b), Chirinko and Fazzari (2000), Batini, Jackson and Nickell (2000), Banerjee and Russell (2000, 2005), Banerjee, Cockerell and Russell (2001), Banerjee, Mizen and Russell (2007).

Fifth, a rise in the level or variability of inflation lowers investment productivity through its interaction with the asymmetry of information. On the one hand, due to the fact that when inflation is higher and more variable, the probability of obtaining external financing for future projects decreases, firms are less inclined to make R&D expenditures aimed at raising the profitability of potential future investment (Smith, van Egteren 2005). Even if they obtain external financing in the future, despite a lower probability of success, the investments undertaken by them will be less profitable (a model with a similar mechanism has been proposed by Aghion, et al. (2004), but although they show that investment productivity depends positively on the level of financial market development and negatively on the variability of macroeconomic conditions, they do not associate either the variability or the financial depth level with the level of inflation). On the other hand, the most productive technologies are often characterized by a relatively large scale of required investment, exceeding the financial capacity of a single enterprise, and by the necessity to freeze capital for a longer period of time. Both of these characteristics force enterprises willing to implement them to seek external financing (Huybens, Smith 1999). Such a conclusion is consistent with the observation made by Hicks (1969), who pointed out that the development of financial institutions was a necessary condition for the first industrial revolution to have taken place. Hicks indicated that most technologies that played a key role in that revolution had been invented much earlier. However, the use of these technologies required very large capital outlays (exceeding the financial capacity of a single firm), which on top of that had to be frozen in the investment for a long time. Thus in conditions of the inevitable asymmetry of information firms were not able to undertake such investments until institutions were created that provided the necessary funds.

Sixth, by reflecting macroeconomic instability, inflation introduces additional "noise" into the evaluation of investment projects by the lenders (Baum, Caglyan, Ozkan 2004), making the identification of profitable projects more difficult. One, but not the only one, of the possible mechanisms leading to this outcome was presented by De Gregorio and Sturzenegger (1994). When inflation is sufficiently high consumers are prepared to conclude a transaction with a less efficient firm if they come across one, thereby giving it an opportunity to operate, despite the fact that there are other firms in the market that offer the same good at the same time at a lower price. Such behaviour of consumers is due to the fact that their refraining from making a purchase with a view to finding the best offer is connected with a loss of a part of their money balances' purchasing power. At the same time, transactions concluded with inefficient firms decrease sales of goods produced by more efficient ones. As a result, although consumers' readiness to accept more expensive offers under the influence of inflation allows firms to raise prices, the shift of realized demand towards goods offered by less productive enterprises ultimately lowers the markup, that is, the relationship between markups and inflation, as indicated by most theoretical and empirical studies (see foregoing paragraph), is preserved.

Figure 1 contains a summary of the main conclusions from the theoretical models analyzed.

Figure 1
Inflation's impact on investment – the financial market channel



3.3. Inflation's impact on the financial sector – empirical results

In the empirical literature one can distinguish two approaches to verifying the hypotheses of the models presented above. The first one concentrates on investigating the relationship between inflation and the level of financial sector development while assuming that the latter is an important factor determining the size and productivity of corporate investment. The other approach consists in verifying the hypothesis of inflation's negative impact on financial sector's effectiveness in mobilizing savings and their efficient allocation.

Inflation and the level of financial sector development

The results of studies within the first approach confirm that higher inflation leads to reduced financial depth.

A simple comparative analysis conducted by Boyd and Champ (2003) revealed that in a group of 98 developed and developing countries in the years 1980–1995 the average value of the credit-to-GDP ratio was 50% for the first quartile of inflation and 19% for the fourth quartile. In a group of 23 countries in the period 1970–1995 the average ratio of capitalization to GDP amounted to 55% in the first quartile of inflation and 12% in the fourth quartile, and the stock-market-turnover-to-GDP ratio amounted to 20% and 3% respectively.

Beck, Demirguc-Kunt and Levine (2003) conducted a direct analysis on a sample of 5000 firms from 49 countries of the relationship between inflation and the burdensomeness of barriers that entrepreneurs face when trying to obtain external financing. According to their results, a rise in barriers to external finance, caused *ceteris paribus* by inflation, can result not only from increased credit rationing by banks, but also from more restrictive non-price loan-terms, e.g. collateral level requirements.

A negative relationship between financial depth and inflation has also been found in time-series studies (see e.g. Boyd, Choi, Smith 1996, who investigated the relationship between inflation and the growth in the real value of stock-market transactions, separately for the United States, Chile, South Korea and Taiwan).

Quagliariello (2009) has shown how uncertainty on macroeconomic conditions, measured i. a. by conditional volatility of inflation, affects lending decisions of Italian banks. Estimated models indicates that higher inflation uncertainty reduces the cross-sectional variance of the share of loans held in banks' portfolios, which indicates that making the identification of profitable projects is more difficult in environment of volatile inflation – result predicted by the earlier described portfolio model proposed by Baum, Caglyan and Ozkan (2004).

Furthermore, studies within the first approach confirm that the relationship between financial depth and inflation is non-linear.

The analysis by Boyd, Levine and Smith (2001) conducted on data from the period 1960–1995 for 97 countries, indicates that as inflation rises, the size of the financial sector declines in relation to GDP, but the marginal impact of changes in inflation falls. Moreover, when inflation exceeds 15% the partial correlation between inflation and indicators of credit-market and stock-market activity disappears; inflation's all negative consequences for financial development manifest themselves already at lower inflation levels.

Similar results have been obtained by Rousseau and Wachtel (2002) for a panel of 84 countries (developed and developing) in the period 1960–1995. They used rolling regression in order to identify the potential nonlinearity of the investigated relationship. This method allowed them to find that the whole negative impact of inflation on financial depth materializes before inflation exceeds, depending on the measure, 10.6% (in the case of the M3 aggregate), 21.9% (the difference between M3 and M1) or 16.1% (bank credit).

A non-linear relationship between financial depth and inflation has also been found by Khan, Senhadij and Smith (2006) who studied a panel of 168 countries (developed and developing) in the period 1960–1999. In model estimation they employed the methodology proposed by Hansen (2000), which enables one to set objective values of the thresholds at which a shift occurs in the direction or the magnitude of the relationship between the independent variable and a given dependent variable (in other words, in contrast to *ad hoc* methods it allows one to avoid the arbitrary choice of the threshold values of the dependent variable). They also found that up to the level of 3–6%, depending on the financial depth measure used, inflation has no effect on financial depth, or – in the case of one of the measures (stock-market turnover) – it even has a weak positive impact; after exceeding that threshold, inflation significantly lowers financial depth.

Despite the fact that most studies within the first approach do not analyze developed and developing countries separately (see Boyd, Choi, Smith 1996; Boyd, Levine, Smith 2001; Rousseau, Wachtel 2002; Boyd, Champ 2003 and Khan, Senhadij, Smith 2006), one can find studies in this vein confirming that as capital stock per employee rises the negative impact of inflation on financial depth becomes stronger. For instance, Cuadro, Gallego and Herrero (2003) have found, using a cross-section sample of 134 countries, that in developing countries the impact of inflation on financial development was much weaker (by approximately 1/3) than in all countries taken together, although still negative and statistically significant. Dong-Hyeon and Shu-Chin (2010) using an unbalanced panel covering 87 countries in the period 1960–2005 have shown a negative long-run relationship between inflation and financial development for the whole sample of countries. However, in subgroups differentiated in terms of inflation and income level these results hold only for low-income or low-inflation countries.

The results of the empirical studies cited are thus generally consistent with the main hypotheses formulated on the basis of theoretical models' predictions. In order to conclude about inflation's negative impact on the size or productivity of investment it is necessary to assume a positive relationship between the size or productivity of investment and the scope of financial intermediation. Such an assumption seems justified in light of the available results of empirical research. A full analysis of the literature on the dependence between investment (or, more broadly, economic growth) and financial development goes beyond the scope of this article. Suffice it to say, however, that since the seminal article by Goldsmith (1969) this relationship has been confirmed to be positive by numerous empirical studies. An exhaustive review of the results of research within this strand can be found for instance in Levine (2004). Nevertheless, caution is warranted when making conclusions about inflation's impact on investment on the basis of the foregoing results. As emphasized by Mayer (1993), econometric verification of research hypotheses does not satisfy the transitivity conditions. Separate rejection of the hypotheses that, respectively, variable A has no influence on variable B, and variable B has no impact on variable C at a given significance level does not lead automatically to the rejection of the hypothesis that variable A has no impact on variable C at the same significance level. Thus, whereas the relationships between, correspondingly, inflation and financial development, and financial development and investment can be statistically significant at a given significance level, the relationship between inflation and investment may not show such significance at the same level.

Inflation and financial sector's effectiveness in mobilizing savings and their efficient allocation

The other approach to investigating the relationship between inflation, the financial market and investment concentrates on the verification of the hypothesis that inflation has a negative impact on financial intermediaries' effectiveness in mobilizing savings and allocating them efficiently. The hypothesis stemming from theoretical models and tested in such studies assumes that from a certain level higher inflation lowers the financial sector's ability to identify ways of the most productive capital use. We are, however, unaware of studies analyzing inflation's direct effect on the strength of the relationship between productivity and the size of investment on the one hand, and financial depth on the other hand. The existing literature verifies this hypothesis in an indirect way, i.e. by studying inflation's impact on the strength of the link between economic growth and financial sector development. It is assumed in these studies that a weakening of this relationship in reaction to a rise in inflation above a certain level means that price growth is fast enough to limit financial institutions' ability to identify highly productive investments.

As a result, at a certain inflation level the rise in financial sector's importance in the economy ceases to raise investment and the quality of implemented investment projects. This, in turn, is reflected in economic growth's weaker dependence on financial depth measures. Below selected empirical studies are discussed that verify this mechanism.

Drawing on the earlier mentioned rolling-regression results, Rousseau and Wachtel (2002) conclude that an inflation rise within the low-value interval leads through its impact on investment to a lower magnitude of financial depth's effect on GDP growth. After inflation exceeds the threshold value which is equal to, depending on the financial-depth measure used, 6.5% (in the case of M3), 13.4% (the difference between M3 and M1) and 8.1% (bank credit), the analyzed relationship ceases to be significantly positive at the 5% significance level.

A similar analysis was conducted by Barnes (2001). He used panel data from 49 developed and developing countries in the years 1965–1995 while employing Hansen's (2000) methodology which, as already mentioned, allows one to avoid arbitrariness when setting the threshold values. In a sample of observations in which inflation did not exceed 14%, financial depth's effect on economic growth turned out to be positive and statistically significant. In a sample made up of the remaining observations the model did not confirm the existence of a relationship between these two variables.

Hansen's (2000) methodology was also used by Lee and Wong (2005), who applied it to quarterly data for Taiwan in the years 1965–2002 and for Japan in the years 1970–2001. In their study the relationship between economic growth and the financial-market development index turned out to be statistically significant solely for inflation not exceeding 7.2% in the case of Taiwan and 9.7% in the case of Japan. A lower threshold value for inflation in the less developed country (Taiwan) than in the more developed one (Japan) can be explained (at least) in two ways. First, a yearly growth rate of a certain monetary aggregate was used as a proxy for financial development, whereas most research measures financial development with the ratio of a certain monetary aggregate to GDP. In the case of the measure employed by Lee and Wong (2005) an important role in gauging its impact on economic growth at different levels of inflation can be played by the initial level of financial development. Second, as demonstrated by Levine, Loayza and Beck (2000), the monetary aggregate used in Lee and Wong's (2005) study (the sum of currency in circulation, demand deposits and time deposits) may not be a good measure in research of this kind as it does not describe correctly the financial sector's role in limiting information asymmetry.

The results of empirical research confirm that from a certain level upwards, a rise in inflation is accompanied by a decline in the magnitude of financial depth's impact on economic growth. This result can be treated as a confirmation of the hypothesis that inflation exerts a negative impact on the ability of financial institutions to stimulate investment and to identify the most productive projects. It should be emphasized, however, that the weakening of the link between economic growth and financial development at sufficiently high inflation levels may also reflect the impact of factors other than those included in the model. The effect of these factors on the level or productivity of investment may manifest itself only when inflation is sufficiently high. In such a situation the true magnitude of the relationship between financial depth and economic growth could be constant and its estimated strength would decline due to the inflation-induced impact on investment of variables omitted in the model. Thus further research is warranted in order for the conclusions formulated in the foregoing studies to hold.

The results of the earlier mentioned analysis by Rousseau and Wachtel (2002) (unpublished in their article) suggest that the negative relationship between inflation and economic growth can be interpreted as a confirmation that the "inflation – financial sector development – investment" mechanism is not the only channel through which inflation can negatively influence growth. In the following section we discuss inflation's impact on investment through its effect on uncertainty.

4. Inflation – uncertainty – investment

Investment is an activity connected with incurring certain costs today in order to obtain the expected results in the future. Firms must compare costs, which, in the simplest case, they can determine in advance, with expected results which are uncertain. Contrary to what monetary growth models assume, the scale of uncertainty can play an important role in firms' investment decisions.

4.1. Defining uncertainty

In the assessment of the role of inflation-related uncertainty in firms' investment decisions the classification put forth by Knight (1921) may be useful. Therefore, in this article we will limit the analysis to this classification. An exhaustive review of the concept of uncertainty within different decision– making theories can be found e.g. in Machina (1987), more recent theories have been presented, among others, in Gilboa (2004).

Knight (1921) distinguished two types of uncertainty.

The first, known as risk in the sense of Knight or classic uncertainty refers to a situation in which all events that can have an influence on a decision can be assigned unambiguously determined probabilities, i.e. known and evaluated at the same level by all economic agents. The theory that describes uncertainty within this line of reasoning is von Neumann and Morgenstern's (1944) expected utility theory in which probabilities are objective.

The other type, uncertainty in the sense of Knight (1921) or (following Ellsberg 1961) ambiguity refers to a situation in which events cannot be assigned objective probabilities. This does not mean, however (which is often wrongly attributed to this definition), that economic agents do not impute any probabilities to these events: these probabilities are subjective, that is, they reflect the convictions of individual agents.

The gist of this distinction was aptly expressed by Hicks (1979, p. 107): "Risks, according to Knight, arise from random sequences; so they can be covered, if there are enough of them, by insurance. True uncertainties, which he recognizes to be of greater importance in economics, cannot". According to this interpretation, firms' investment decisions are made under uncertainty and not under risk because in most cases the firm cannot insure against potential loss.

4.2. Mechanisms of the inflation-uncertainty-investment relationship

Two mechanisms determine the inflation–uncertainty–investment relationship. The first one concerns inflation's influence on the uncertainty surrounding those variables that form the basis for entrepreneurs' judgments about future outcomes of current investment. The other is related to how uncertainty surrounding future profits can shape firms' investment decisions. As these are, in principle, two disjoint mechanisms, we analyze them separately.

Uncertainty about variables key in investment decisions

There are several ways in which inflation can increase uncertainty linked to the variables key in firms' investment decisions. It can increase relative price variability (henceforth, RPV), uncertainty about future inflation and/or uncertainty about the future macroeconomic situation.

Increased relative price variability

Several theoretical approaches exist that provide a rationale for such inflation's role in increasing RPV.

Menu cost models (cf. e.g. Sheshinski, Weiss 1977; Rotemberg 1983, Benabou 1992a) explain it by discontinuous price adjustments resulting from costs connected with such changes. In a model economy, firms change prices according to the (S, s) rule: the nominal price set by a firm is kept constant until the relative price reaches the level of s, then the nominal price is raised until it reaches the level at which the relative price equals S. The higher the inflation, the larger the difference between the values of s and S, and, as a result, the more variable the relative prices.

Signal extraction models (Lucas 1972; Barro 1976; Hercowitz 1981) relate changes in RPV to unexpected changes in inflation. Such unexpected changes in inflation make aggregate demand shifts less predictable, which encourages firms to limit the scale of supply adjustments in reaction to all shocks, including idiosyncratic demand shifts. In order to equilibrate the more variable demand with the less variable supply, price changes in each market must be larger.

Multisector general equilibrium models indicate that inflation may lead to a rise in RPV through technological shocks correlated across sectors (Balke, Wynne 2000). Whereas the previously discussed models explain the existence of a short-run relationship between inflation and RPV, Balke and Wynne demonstrate that this may be a long-run relationship.

The relationship between inflation and RPV has been a subject of empirical research for a very long time. The following general conclusions can be drawn from this line of research.

The relationship between inflation and RPV is positive and statistically significant. Nautz and Scharff (2005) analyze the results of 11 studies confirming this relationship. Out of the 15 studies analyzed by Banerjee, Mizen and Russell (2007), only 4 did not confirm this relationship. On the basis of their literature review, Binette and Martel (2005) conclude that this relationship has almost become a stylized fact.

Inflation's impact on RPV is significant even when inflation is low or moderate. A confirmation of inflation's positive impact on RPV has been obtained for countries which did not experience episodes of high (above 30%) inflation in the investigated periods. These countries include, for instance, Germany (Nautz, Scharff 2005), Canada (e.g. Binette, Martel 2005), the United States (e.g.

Chang, Cheng 2000), the United Kingdom (e.g. Banerjee, Mizen, Russell 2007), as well as the euro area (Nautz, Scharff 2006; Caporale, Onorante, Paesani 2010).

This relationship can exist not only in the short-, but also in the long-run (see e.g. Parsley 1996; Nath 2003).

Inflation's effect on RPV can also be non-linear (see Nautz, Scharff 2006).

Higher RPV increases uncertainty related to investment decisions at least in two ways.

On the one hand, it is more difficult for entrepreneurs to assess the current and future relations between the prices of goods produced by them and the prices of intermediate, substitute or complementary goods. As a result, it is more difficult for them to determine what is and what is not worth producing.

On the other hand, the number and the average duration of long-term contracts diminishes. These contracts eliminate a sizable part of the uncertainty about the future level of demand and prices, and, as a result, reduce the uncertainty about future profits from started investments (see e.g. Reagan, Stulz 1993; Guerrero 2005).

Uncertainty about future inflation

Inflation leads to higher inflation uncertainty, understood as the possibility of unexpected higher inflation rates in the future. In the literature several theoretical approaches can be found that explain this phenomenon.

Ball (1992) describes it as a result of a game between economic agents and monetary policy makers. When inflation is low, policymakers prefer to keep it at a low level. However, if inflation is high those policymakers who believe in a short-term trade-off between inflation and unemployment may not be determined enough to take necessary steps to lower inflation. Economic agents do not know what kind of monetary policy will be pursued in high-inflation conditions. The higher the inflation, the higher the uncertainty about the direction of monetary policy and the future inflation level.

Holland (1993a) finds that the relationship between current inflation and the uncertainty about its future level results not so much from the uncertainty surrounding future monetary policy, but rather from the uncertainty about monetary policy transmission to inflation. He demonstrates that if there is uncertainty about the length of the monetary policy transmission lag, uncertainty about the level of future inflation is positively correlated with current inflation squared.

Evans and Wachtel (1993) and Holland (1993b) explain the existence of this dependence with uncertainty about the parameters of the process describing inflation. They show that if economic agents are uncertain about inflation persistence, the uncertainty surrounding future inflation is an increasing function of current inflation. Such an explanation is consistent with both earlier-mentioned hypotheses, Ball's (1992) as well as Holland's (1993a): uncertainty about the parameters describing inflation may result both from uncertainty about the direction of monetary policy conducted under different regimes, as well as from the strength and lags in monetary transmission to inflation.

The results of empirical studies of the relationship between current inflation and inflation uncertainty lead to the following conclusions:

A positive relationship exists between inflation uncertainty and inflation level. For instance, Golob (1994) concludes that a confirmation of the positive relationship between inflation and inflation uncertainty was obtained in 17 out of the 21 studies he analyzed. A similar conclusion was reached by O'Reilly (1998) who reviewed further 10 studies from the years 1993–1998 which confirmed this relationship.

The relationship is causal and runs from inflation to uncertainty (see e.g. Grier, Perry 1998; Holland 1995).

The positive dependence between inflation uncertainty and inflation level is significant even when inflation is low or moderate. A confirmation of inflation's positive impact on inflation uncertainty was obtained for countries which did not experience episodes of high (above 30%) inflation in the periods investigated, e.g. the United States (e.g. Holland 1995; Golob 1994), the UK (e.g. Fountas 2001; Kontonikas 2004), Canada (e.g. Crawford, Kasumovich 1996), or G7 countries (e.g. Ricketts, Rose 1996).

Inflation has a stronger impact on the long-term rather than on the short-term uncertainty about future inflation (see i.a. Ball, Cecchetti 1991; Evans 1991; Evans, Wachtel 1993).

It should be emphasized, however, that the measures of uncertainty used in these studies do not fully satisfy the definition of uncertainty used in theoretical models, expressed as the variance of expected inflation.

Higher uncertainty about future inflation may influence the uncertainty about the future return on investment through several mechanisms.

It increases uncertainty about that part of future tax burdens (that have a direct or an indirect impact on the user cost of capital) which is determined by factors that are not inflation-indexed (we discuss this in more detail in the following section).

It is reflected in the growth of uncertainty about the future level of interest rates. This uncertainty can be evoked by both fluctuations in the inflation-related risk premium and the difficulty in assessing the impact of taxes on the real-interest-rate level.

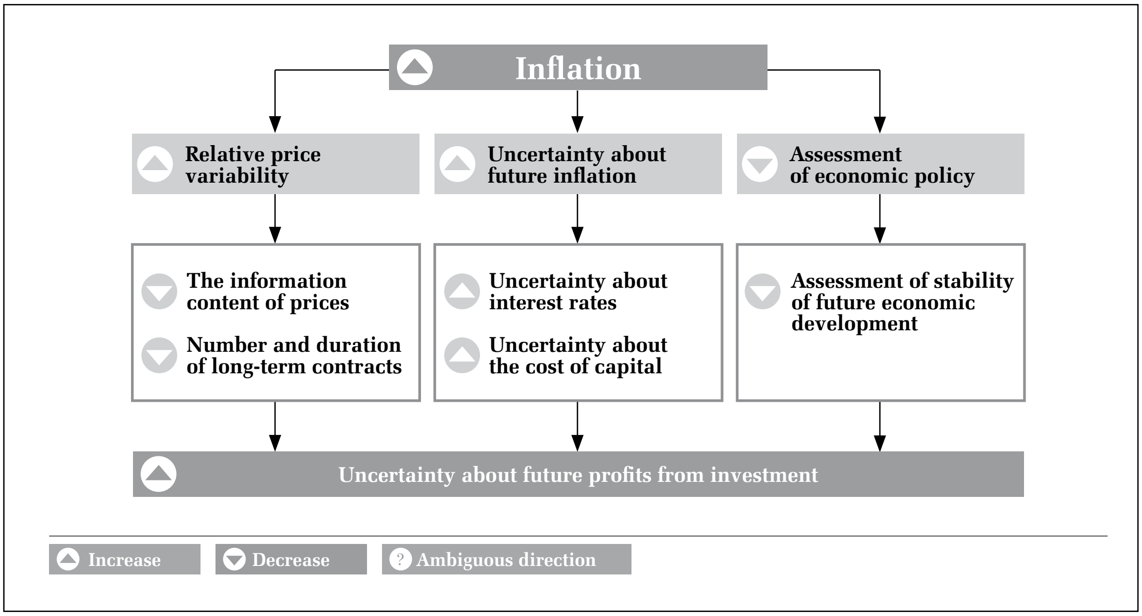
Finally, it intensifies the uncertainty stemming from RPV as long as nominal price rigidities emerge (Friedman 1977).

Uncertainty about future macroeconomic situation

Inflation may lead to a rise in the uncertainty about a country's future economic situation. Fischer (1993) concludes that due to the lack of economic justification for letting inflation run high, authorities that allow inflation to rise can be assessed by economic agents as unable to conduct a consistent and stable economic policy (a similar argument is put forward by Eberly 1993). As a result, economic agents' decisions may depend directly on the inflation level even when inflation does not have a direct impact on the uncertainty about the factors that should be considered when taking these decisions. Such a relationship is characteristic of models in which the behavior of economic agents depends on "self-fulfilling prophecies" and "sunspots" (cf. e.g. Woodford 1990; Farmer 1993). A "sunspot equilibrium" arises when a variable that has no unambiguous (direct or indirect) effect on the economy, exerts such an influence because economic agents believe that such an impact exists and react to changes in the values of this variable. We are, however, unaware of any empirical research confirming that economic agents indeed perceive inflation in this way.

Both economic theory and the results of empirical research point to several channels through which inflation intensifies the uncertainty surrounding those variables that influence the results of firms' investments. Figure 2 illustrates these mechanisms.

Figure 2
Inflation's impact on investment – the uncertainty channel



Uncertainty about future profits from investment

The above described mechanisms can have an effect on firms' investment decisions only when uncertainty constitutes a significant determinant of investment. We analyze this further in this section.

Uncertainty about future profits from investment – theoretical results

The predictions of theoretical models as to the direction of this relationship do not give a straight and unambiguous answer.

In some models in which it is assumed that economic agents make decisions under uncertainty, their decision-making problem is formulated in such a way, so as to *de facto* eliminate uncertainty and its effects. An example of such an approach is the model of Lucas and Prescott (1971), in which it is assumed that all possible states of nature are foreseen by economic agents under rational expectations. As a result, the model does not predict any impact of changes in uncertainty on investment, as by assumption it is based on a "(...) theory linking current investment to observable current and past explanatory variables, rather than to 'expected' future variables" (Lucas, Prescott 1971).

Other models (e.g. Hartman 1972; Abel 1983), in which the uncertainty connected with investment is irreducible, offer the counterintuitive conclusion that a rise in uncertainty about the future price level leads to an increase in investments started by a firm. These models assume that there is perfect competition between firms, the production function exhibits constant returns to scale and that capital adjustment is costly, which allows labor inputs to be adjusted to price changes more flexibly than capital inputs.[2] Under such assumptions the marginal product of capital changes more than prices – it is a convex function of the price. In this case, assuming firms are risk-neutral, a rise in uncertainty, given a mean-preserving spread, raises the expected marginal product of capital (Rotschild, Stiglitz 1970) in line with Jensen's inequality, and hence also the investment rate and the optimal level of capital.

However, at least some of the assumptions leading to uncertainty's positive impact on investment are inconsistent with reality (Dixit, Pindyck 1994).

First, most investment is partly or fully irreversible. If disinvestment is connected with higher adjustment costs than investment, then negative shocks have a larger impact on the profitability of an investment project than positive shocks (however, investment irreversibility is not a sufficient condition for achieving a negative impact of increased uncertainty on investment – see Caballero 1991; Abel, Eberly 1995).

Second, entrepreneurs rarely have to choose to "invest immediately or never". In most cases they can postpone the investment decision until they obtain information allowing them to eliminate part of the projected-related uncertainty.

In order to take account of these two features of the investment process it is necessary to modify the classic rule of positive net present value (henceforth, NPV) that describes the firm's investment decisions. The expected return on investment must be higher than the cost by an amount equal to (at least) the value of the so-called real option. The real option allows one to postpone investment implementation until new information about the determinants of the project's profitability is available, and, as a result, makes it possible to avoid the cost connected with maintaining too large a capital stock (McDonald, Siegel 1987; Abel et al. 1996). As the value of this option is due to the opportunity to avoid negative consequences of investment decisions, it is determined solely by potential negative shocks. The real option concept reflects the bad news principle formulated by Bernanke (1983), according to which, the decision to start an investment is sensitive only to the expected severity of unfavourable states of nature. Numerical solutions of real-option models indicate that the value of such an option can be significant even at a relatively low uncertainty level. As a result, this concept can also be helpful in explaining why the hurdle rate of return, that is the expected rate of return, after exceeding which a firm is inclined to start an investment, is in practice many times higher than the cost of capital (Summers 1988).

Model results obtained in the analysis of a single firm cannot be mechanically generalized to the whole sector or economy. Nevertheless, the assertion that uncertainty can have significant effects on investment also in the aggregate, can be justified – in at least two ways (Bernanke 1983).

[2] The impact of uncertainty on firm behavior has also been analyzed within the framework of models assuming a lack of capital-adjustment costs. The lack of adjustment costs eliminates the intertemporal element from the optimization problem. As a result, it can be reduced to the static problem. Furthermore, the lack of adjustment costs allows the firm to adjust immediately (i.e. in the same unit of time) the current capital level to the optimal level, which means that the investment rate is infinite. And so the investment function does not exist. Models without capital-adjustment costs have thus concentrated on the assessment of uncertainty's impact on the optimal output level (Sandro 1971; Leland 1972) or on the optimal labour-to-capital ratio (Holthausen 1976; Das 1980). Generally speaking, the direction of uncertainty's impact on these magnitudes depends on the assumption about the firm's aversion to risk: for a risk averse firm uncertainty decreases (increases) the optimal output level and the labour-to-capital ratio, whereas for a risk-neutral firm a change in uncertainty does not have an impact on these magnitudes. Such a result can be hardly regarded as a realistic picture of uncertainty's role in firms' decisions.

First, while the effects of idiosyncratic uncertainty may offset each other at the macro level, the consequences of uncertainty related to macroeconomic factors may not. Such a conclusion is consistent with the argumentation put forward by Pindyck (1993) and Caballero and Pindyck (1996). They showed that investment irreversibility is a sufficient condition for the existence of a negative impact of uncertainty on investment at the industry level, as long as this impact is characterized by freedom of entry into the market, and that uncertainty concerns many firms, not just one. Given such assumptions the positive effects of potential aggregate shocks are limited by new firms entering the market, while the consequences of negative shocks affect only those firms already present in the market. Being aware of this mechanism, firms react only to a rise in the probability of unfavourable outcomes in the future. This leads to lower investment, both at the individual-firm level and in the whole industry. An important illustration of aggregate uncertainty's role in shaping investment is the uncertainty surrounding the future interest-rate level. Ingersoll and Ross (1992) have demonstrated that this type of uncertainty causes an increase in the value of the option to invest. In other words, this uncertainty encourages firms to abandon investment, even if they have perfect certainty about the other determinants of cash flows generated by this investment.

Second, the mechanism based on investment decisions of individual firms can make the effects of uncertainty experienced by these firms "spill over" to the macro level. If we assume that *ex ante* enterprises cannot differentiate correctly between temporary and permanent demand changes, then the abandonment of investments by some firms under the influence of higher uncertainty, may, through lowering demand in the economy, encourage other firms to cut investment as well (Bernanke 1983). Similarly, Bertola and Caballero (1994) show that idiosyncratic uncertainty in conjunction with investment irreversibility has a significant impact on investment growth at the aggregate level if only firms do not make constant adjustments to the capital level (which is consistent with reality). Serven (1997), on the other hand, concludes that the impact of aggregate uncertainty on the level of investment in the economy can be nonlinear and may depend on such factors as the size of idiosyncratic uncertainty.

Uncertainty about future profits from investment – empirical results

Due to the ambiguity of conclusions drawn from these models only empirical results can provide the answer to the question of the direction and strength of uncertainty's impact on investment (Cecchetti 1993). Below we concentrate on studies analyzing the dependence between investment and inflation-induced uncertainty (a review of research on the impact on investment of uncertainty related to factors other than inflation can be found in Carruth, Dickerson, Henley 2002; Bo, Lensink, Sterken 2001).

The principal weakness of empirical research is that due to uncertainty's nature none of the uncertainty measures used can be a "perfect" measure, that is, one reflecting *ex post* the actual uncertainty that entrepreneurs perceived *ex ante*. These measures are constructed on the basis of one of the following three methods.

First, in some studies simple *ex post* variability measures of analyzed variables are used to approximate uncertainty (such an approach was followed e.g. by Serven, Solimano 1993; Pindyck, Solimano 1993; Yeyati 1996; Serven 1997). Associating uncertainty with variability has, inter alia, the drawback that one can imagine a situation in which big changes in inflation (e.g. under a credible disinflation policy) occur in a situation of low uncertainty among economic agents. And conversely, perceived uncertainty can be high in a situation of low *ex post* variability of inflation (e.g. in the case of an announced but unsuccessful disinflation policy).

The second approach is based on the rational-expectations paradigm and consists in estimating a model describing a variable's behaviour in time and in approximating the uncertainty related to this variable with the variance of the model's residuals (this measure was used e.g. by Huizinga 1993; Ghosal, Loungani 1996; Serven 1998; Kalckreuth 2000). Even a superficial review of the literature on modeling economic variables indicates that economists simultaneously employ many competitive models describing the same magnitude. Assuming that entrepreneurs use only one type of model leads to an underestimation of the actual uncertainty level (Frydman, Goldberg 2007). This problem is exacerbated by the fact that each type of model is sensitive to changes to its specification. Finally, the adequacy of an uncertainty measure obtained in the estimation of a model of a given variable is undermined also by the fact that the measure is always based on historical data, and, as a result, does not allow to include information about the future which economic agents could have at a given moment.

The third approach consists in estimating uncertainty with the use of data containing information about economic agents' expectations as to the future level of variables affected by uncertainty. The main measures used within this approach are: (1) the level of the risk premium included in the term structure of interest rates (which was used e.g. by Ferderer 1993), (2) expectations-differentiation measures calculated on the basis of survey data (e.g. Driver, Moreton 1991; Butzen, Fuss, Vermeulen 2002) and (3) statistical variance calculated on the basis of subjective probabilities assigned in questionnaire surveys to the event of a variable's future value falling within a given interval. The first of these measures has most of the drawbacks of the measures within the second approach as it is based on the same rational-expectations paradigm. In contrast to the latter, however, it reflects uncertainty about the future observed at a given moment. The second and the third measure within the third approach do not require the rational-expectations assumption. Some authors indicate that measures of heterogeneity do not reflect individual-agent uncertainty but the dispersion of individual agents' assessments (e.g. Grier, Perry 2000). Others emphasize, however, that given certain, rather general, assumptions, uncertainty perceived by individual agents is strongly correlated with heterogeneity measures (e.g. Zarnowitz, Lambros 1987; Bomberger 1996; Giordani, Söderlind 2003; Bachman, Elstner, Sims 2009). The third of the measures, namely variance calculated on the basis of the distribution of subjective probabilities, is the most consistent one, among the measures presented here, with Knight's definition of uncertainty. Its principal weakness lies in the limited availability of data, especially at the firm level.

Despite these weaknesses the following conclusions can be drawn from empirical research.

Irrespective of the measure of inflation-driven uncertainty used, most studies indicate a negative impact of inflation uncertainty on investment. Different results, e.g. in Huizinga (1993), who analyzed this relationship for the US in the years 1954–1989, concerned one variable (uncertainty connected with the prices of industrial production) in one of the methods of analysis used (a cross-section model). According to the author himself, these dissimilar results could be due to the endogeneity problem. In Ghosal, Loungani (1996), who analyzed 254 branches of manufacturing in the US in 1958–1989, the opposite direction of the relationship in question was a result of including in the study low-competition branches in which firms are price givers. In a subsample consisting of branches with higher competition the obtained sign of the relationship was negative and statistically significant. A similar problem, namely that of statistical significance and of a change in the analyzed relationship's direction depending on model specification, was present in Butzen, Fuss, Vermeulen (2002) who based their study on data from questionnaire surveys conducted in 1986–2001 on 2500 Belgian firms. As the sample consisted solely of large enterprises, of which a large proportion were price givers, not price takers, the question about anticipated price changes might not have reflected firms' perceived uncertainty but their plans to change product prices. This hypothesis is partly confirmed by the results concerning the impact of demand uncertainty on planned investment, which in almost all specifications indicated a significantly negative impact of this uncertainty measure on investment plans.

The identified negative relationship between investment and inflation-induced uncertainty usually exhibited high robustness to changes to the specification of the investment equation. For instance Ferderer (1993), in his analysis of US firms' investment decisions in the years 1963–1989, obtained a negative dependence in all 4 groups of models he estimated.

If the inflation-induced uncertainty had a negative influence on investment, then this impact was usually strong. In Ferderer (1993), for instance, it was stronger than the influence of the user cost of capital, and of the *q* coefficient, that is, classic variables explaining investment. In Serven, Solimano (1993), who analyzed 8 countries from Latin America, 3 Asian and 2 African countries in the period 1975–1988, inflation-induced uncertainty made the same contribution as GDP growth to explaining the variability of the private investment rate, that is, a variable which according to numerous studies, is an important determinant of investment. In Pindyck, Solimano (1993), who studied 30 countries (16 developed OECD countries and 14 developing countries) in the period 1962–1990, inflation turned out to be the only variable among the analyzed measures of economic and political instability which significantly and in the expected direction influenced the variability of marginal productivity of capital, which negatively affects investment (in Serven 1997, some variables describing political instability, such as e.g. the number of socio-political conflicts had a stronger impact on investment than that of inflation, but he investigated the countries of Sub-Saharan Africa in which these conflicts were exceptionally intense).

A negative dependence between investment and inflation-induced uncertainty has been established both in developing and developed countries, or in other words – both in high-inflation and low– or moderate-inflation economies. Pindyck and Solimano (1993) obtained this result while estimating a series of panel regression models for the years 1960–1990, separately for 6 developed and 6 developing countries (with the caveat that in developing countries this relationship was statistically significant only in those specifications in which the dependent variable was the total investment rate, whereas in the case of both groups of countries it could have reflected inflation's impact on investment not only through higher uncertainty but also through other channels). Serven (1998) identified a negative relationship on a sample of 94 developing countries in the years 1970–1995, Yeyati (1996) – in 10 Latin American countries in the period 1961–1992, Serven and Solimano (1993) – in 8 Latin American, 3 Asian and 2 African countries, Serven (1997) – in the case of 40 countries in Sub-Saharan Africa in the years 1970–2002 and Fisher (2009) – for the panel of small, microfinance-funded firms in the Dominican Republic. In turn, Kalckreuth (2000) confirmed these results while analyzing German data from the period 1987–1997, Ferderer (1993) and Byrne and Davis (2004) – US data, in the years 1963–1989 and 1964–1999 respectively, and Driver and Moreton (1991) – UK data from Q4 1978 to Q4 1987.

These conclusions suggest that inflation-induced uncertainty has a rather negative impact on corporate investment, thus calling into question the ambiguous results of theoretical models as to the direction of this relationship.

5. Inflation – tax system – investment

The models discussed so far, explaining inflation's impact on corporate investment decisions, neglected taxes. The tax systems functioning in contemporary economies are based on nominal, not real magnitudes. Hence, if taxes influence corporate investment, non-zero inflation can strengthen or weaken this impact. Inflation's effect on investment through interactions with the tax system depends on the direction and strength of two relationships: inflation's and taxes' impact on the user cost of capital and the impact of the user cost of capital on firms' investment decisions.

The magnitude and the direction of inflation's and taxes' impact on investment are determined by the particular tax system arrangements in a given country, and in the case of open-economy, also by the relations between these arrangements and those of other countries. Generally speaking, the magnitude and the direction of inflation's and taxes' impact on investment are derivative to three types of tax arrangements:

nominal interest paid on the debt is treated as a tax deduction in the case of a firm and as taxable income in the case of a natural-person creditor.

capital gains (understood as income from shares in the company) are taxed on a nominal basis, without taking account of changes in inflation.

depreciation write-offs are calculated on the basis of a fixed asset's historical cost (or cost of purchase), hence in a situation of rising inflation, the present discounted value of depreciation write-offs declines virtually in every depreciation scheme.

5.1. Inflation's impact on investment via the tax channel – theoretical results

Drawing on the model of Feldstein, Greek and Sheshinski (1978) one can demonstrate that, first, by interacting with the tax system inflation raises investment by enabling the firm to deduct the nominal interest on the debt incurred for investment purposes (as long as the nominal interest rate increases with inflation). Second, inflation either lowers investment, if the capital gains tax is higher than the tax rate on nominal interest received by the creditor, or increases investment – in the opposite case. Third, it reduces investment due to the lower present value of depreciation write-offs. The ultimate direction and magnitude of inflation's impact on investment through the tax system cannot be defined a priori, that is, without taking account of the parameters of a specific tax system. Moreover, as Cohen, Hassett and Hubbard (1999) have noticed, this impact may be spread out over time and may depend more on the expected than the current inflation level if the costs of adjusting the capital level increase in a non-linear fashion and with the size of investment (these authors have also demonstrated the effects of relaxing other simplifying assumptions of the original model – e.g. that the tax rate on nominal income from shares, regardless of whether the firm retains the profit or pays out a dividend, is the same as the tax rate on interest income).

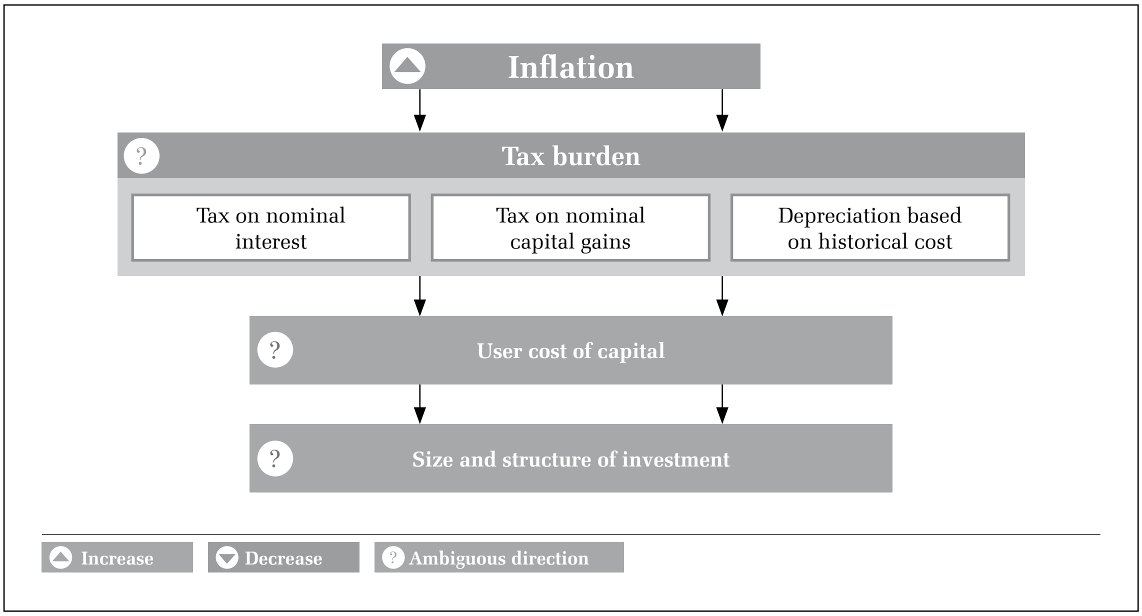
Inflation's impact on investment through its interactions with the tax system depends not only on the tax system's design, but also on the objectives to which the state allocates the potential income generated by these interactions. Bullard and Russell (2004) have shown that even if inflation increases the effective tax rate on capital, the state's allocating additional income to limiting its own borrowing needs can eventually lower the user cost of capital and increase investment. In other models it is assumed that a rise in inflation triggered by a rise in budget income leads to lower taxes (e.g. Feldstein 1996; Black, Macklem, Poloz 1994).

The analysis of the direction and magnitude of inflation's impact on investment through its interaction with the tax system becomes more complex in the open-economy case. According to Hartman (1980), with perfect capital mobility capital will be allocated to economies with higher inflation. But Desai and Hines (1997) have shown that Hartman's result is a special case. If in the case of domestic firms the benefits stemming from the possibility to deduct nominal interest exceed the costs resulting from a fall in the current value of depreciation write-offs, there is a rise in domestic investment in response to a rise in inflation. The shortage of capital is covered with the inflow of capital from abroad. If, however, the domestic benefits reaped by firms due to the possibility to write off nominal interest are lower than the costs stemming from a fall in the current value of depreciation write-offs, inflation causes a decline in both investment and domestic saving. Depending on the height of the tax rate on interest income, investment may fall more or less than domestic saving, causing capital outflows or inflows, respectively. In turn, Sorensen (1986) showed that capital will not flow into a higher-inflation country if exchange-rate losses and gains are not taxed in the same way. Finally, in Sinn's (1991) model a rise in inflation in a given country lowers investment unambiguously and causes the export of capital if there are transaction costs and depreciation is based on historical cost. In none of the models mentioned is the role of financial intermediation in the economy taken into account. Introducing financial intermediation into the models could further complicate the analysis. The models' conclusions could also change after relaxing the assumption, weakly supported by empirical data (see, e.g. Rogoff 1996; Taylor, Taylor 2004), that exchange rates are driven by purchasing power parity, which means that future exchange-rate changes between two countries are related to the difference in inflation between these countries.

Regardless of the direction of inflation's impact on investment through its interaction with the tax system, this interaction distorts the investment structure towards those types of assets or economy sectors in which the cost of capital (and hence the relative attractiveness of investment) depends to a lesser degree on inflation. The main mechanism of inflation's impact on the structure of investment is its effect on the discounted value of depreciation write-offs.

In the simplest case, described by Fischer and Modigliani (1980), long-lived capital goods are substituted with short-lived ones, because the longer the depreciation period for a good, the more the inflation lowers the value of depreciation write-offs. But Auerbach (1978; 1981) demonstrated that if a good depreciates exponentially and depreciation write-offs are made according to economic depreciation (that is the actual depreciation of a fixed asset), the user cost of capital will be more sensitive to changes in inflation in the case of short-lived goods, causing substitution in a direction opposite to that predicted by Fischer and Modigliani. In turn, Cohen, Hassett and

Figure 3
Inflation's impact on investment – the tax channel



Hubbard (1999) and Cohen and Hassett (1999) have shown that the result obtained by Auerbach is sensitive to changes to the assumption concerning the depreciation scheme. Intuitively, whether inflation raises to a higher degree the cost of goods with a shorter or longer depreciation period depends on the outcome of the interplay of two opposite effects. On the one hand, the purchasing power of a depreciation write-off made on the basis of the cost of purchase is the lower the further from the moment of purchase is the moment of making the write-off, which works against long-lived capital goods. On the other hand, the income from using a fixed asset consists of two parts: the first, insensitive to inflation, resulting from using the good in the production process, and the second, sensitive to inflation, resulting from depreciation write-offs. The second effect works against short-lived capital goods as in the case of these goods a larger share of income is sensitive to inflation changes (see also e.g. Howitt (1996), who shows the impact of inflation, through its interaction with the tax system, on capital allocation between particular sectors and firms).

The inflation – taxes interaction which arises when there is a lack of a full indexation of the tax system is not irrelevant to investment decisions of enterprises. Figure 3 illustrates this mechanism.

5.2. Inflation's impact on investment via the tax channel – results of empirical studies

The direction and the magnitude of inflation's effect on investment through the tax channel depend, *inter alia*, on the structure of the tax system; hence they cannot be unambiguously determined on theoretical grounds. One of the first to investigate empirically the strength of inflation's impact on investment through the tax system was Feldstein (1980). In each of the approaches employed (the estimation of net investment's dependence on, respectively, the real rate of return on investment, or on the difference between the maximum net potential return (MNPR) and the cost of capital; or the calibration of Hall and Jorgenson's (1967) modified neoclassical model of investment), he found a strong negative impact of the inflation–tax system interaction on investment in the United States in the years 1953–1978. This effect was found responsible for even a half of the decline in the US investment rate in the 1970s. In another study, Feldstein (1981) showed using the example of the US in the years 1960–1979 that taking account of the effects of the interaction between inflation and taxes in the calculation of the cost of capital may change the assessment of the impact of monetary policy changes on the cost of financing investment. Moreover, depending on the type of capital good, the same policy may either raise or lower the cost of its financing. The method proposed by Feldstein (1980; 1996) which consisted in calibrating Hall and Jorgenson's (1967) model was subsequently used by other economists, e.g. by Bakhshi, Haldane and Hatch (1998) who studied the British economy and reached similar conclusions.

The results obtained by Feldstein have been subject to criticism by Chirinko (1987), who argued that in his analysis Feldstein did not take into account the possibility of inflation-induced growth in the relative value of capital in relation to other goods. Feldstein (1987) concluded, however, that the modification proposed by Chirinko did not improve the description of investment: the capital gains anticipated by firms due to a rise in the relative value of capital relative to other goods do not themselves constitute a significant determinant of firms' decisions.

The analysis based on a partial equilibrium model was extended by Cohen, Hassett and Hubbard (1999). By calibrating the model to US data (hence the conclusions cannot be extended to economies with tax systems that are significantly different from the American one), they concluded that in a closed economy a given rise in inflation raises the user cost of capital by the same amount regardless of the initial inflation level. In the open-economy case, the direction of inflation's impact on the user cost of capital depends on the method of financing the marginal capital unit: if capital is financed with share issues, inflation's impact is similar to that in a closed economy. If, however, investment is financed with debt, then a rise in inflation leads to a decline in the user cost of capital. The impact of inflation on the user cost of capital depends on the type of goods and their depreciation periods – mainly due to the differences in methods, according to which they can be depreciated. However, inflation-induced changes in the structure of investment do not bear much significance for economic growth and welfare. Anticipated changes in inflation lead to significant changes in the user cost of capital before the changes in inflation even begin.

The weaknesses of the partial-equilibrium approach of the foregoing research were highlighted by Bullard and Russell (2004). By calibrating a general equilibrium model for the United States they demonstrated that a rise in inflation can encourage firms to significantly raise investment, if only one assumes that the government allocates the additional funds obtained through a rise in the effective tax on capital income to lowering borrowing needs. Even though the authors did a robustness check for changes to some of the model's parameters, the strong rise in investment in reaction to a small change in inflation may raise doubts, at least in light of the literature on fiscal deficit's effects (see e.g. Ball, Mankiw 1995 or Elmendorf, Mankiw 1998).

One of the few analyses of the effects of the interaction between inflation and the tax system going beyond the case of a single country was conducted by Bayoumi and Gagnon (1996). While attempting to verify the hypothesis concerning the direction of inflation's impact on investment through the tax channel in an open economy, they estimated the magnitude of inflation's direct impact on the size of net financial assets. The relationship obtained by them turned out to be negative and statistically significant in a cross-section analysis of data from 18 OECD countries in the years 1981–1989, and in the case of 2 out of the 6 countries in the studied sample with the smallest barriers to capital flows, for which a time series analysis was performed. This relationship did not necessarily reflect inflation's positive impact on investment as the same result would have been obtained if inflation caused a fall in domestic saving instead of a rise in domestic investment.

6. Summary and conclusions for monetary policy

Inflation's negative impact on investment is one of the reasons why price stability should be the main goal of monetary policy. Although research into the various individual channels of inflation's effect on investment has been prolific, there seems to be a lack of survey articles which would analyze the results of this research systematically and comprehensively.

Proper understanding and modelling of how inflation affects investment is not straightforward, among others due to the multitude and complexity of channels of this impact, as well as due to difficulties with ensuring that economic models produce robust results. For instance, traditional monetary models with exogenous growth do not allow economists to determine unambiguously the direction of the relationship between inflation and investment. Regardless of the formal way of introducing money into these models, the direction of the relationship between investment and inflation hinges critically on arbitrary, that is, difficult to be verified empirically, assumptions (such as the signs of cross derivatives of production or utility functions). A change to these assumptions leads to a reversal in the direction of the relationship even within the same model. The main reason why it is problematic to determine unambiguously the direction of the relationship between inflation and investment on the basis of monetary growth models is that they do not take account of market imperfections such as informational asymmetries, uncertainty and nominal rigidities in tax systems. In light of empirical results these imperfections can constitute significant channels of inflation's impact on investment.

Once information asymmetry between economic agents in the process of financing investment is taken into account, financial sector development gains importance. Financial sector's principal role is neutralizing the effects of this asymmetry, such as adverse selection, moral hazard and costly state verification. Inflation, even within the low– or moderate-value interval, makes performing this task more difficult for financial institutions. Inflation can lower the real rate of return on savings, and, as a result, discourage from saving and encourage taking out loans, including by persons who are unable to repay them. Moreover, it constitutes a tax imposed on the real value of firms' own funds which must often be used in the investment as a prerequisite in order for the firm to obtain external financing. Inflation lowers not only the propensity but also the ability of firms to accumulate their own funds because it lowers markups (in this regard empirical studies are less ambiguous than theory). At the same time, it introduces additional "noise" to the lenders' evaluation of investment projects, by making it more difficult to identify profitable projects. In light of both theory and empirical research inflation changes in the low-value interval do not influence the scope of financial intermediation. Once a certain low threshold is exceeded, however, a further increase in inflation hampers the development of financial intermediation. Inflation's all negative effects on the financial sector manifest themselves at moderate inflation rates. Furthermore, in developed countries inflation's negative impact on the financial sector, and further – on firm investment, is revealed at an inflation level lower than in developing countries. This strand of literature is, however, relatively new: the main theories and concepts were developed in the mid-1990s and the majority of empirical research was conducted after the year 2000. Hence caution is warranted with respect to these results and conclusions drawn from them as the number of studies investigating the issue at hand is still limited.

The second important mechanism of inflation's impact on investment is its impact on the uncertainty surrounding the future values of variables crucial to firms' investment decisions. Inflation's impact on investment through uncertainty depends on two, in principle disjoint, relations. On the one hand, it is derivative to inflation's influence on the uncertainty related to those variables on the basis of which firms formulate their assessments of future investment profits. The conclusions drawn from a review of theoretical and empirical literature are unambiguous here: inflation, even in the low– and moderate-value interval constitutes a significant source of uncertainty. On the other hand, inflation's impact on investment through its influence on uncertainty is determined by investment's dependence on the uncertainty about the profits from investment. Even though we may intuitively be inclined to draw the conclusion that the higher the uncertainty the lower the propensity of firms to start new investments, this relationship is not clear-cut in light of theory. Most empirical research indicates, however, that a rise in inflation, by increasing the uncertainty surrounding investment decisions of firms, lowers (strongly) firms' propensity to invest. However, these results must be treated with caution, mainly due to the limitations and imperfections of the measures of entrepreneurs' perceived uncertainty used in these models.

The third important mechanism of inflation's impact on corporate investment are its interactions with the tax system. If the system is not fully-indexed then inflation affects the user cost of capital. At the same time, it can differentiate it depending on the type of capital good (length of the depreciation period) or on the investment's financing structure. As a result, it leads to a change in both the level and the s of capital allocation. The sign and the magnitude of this influence depend, however, on many assumptions concerning, i.a., the detailed tax system arrangements, the freedom of capital flows or the way in which tax revenues are used by the government. Nevertheless, models indicate equivocally that due to inflation's interactions with the tax system changes in inflation are not indifferent to firms' investment decisions. Empirical research also does not provide an unambiguous answer as to the direction and magnitude of inflation's impact on investment through its interactions with the tax system. The main reason for this ambiguity is that a large part of empirical research is closely linked to assumptions of theoretical models. The dependence on arbitrary assumptions made in these models translates into results of empirical research.

All three mechanisms of inflation's influence on investment are closely related. For instance, uncertainty is one of the reasons why markets are incomplete, and hence, why their level of development, related to the inflation – asymmetry of information relationship, exacerbates the effects of uncertainty. Finally, the effects of both uncertainty and information asymmetry can be amplified by inflation's interactions with the tax system. Whereas the links between the first two mechanisms are emphasized in the literature, the third mechanism is analyzed in complete isolation from the other two. All models known to us analyze the investment impact of the interaction between anticipated inflation and a tax system with a defined structure, ignoring, on the one hand, the problem of uncertainty connected with future inflation and future changes in the tax system, and, on the other hand, the results of changes in cash flows triggered by inflation's interactions with the tax system due to the asymmetry of information. Including all these mechanisms of inflation's impact on investment within the framework of a single consistent model could be an important avenue for future research.

Inflation's effect on investment bears great significance for monetary policy. Some general conclusions that can be drawn from the survey of literature on this relationship are presented below.

Inflation emerges as a more important determinant of corporate investment decisions than variables determining the user cost of capital, among them the interest rate. At the same time inflation's negative effect on investment is not limited to the size of investment only, but also concerns its productivity.

Inflation's damaging consequences for investment are not confined to cases of hyperinflation or even high (above 30%) inflation. A given rise in inflation is most detrimental to investment when inflation rises above relatively low values, close to the inflation targets of most central banks pursuing inflation targeting.

Given the importance of information asymmetry, uncertainty or nominal rigidities of the tax system for evaluating the magnitude and the direction of inflation's effects on investment, models employed in policymaking should take better account of these market imperfections. Unfortunately, many structural econometric models used in central banks to forecast inflation and to evaluate the effects of monetary policy have their theoretical foundations in models that do not take account of these imperfections.

DSGE models, which have been more and more widely used by central banks in recent years, incorporate a number of market imperfections into a real business cycle core model (see e.g. Smets, Wouters 2003). Thus, they conceptually allow for capturing effects of information asymmetry, uncertainty or nominal rigidities of the tax system. However, it seems that as of yet a negative link between inflation and investment obtained in these models is most often mainly a result of the monetary policy rule which usually requires a more than one-to-one response to a change in inflation (which in many models of this class is a condition of stable solution). In the light of the studies surveyed in this paper the impact of inflation on the cost of capital does not necessarily have to be the most important channel through which inflation has an adverse effect on capital accumulation. Thus, there are reasons to believe that further research on how to introduce in practice information asymmetry, uncertainty or nominal rigidities of the tax system into models used by central banks could improve the explanatory and predictive power of models and hence aid the conduct of monetary policy.

Considering the results of research surveyed in the article it appears that in order to assess the effects of tighter monetary policy on corporate investment it is not enough to take account of the effects of the implemented interest-rate hikes only. One should also take into account, how a rise in inflation caused by abandoned or delayed rate hikes could influence firm investment decisions. Such an assessment is not possible, for instance, with the use of structural models with the interest-rate rule switched off. In such models higher inflation, given an interest-rate path, results in a lower cost of capital, and, as a result, in higher investment.

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