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Drivers of Agricultural Physical Capital Development

Theoretical Framework and Hypotheses

ABSTRACT

This paper aims to identify drivers of physical capital adjustments in agriculture. It begins with a review of some of the most important theories and modelling approaches regarding firms' adjustments of physical capital, ranging from output-based models to more recent approaches that consider irreversibility and uncertainty. Thereafter, it is suggested that determinants of physical capital adjustments in agriculture can be divided into three main groups, namely drivers related to: i) expected (risk-adjusted) profit, ii) expected societal benefits and costs and iii) expected private non-pecuniary benefits and costs. The discussion that follows focuses on the determinants belonging to the first group and covers aspects related to product market conditions, technological conditions, financial conditions and the role of firm structure and organization. Furthermore, the role of subjective beliefs is emphasized. The main part of this paper is concerned with the demand side of the physical capital market and one section also briefly discusses some aspects related to supply of farm assets.

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1. Introduction

Physical capital is generally considered as one of the three primary factors of production in economic theory, with the other two being labour and land (natural resources). Typical examples of physical capital goods agriculture include farm machinery, farm buildings and different types of facilities and equipment used in agricultural production. A firm's stock of physical capital is a result of the firm's current and past investments in physical capital, as well as the depreciation of previous investments. Investments in physical capital, or physical capital adjustments, may play different roles for the firm and are driven by a large number of determinants. In general, a firm's investment behaviour represents their capital stock adjustments as a response to market opportunities and competitive pressures. Particularly in agriculture, factors such as family traditions, attachment to land and substitutability and complementarily of production factors influence decisions on physical capital adjustments.

This paper aims to identify the main determinants for adjustments of physical capital used in agricultural production. For that purpose, it begins with a review of some of the most important theoretical approaches and concepts regarding firms' adjustments of physical capital, ranging from output-based models to approaches that consider irreversibility and uncertainty. Investments undertaken in agricultural production are often characterized by irreversibility and a large share of sunk costs as re-sale markets for agricultural buildings hardly exists. This implies that the new investment theory, which considers irreversibility, uncertainty and flexibility, may be especially relevant when analyzing investments in agriculture. However, the different investment theories and modelling approaches should generally be viewed as complements to each other. Furthermore, physical capital stock changes in agriculture have to be seen in relation to other production factors, such as land and labour, as they constitute complements as well as substitutes to physical capital. Moreover, investment criteria applied by family farms can be expected to not just be based on returns to capital but also to household income.

Physical capital adjustments in agriculture are expected to be driven by a large number of determinants and to be influenced by subjective beliefs as well as individual farm strategies. In this paper, we suggest that the drivers of physical capital adjustments in agriculture can be divided into three main groups, namely; (I) Expected (risk-adjusted) profit, (II) Expected societal benefits and costs, and (III) Expected private non-pecuniary benefits and costs. The main rational drive of physical capital replacement or adaptation is the expectation of sustaining or increasing expected (risk-adjusted) profit from producing a good or providing a service. Furthermore, investment in physical capital may be driven by expected societal benefits and costs. For example, certain policies may drive investment if they impose specific technological regulations, such as for example environmental regulations. Expected private non-pecuniary benefits and costs that could drive capital adjustment include for example

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reputation or organizational legitimacy gained through compliance with higher quality standards or environmental regulations. This paper will mainly focus on the determinants related to (expected) profit generation, including product market and technological conditions, financial conditions (this topic is elaborated in Deliverable 4.3) and factors related to firm structure and organization.

Although this Deliverable is mainly concerned with the demand side of physical capital markets, section 4 briefly mentions some theoretical and practical aspects related to supply of physical capital goods and other farm assets. In this section, we distinguish between mobile and immobile farm assets. Examples of assets belonging to the former group include farm machinery and equipment whereas buildings and agricultural land provide examples of farm assets belonging to the latter group. Physical capital can generally be considered as a complement to land in agricultural production, and a farm's access to agricultural land will therefore influence its investments in physical capital. Therefore, characteristics of the land markets in the member states, such as factors related to (imperfect) institutions and regulations which are discussed in other deliverables, will influence farms' physical capital adjustments.

Clearly, the existing literature related to physical capital adjustments, including for example the literature on investment theory, capital theory, decision theory and production economics, is extensive and this Deliverable is therefore only able to consider a limited number of aspects and papers/contributions related to this topic.

The remainder of the text is structured as follows. The following section defines and categorizes physical capital and investments and gives an overview of traditional investment criteria. Section 3 reviews some existing theories and modelling approaches related to physical capital adjustments and suggest a framework for drivers and demand for physical capital adjustments. This is followed by a brief discussion of the supply side of agricultural physical capital goods (including land) in section 4. The paper ends with a summary.

2. Physical capital and investment - definitions and categorizations

2.1 Definition of physical capital

Physical capital is generally defined as an asset that is used in production and which is manufactured by humans. The latter characteristic means that it is reproducible. It may be for example machinery, buildings or vehicles**.** It is different from other types of capital such as human or financial, which is indicated by the word "physical".[1] Physical capital sometimes refers to fixed capital, but definition will not be used in this paper. The standard definition of physical capital thus excludes non-reproducible production factors such as land.

2.2 Categorization of physical capital and other assets used in production

Physical capital goods used in (agricultural) production can often be classified as machinery, equipment or buildings. Examples of farm machinery include tractors, ploughs and combines. Farm equipment may be exemplified by milking machines and fences. Barns, silos and different types of storage provide examples of agricultural buildings.

Assets used in production, including physical capital, can be categorized according to its (physical) properties and characteristics in the production process. Table 1 provides an overview of some categorizations concerning production assets' tangibility, durability, mobility and reproducibility. The last column indicates whether assets belonging to the specific category can be labelled as physical capital according to its general definition ("an asset used in production and manufactured by humans").

[1] Deardorff's Glossary of International Economics.

Table 1. Categorization of assets used in production.

Categorization	Definition	Examples relevant for agricultural production	Assets in this category can be (but are not necessarily) labelled as physical capital according to its standard definition†
Tangibility††			
Tangible	An asset whose value depends on certain physical properties. It has a physical form.	Buildings, machinery, different types of facilities and equipment used in agricultural production	Yes
Intangible	An asset that do not have a physical form.	Human capital, managerial skills	No
Durability†††			
Durable (fixed)	An asset used repeatedly over several production periods	Buildings, machinery, different types of facilities and equipment used in agricultural production	Yes
Non-durable (variable)	An asset used within the current production period	Seed, fertilizers, pesticides	Yes
Mobility			
Mobile	An asset that does not have a fixed localization (can be moved).	Machinery, equipment	Yes
Immobile	An asset that has a fixed localization (cannot easily be moved).	Land, buildings, facilities that cannot (easily) be moved	Yes
Reproducibility††††			
Reproducible	A tangible asset that can be matched or duplicated	Buildings, machinery, equipment, different types of facilities and equipment used in agricultural production	Yes
Non-reproducible	A tangible asset that cannot be reproduced (i.e. it is unique)	Land	No

† By standard definition we refer to the definition: "An asset used in production and manufactured by humans", ††Investiopedia.com, ††† Following Johnson and Quance (1972), †††† Encyclo Online Encyclopedia

Source: own compilation.

Assets can be either tangible or intangible depending on whether they have a physical substance and can "be seen", in which case they belong to the category "tangible assets". Physical capital is thus a tangible asset. Intangible assets, which do not have a physical substance and may be difficult to value, include firm assets such as patents, human capital and managerial skills.

Another categorisation of production assets refers to their durability. That is, it has to do with the duration in the use of assets. If they are used shortly after they have been acquired (which in agricultural production is relevant for variable inputs such as fertilizers, pesticides and seeds), they belong to the group of non-durable assets. Durable assets, on the other hand, can be used over several time periods and examples relevant for agricultural production include assets such as machinery and buildings.

The third categorization in Table 1 concerns the mobility of assets. That is, whether an asset is possible move or if it is fixed to a certain geographical location. Agricultural land constitutes an example of an immobile production factor used in agriculture.

The last categorization mentioned here refers to the reproducibility of assets. Reproducible tangible assets include assets that can be matched or duplicated (e.g. machinery) whereas non-reproducible assets cannot be reproduced (e.g. land).

2.3 Definition of investment

Investments may be undertaken by private individuals, private firms, or governments. They represent a flow of expenditures that are to increase or sustain capital stock. More precisely, an investment is a flow of expenditures that are assigned to projects, realization of which does not constitute an immediate consumption. These investment projects can increase physical and human capital, as well as (material) stock (Pearce et al., 1992). Another, slightly simplified, way of defining investment is to say that it refers to the "production of goods that will be used to produce other goods" (Hassett, 2011). It should be noted that the definition of investment used in economics differs from the definition used in finance, where it refers to the purchase of financial assets such as stocks or bonds.

As already noted, an investment does not have to be in the form of privately owned physical goods; it can also be of nonphysical character such as investments in human capital. Education and trainings provide examples of human capital investments. Because this Deliverable is concerned with physical capital, the remainder of our discussion will be limited to investments in physical capital.

Investments by private individuals, private firms, or governments may be financed either by savings (i.e. forgone consumption) or through loans. An important difference between these two ways of financing investments are that in the latter case, some of the future returns to capital must be used for the cost of lending. Efficient investment composes of projects changing the current state of firm capital endowment which has a positive net present value (principle of marginal return on capital), or projects with internal rate of return larger than interest rate (Pearce et al., 1992).

2.4 Types of investment

Investments are carried out for different purposes and play different roles for the individual firm. It is therefore meaningful to differentiate between different types of investments. A *replacement investment* is an investment carried in order to replace a (technically) depreciated asset that has been and will be used in the firm's production. Its purpose is (at a steady state level) to maintain current levels of profits (Nwaeze, 2005). An *adaptation investment*, on the other hand, is carried out in order to adopt the production to, e.g., a new technology or to modernize the production. In opposite to replacement investments it is thereby expected to affect the firms' value (see for example Nwaeze, 2005). Gross investment equals the sum of reinvestment (replacement investment) and net investment (modernizing investment or rationalizing investment).

A *start-up investment* is carried out for starting-up a business, for example as a response to new product demand or filling in a market niche with an innovative product/service. Investments may also be *competition/technology driven* (efficiency advantage of adopting newest technologies) or carried out in order to *expand current production*[2] (for example to achieve scale advantages), *diversify production* (to achieve scope advantages), or *need to restructure current production* (to increase organizational efficiency).

2.5 Traditional investment evaluation criteria

In order to decide whether an investment is to be undertaken or not and/or to compare the profitability among different investment options, a number of different decision rules (or investment evaluation criteria) exist. The traditional investment criteria typically consider the future expected cash flows caused by the investment, the cost of investment and /or the firm's cost of capital (required rate of return).

Three of the traditional investment criteria are the *Net Present Value (NPV), Return on capital (ROC)* and the *Internal Rate of Return (IRR)*. The NPV of an investment is the discounted future cash flows of the project subtracted by the investment costs. According to this investment rule, an investment is profitable if the net present value is non-negative. The higher the NPV, the more profitable is the investment. Formally, the NPV can be written as

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

where t is the time of the cash flow, r is the discount rate/rate of return/interest rate, C_t is the net cash flow at time t and C_0 is the investment cost undertaken at t=0.

ROC is the ratio of the (after tax) income by the book value of invested capital. A ratio higher than one thus indicates a profitable investment. The IRR is the discount rate that corresponds to the net present value of all cash flows related to an investment (if investment cost is considered as a negative cash flow) equal to zero. This method can thus be used to compare the profitability among different projects and a higher IRR implies a higher profitability of the project.

On a theoretical level, the existence several investment criteria - and not only one "universal" - has sometimes been emphasized as a weakness of capital theory. For example, Jorgenson (1967) pointed out that investment criteria such as ROC and IRR are inconsistent with utility maximization and argued that the only criterion consistent with utility maximization is maximization of the present value of the firm.

Another limitation of the above mentioned traditional methods for investment evaluation are that they do not consider any form of uncertainty or risk connected to the returns of the project. Moreover, they consider any investment decision as a "now-or-never"-decision. In most real investment situations, the decision maker has the option to "wait-and-see" as more information about the uncertainty in returns becomes available. This option is especially important when the investment is (at least partly) irreversible as flexibility in the timing of the investment then has a value. The value of flexibility is the focus of the new investment theory (the Real Options Approach) which is discussed in section 3.1.9.

A further limitation of the traditional investment criteria is that they do not account for any strategic values considering competitive interactions. Current investments may interact with future investments, be in conflict with future strategic advantages, or may be affected by/affect actions of external parties (Smit and Trigerios, 2004).[3]

When both flexibility and strategic values are considered, the expanded NPV consists of three parts and can be written as:[4]

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[2] See for example Eisner (1972).

[3] Smit and Trigerios (2004) provide an overview of investment evaluation methods that consider these aspects, making use of real options theory and game theory.

[4] Figure 1.3 in Smit and Trigerios, 2004.

Expanded (strategic) NPV = (passive) NPV + flexibility (option) value + strategic (game-theoretic) value

Specifically in agriculture, any change in the capital stock has to be seen in relation to other production factors, such as land and labour which can be seen as complements as well as substitutes to physical capital. This is of particular relevance for family farms with a close links between farm and household. Accordingly, investment criteria applied by family farms can be expected to not just be based on the returns to capital but also to household income.

3. Demand for physical capital

3.1 Theories and modelling approaches related to physical capital adjustment

A wide range of approaches aiming to model physical capital adjustments have been suggested in the literature, ranging from models that preceded the neoclassical models (e.g. the accelerator and liquidity theories of investment) to more recent approaches that consider uncertainty and irreversibility (e.g. the real options approach). The neoclassical investment theory basis its analysis on the assumptions typically made in neoclassical economics, e.g. those of fully informed rational agents and maximization of (expected) utility, firm profit or firm market value. Neoclassical investment models, such as Jorgenson's model, typically assume that perfect resale markets exist. From the neoclassical view, an investment decision is thus riskless and irreversible. Furthermore, capital stock adjustments are assumed to be driven only by the returns on investment projects and the firms' investment decisions are assumed to be separable from other factors such as financial decisions within the firm. More recent investment models also consider uncertainty in returns from and irreversibility of the investment decision. Although adopting assumptions that are more plausible in many real investment situations, not at least in the case of farm investments, the quality of empirical applications of these approaches is of course highly dependent on the quality of available empirical data.

The various existing theories and approaches for modelling investment behaviour are typically concerned with one or a few determinants and can therefore often be viewed as complements to each other. Table 2 gives an overview of determinants considered by different theories and models. In the following subsections a brief overview of the following groups of investment models/theories is provided; Accelerator models (section 3.1.1), Liquidity theory (section 3.1.2), Neoclassical investment models (section 3.1.3), the Q theory of investment (section 3.1.4), Information theories of investment (section 3.1.5), Agency theory (section 3.1.6), Euler equations (section 3.1.7), theories that consider asset complementarity, sunk cost and specificity of assets (section 3.1.8), Real option theory (section 3.1.9), and theories and models related to technology, adoption and diffusion (section 3.1.10). Our brief review does generally not report the formal (mathematical) representations of the investment models/theories. Instead, it focuses on the main assumptions and their implications. The theoretical literature has also been concerned with the role of subjective beliefs in decision making, which is briefly discussed in section 3.1.11.

Table 2. Overview of some existing theories and modelling approaches related to investment behaviour

Determinants	Group of model/theory (section)	Authors (examples)
	Accelerator models (section 3.1.1)	
Rate of growth of demand or output	Accelerator model	Clark (1917), Chenery (1952), Koyck (1954)
	Revised accelerator model	e.g. Eisner and Strotz (1963)
	Liquidity theory (section 3.1.2)	
Profitability (size)	Liquidity theory (residual funds, future profitability)	Dusenberry (1958), Meyer and Kuh (1957), Kuh (1963)
	Liquidity theory (financing hierarchy)	Koch (1943), Donaldson (1961)
	Neoclassical investment models (section 3.1.3)	
Cost of capital (taxes, interest rate)	Neoclassical model (investment and financial decisions separate)	Jorgenson et al. (1963, 1966, 1967, 1971), Jorgenson and Siebert (1968)
Relative prices of capital services	Modified neoclassical model (putty-clay approach)	Bischoff (1971)
Firm market value, Capital replacement cost	**The Q-theory of investment** (section 3.1.4)	Brainard and Tobin (1968), Tobin (1969)
Information asymmetry, Credit rationing	**Information theories of investment** (section 3.1.5)	Stiglitz and Weiß (1981), Greenwald et al. (1984), Myers and Majluff (1984)
Information asymmetry, Managerial preferences	**Agency theory** (section 3.1.6)	Jensen and Meckling (1976), Holmström (1979)
Adjustment costs	**Euler equations** (section 3.1.7)	Hayashi (1982)
	Theories that consider asset complementarity, sunk costs and specificity of assets (section 3.1.8)	
Complementarity of assets, sunk costs, asset specificity	Fixed assets theory	Johnson (1956), Johnson and Quance (1972), Balmann et al. (1996)
Relation-specificity of investments	The hold-up problem, opportunism	Tirole (1988), Williamson (1975)
Uncertainty, Irreversibility of investment	**Real option theory** (section 3.1.9)	Henry (1974), McDonald and Siegel (1986), Pindyck (1991), Dixit and Pindyck (1994)
	Theories and models related to technology, adoption and diffusion (section 3.1.10)	
Firm size, Human capital, Time of technology use	The threshold model of technology and adoption	David (1969)
Distance and geography (travel and transport cost)	Innovation geography (technology adoption and diffusion)	Rogers (1962)
Output prices, Elasticity of demand	The treadmill model (technology adoption and diffusion)	Cochrane (1979)

Source: own compilation.

3.1.1 Accelerator models

This group of models was originally suggested by Clark (1917) and has been modified and revised by a number of authors including Chenery (1952), Koyck (1954), and Eisner et al. (e.g. 1963). The accelerator models are based on the assumption that the "desired" capital stock is proportional to the output in the same time period, i.e. $K^d = \alpha Y$, where K^d is the desired capital stock, Y is the output and α is a constant. This basic formulation uses "desired capital" instead of capital as it is assumed that the capital stock cannot immediately be adjusted to changes in output. The slow reaction on capital is also considered in the so-called flexible accelerator models which generally assume that capital stock changes (investments) can occur over several time periods. A popular flexible accelerator model is the one suggested by Eisner and Strotz (1963) who assume the presence of adjustments costs when the actual capital stock deviates from the desired.

3.1.2 Liquidity theory

The liquidity theory of investment (e.g. Meyer and Kuh, 1957; Dusenberry, 1958; Kuh, 1963) assumes that the desired capital is proportional to liquidity. Thus, this theory replaces output in the accelerator models with a measure of the firm's liquidity. As noted by Samuel (1996), the replacement of output by liquidity was motivated by at least to reasons. The first is that actual realized profits are a measure expected profits, and profit expectations governs investment, and the second is that supply of funds constrains a firms investments.

3.1.3 Neoclassical investment models

The original investment model suggested by Jorgenson (1963) is output-based and the desired capital stock is assumed to be a linear function of output. It adopts neoclassical assumptions such as a perfect competitive market and the production technology is represented by a Cobb-Douglas production function. Unlike the preceding accelerator models, Jorgensen's model assumed that investment is a function of price of capital, in addition to output. Several variants of Jorgensen's original model have been suggested including the modified model by Bischoff (1971) which relaxed the assumption about a symmetric relation between output and the rental price.

3.1.4 The Q theory of investment

The Q models of investments (e.g. Brainard and Tobin, 1968; Tobin, 1969) differ from the preceding investment models such as the accelerator models and Jorgenson's model in that they are not output-based. Investment is thus not viewed as a function of output as in the previous models, but instead assumed to be determined by the firm's market value. As noted by Clark (1979), the Q models should therefore not be viewed as complements but rather substitutes to the standard neoclassical models. They are based on the assumption of convex adjustment costs.

3.1.5 Information theories of investment

Stiglitz and Weiss (1981) argued that the price of credit (the interest rate) is not necessarily at a level that equilibrates the market, which the law of supply and demand would predict under perfect information. They explained this by the fact that credit markets are characterized by imperfect information which leads to credit rationing. In a joint paper with Greenwald (Greenwald et al., 1984), they further argued that it is not the price of credit but the credit availability that affects firms' investments and that the effective cost of capital can affect investments also on firms that are not credit constrained.

Myers and Majluff (1984) analyzed the case when the firm managers have information that the investors don't have and develop a model that shows that, under asymmetric knowledge of managers and investors, firms may pass up profitable investment opportunities as they may refuse to issue stock.

3.1.6 Agency theory

Agency theory (e.g. Holmström, 1979; Jensen and Meckling, 1976) is concerned with incentive problems within the firm, which are suggested to affect firms' investment behaviour. One strand of the agency theory literature is concerned with the so-called principal-agent problem (e. g. Holmström, 1979) that arises when asymmetric information is present when a contract is established between two or more parties. The parties typically consist of a "principal" who has delegated work to one or several "agents". The theory separate between two types of problems caused by information asymmetry between the parties. The first, which is usually called the moral hazard problem, refers to the problem that arises when the principal cannot fully observe the activities (effort) of the agent and the goal functions of the two parties differ. The second type of problem refers to the unobservability of "types", e.g. when a manager is not able to separate high-productive workers from low-productive workers (adverse selection).

Jensen and Meckling (1976) defined agency costs as the sum of the monitoring expenditures by the principal, the bonding expenditures by the agent, and the residual loss. In the corporate finance literature, agency costs are assumed to affect the relation between the manager (the agent) and the stockholders (the principal). With the help of agency costs, Jensen and Meckling (1976) showed that a firm manager in a firm with a capital structure consisting partly of debt will choose a set of activities that do not maximize the firm's value.

3.1.7 Euler equations

Euler equations are a group of dynamic investment models and originate from the work of Hayashi (1982). They have an explicit structural interpretation and are derived from dynamic models under rational expectations, and are therefore more theoretically appealing compared to traditional models of investment (see for example Oliner et al., 1995).

Euler investment equations are derived from the same underlying model as Q models and are, like Q models, based on the assumption of convex adjustment costs. A crucial difference between the two modelling approaches is however that Q models incorporate the shadow price of capital exogenously into the firm's dynamic optimization problem whereas Euler equations do not require information on the shadow value of the firm's capital stock. Euler equations may thus be more appealing for those countries where financial information is insufficient. A further difference is that Euler equations allow relaxing the assumption of perfectly competitive markets which is assumed in the Q models.

3.1.8 Theories that consider asset complementarity, sunk costs and specificity of assets

Farm investment behaviour has also been studied by assuming that farm investment affects the output level not only directly but also indirectly though the use of complementary inputs (Johnson, 1956; Johnson and Quance, 1972). Agricultural production is often characterized by large irreversible investments. For example, agricultural buildings can often be considered as sunk cost as they usually do not have any other use and a re-sale market for buildings hardly exist. The presence of sunk investment costs implies that after the investment decision is made, the opportunity costs are lower than before (i.e. the investment decision caused sunk costs). Balmann et al. (1996) show that sunk costs of an asset do not only create asset specificity, and thus affect the future use of this asset, but may also cause further investments into complementary assets which would not occur without the sunk costs of the first asset. These interdependencies affect the shadow prices of production factors in a similar way, though sometimes in opposite directions, as productivity and output prices.

The literature has also dealt with the issue of relation-specificity of assets which arises when one party in a relationship (vertical or horizontal) has to make an investment that has a lower value for the firm outside that specific relationship. This implies that, when the investment is undertaken, the other party may exploit the situation by demanding a higher share of the profits generated by the investment. The problem is thus that the fear of this kind of situation, by the party who has to make the investment, may lead to that otherwise Pareto optimal investments are not conducted. The hold-up problem was formalized by Tirole (1988) but was also discussed by Williamson (e.g. 1975) who used term "opportunism" when talking about this phenomenon.

3.1.9 Real options theory

Studies based on the real option model of Dixit and Pindyck (1994) consider uncertainty and irreversibility of firm investments. In these studies, sunk costs are accounted for ex ante for decision making. The real options approach suggests that a firm, being uncertain about the future and knowing that it might be hard to re-sell capital, may benefit from waiting with an investment activity. If the gains of waiting exceed the costs of waiting, it may be better to postpone investment. Thus, according to the real options approach, irreversible investment decisions under uncertainty should consider the opportunity costs of deferring the investment decision in order to obtain improved information about the involved risks (Henry, 1974; McDonald and Siegel, 1986; Pindyck, 1991; Leahy, 1993). According to this approach, the investment decision can be interpreted as an optimal stopping problem. The formal representation of this model can be found in Dixit and Pindyck (1994).

It was shown by Odening et al. (2005; 2007) that the outcomes of real options applications are sensitive to assumptions about type and measurement of the underlying uncertainty. This implies that it is important to have an accurate understanding of the underlying dynamics of the stochastic variable (e.g. price) when applying the real options method. A further constraint for empirical applications of this approach is that detailed and reliable information about the (volatility of) project returns must be available.

3.1.10 Theories and models related to technology, diffusion and adaption

This subsection will very briefly mention some of the existing theories and models related to technology, diffusion and adaption. A threshold model of technology adoption and diffusion of farm equipment was introduced by David (1969). He derived the minimum farm size required for adoption was while assuming that farm size is the main source of heterogeneity (Sundling and Zilbermann, 2000). In the book "Diffusion of Innovations", Rogers (1962) summarized exiting research on diffusion of innovations and proposed a theory for the adoption of innovation. This theory aims to explain the diffusion of innovations. Rogers suggested that the diffusion of a new idea is influenced by the innovation, communication channels, time, and a social system.

Cochrane's treadmill (Cochrane, 1958) suggests that farmers continuously aim to adapt the newest technologies in order to be prepared for declining prices. The idea is that early adopters of a new technology, which enables them to produce larger quantities at lower unit costs, will temporarily make profits. However, since the increasing number of adopters of the new technology contributes to an increasing supply, the market price is declining. The farmers who have not yet adopted the technology are then forced to do so in order to survive.

3.1.11 Subjective beliefs and decision making

In addition to the determinants considered by the above reviewed theories and models related to investment behaviour, a firm's decisions about physical capital adjustments are likely to also be affected by subjective beliefs and subjective probabilities for project returns. This might be especially relevant for investment projects associated with "Knightian" types of uncertainties[5] (seen from an objective perspective). When the returns of a project are unknown, firms make their investment decisions according to subjective beliefs rather than

[5] In his classical work from 1921, Frank Knight made a distinguishing between measurable uncertainty (risk) and un-measurable uncertainty, often referred to as "Knightian uncertainty".

well-defined probabilities.[6] The subjective beliefs may change when the decision maker get access to new relevant information. These ideas are thus related to the Bayesian approach of probability updating.

The impact of subjective beliefs on decision making has been recognized in the theoretical literature. Several authors have identified that the traditional models for decision making are not able to deal with the type of situations where well-defined probabilities are not available.[7] For example, Runge (2000) noted that "Uncertainty over future value, coupled with limited market structures to serve as benchmarks for value, means that privately arrived at and understood subjective value informs decision-making far more than the calculus of simple neoclassical choice suggests" (page 1). To overcome this shortcoming of standard approaches of modelling decision making, alternative theoretical approaches and analytical tools have been proposed. For example, Grant and Quiggin (2007) suggest a model of choice under uncertainty in which they assume that individuals do not have a complete description of the space of states of the world. The authors make use of decisions trees and describe knowledge in terms of a finite set of propositions.

Several experimental studies have found that the subjective values of the outcomes and their subjective probabilities play a central role in decision making (see for example Huber, 2007). However, Huber noted that, because of the design of these experiments (typically based on gambles), one cannot generalize the results to all decision situations. Huber found that, in quasi-realistic risky tasks, decision makers have low interest in probability information compared to gambling situations, and that risk-defusing operators (the search for additional actions when an alternative leads to a negative outcome) play a crucial role for decision makers.

3.2 Drivers and determinants of demand for physical capital - discussion and hypotheses

A common denominator for most of the theories reviewed in section 3.1 is the main economic underlying principle, such as maximization of expected profit (or an alternative income), value of the firm or managerial utility. These may thus be perceived as the main drivers of the firm's demand for physical capital. In this section, we will re-group the determinants in Table 2 which influence these objective variables into more unifying categories of determinants of physical capital adjustment.

Let us first assume that maximization of expected profit is the main economic underlying principle. Then, in the case of deterministic revenues and costs, a change in the firm's stock of physical capital is, similarly to any other business related decision, primarily subject to profit maximization. In a business environment characterized by non-deterministic profits, with for example stochastic output levels and prices (which is typically the case, particularly in agriculture), a risk averse manager decide on changes in the physical capital stock based on maximization of a risk-adjusted profit (i.e. profit subtracted by a risk premium, where the size of the risk premium depend on the level of risk aversion). The main rational drive of physical capital replacement or adaptation is thus the expectation of sustaining or increasing *expected (risk-adjusted) profit* from producing a good or providing a service in dynamic conditions of market competition. Product market dynamics, representing market growth or diversification potentials of increasing income, and technological potentials of reducing costs of production, together with cost of financing as well as factors related to firm structure and organization, determine the final demand for physical capital adaptation and adjustment. To

[6] It should here be noted that there has been a discussion of how relevant Knightian uncertainty really is. For example, Ellsberg (1961) noted that in situations characterized by Knightian uncertainty, people tend to act "as if" they had assigned numerical probabilities or "degree of belief" to the outcome of an action.

[7] It should here be noted that the ideas of subjective probabilities and the use of Bayesian probability theory are not new in decision theory and were put forward by Leonard Savage already in the 1950's.

understand the demand for agricultural physical capital, the specifics of the agricultural product market, technological possibilities affected by characteristics of agricultural production (e.g., economies of scale and scope, complementarity and substitutability of inputs, etc.) as well as agricultural sector-specific conditions of capital financing must be considered.

Expected private non-pecuniary benefits and costs may also drive capital adjustment. These include for example reputation or organizational legitimacy gained through compliance with higher quality standards or environmental regulations, or through being among the first adopters of a new technology (which may increase prestige of the producer and possibly social standing). The last mentioned aspects may also represent a strategy of increasing profits and reducing income volatility. It could further increase consumers' awareness of the firm and lead to consumers' preferences of its products, and thereby increase the sales and income (and possibly also attract external investors). Such behaviours could vary across regions and especially across member states with mature and transition economies, as it likely is determined by the level entrepreneurship skills or culture and tradition that reflects in consumers responsiveness to producers behaviour and establishment of reputation or organizational legitimacy.

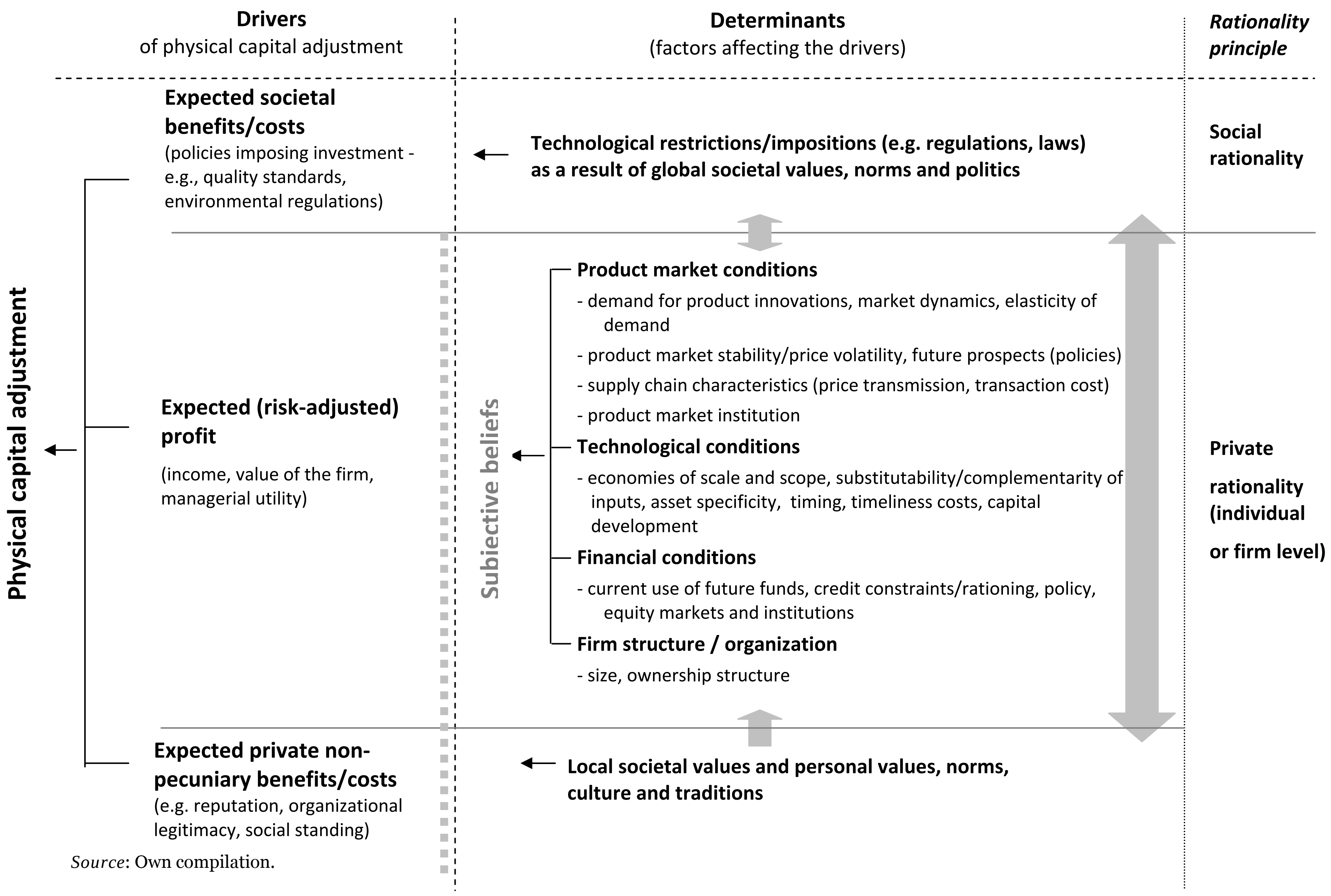
The final effects of the determinants related to the drivers discussed above are likely to be influenced by *subjective beliefs* as well as individual firm strategies. Subjective beliefs may be especially relevant for investments driven by innovations and entrepreneurial activities, as the economic payoff and income volatility reduction related to those activities often are more or less unknown. For example, innovative firms adopt new technologies before its technical efficiency effects are known or tested. The firms’ decisions are then affected by beliefs, personality traits and corporate culture.

Investment in physical capital may further be driven by firms' external incentives and impositions that affect the *expected societal benefits and costs*. Particularly, certain policies may drive investment if they impose specific technological regulations, such as for example environmental regulations. Policies that involve subsidizing adoption and the use of certain technologies (such as organic production methods) imply that affect physical capital adjustments are adjusted through the expected profit determinants. Another example is insecurity in land tenure (e.g. short term leasing) that has been found to affect (reduce) investments in agriculture (e.g. Koester and Brooks, 1997).

Figure 1 illustrates a system of drivers and determinants of physical capital adjustment (beyond pure capital replacement) which considers the three groups of drivers and determinants discussed above. The impact of subjective beliefs is represented in the figure by a filter that adjusts the effect of the determinants.

The following sections will mainly elaborate on the determinants of expected profit generation from adjustment of (investment in) physical capital – product market conditions, technological conditions, financial conditions, and firm structure and organization.

Figure 1. System of main drivers and determinants of firm physical capital adjustment



Source: Own compilation.

3.2.1 Product market conditions

The income increasing potential of investment depends on product market characteristics such as demand for new agricultural products and new market dynamics, position in value/supply chain, product market price stability/volatility, stability and flexibility of product market institutions and future of the agricultural product market.

Demand for *new agricultural products* in creates new *market dynamics* in the form of new markets, new product developments and product substitutability. These characteristics are however less relevant for producers of conventional agricultural products (as within the supply chain, agriculture produces the "raw" product). In general, agriculture with low elasticity of demand and lower scope for product innovation has relatively lower market increase potential than other sectors. However, agricultural policy also increases consumers' protection and awareness and hence the demand for products with new attributes relating to quality and brand names (both allowing for price premiums). These trends require adjustment in physical capital.

Moreover, a desired *position in value/supply chain* can represent an important impediment to investment. Agricultural producers (farmers) are typically characterized by relatively low bargaining power which implies relatively higher bargaining costs. This creates a need for contractual and organizational solutions and implies a more centralized food industry which lowers returns on capital (investment) for agricultural producers when compared to other sectors.

Investment behaviour is further determined by *product market price stability/volatility*. Price volatilities arise as a result of for example weather, seasonality of production and world trade effects. Changes in regional yields and changes in product use (from food to energy) and demand may results in price risk that lowers and/or postpones investment.

Other determinants of farm investment activities relate to *stability and flexibility of product market institutions*. Lack of factors such as protection of property rights, bankruptcy law, contractual reinforcement and flexibility in creating new institutions for new market demands (quality standardization) creates market transaction costs which might result in differences in investment activity between farm types, between new and old EU member states and in particular differences to candidate countries.

Farm investments are also likely influenced by the *future of the agricultural product market*. Foreseen changes in trade and sectoral policies create uncertainties which cause differences in investment activity over time as well as differences between different economic systems (member states and candidate countries).

3.2.2 Technological conditions

Physical capital adjustments further depend on the potentials of technological adjustment in reducing unit cost as well as the development of existing physical capital. Technological potentials and impediments include aspects such as productivity and quality effects of new technologies, economies of scale and scope, asset specificity, substitutability and complementarity of inputs, timing of investment, timeliness costs and capital development (depreciation).

Productivity and quality effects of new technologies may drive investments as they may allow the farmer to produce at a lower unit cost and/or allow for higher quality of the product and thereby potential higher returns.

Physical capital adjustment may also be driven by the goal to reduce unit cost of production by adjusting the optimal scale of production, i.e. *economies of scale* are driving the investment. A firm is producing at the lowest average unit cost when it is producing at its “optimal scale”, i.e. when it is producing at a constant return to scale. When it is producing at increasing returns to scale, it can expand all inputs to achieve lower average unit costs, and when it is producing at decreasing returns to scale, it can reduce all inputs to achieve a lower average unit cost. Physical capital adjustments may thus be a way to adjust to the optimal scale of production.

Another factor expected to influence investments by farms relates to the concept of *economies of scope,* i.e. cost reductions that can be achieved when producing two or more outputs. Economies of scope exist when the joint production of, say, products *A* and *B* can be done at a lower average cost compared to the case when *A* and *B* are produced separately. Agricultural production provides many examples of economies of scope, such as the complementarity between agricultural production and the provision of ecosystem services (e.g. Wossink and Swinton, 2007).

Many investments in physical capital in agricultural production are characterized by *asset specificity*. That is, they are only or mainly useful for one specific purpose and cannot easy be re-sold. These types of assets are therefore often characterized by large shares of sunk costs and this characteristic can, according to some of the theories reviewed in section 3.1, affect the firm's investment behaviour and for example cause investments in complementary assets. In general, *complementarity* as well as *substitutability* of production inputs influences physical capital adjustments.

The *timing of technology adaption* (early versus later adaption) may create comparative advantage of technological innovation in condition of inelastic demand (such as in agriculture). Bad timing may result in Cochrane treadmill, that is, it lowers returns on capital/investment over time faster than in sectors with higher elasticity of demand.

Physical capital adjustment may also be a way to optimize the size of the machinery park subject to minimizing *timeliness costs*. Timeliness cost (e.g. Edwards and Boehle, 1980; Short and Gitu, 1991) refers to the fact that it may be costly for the farmer if a field operation cannot be performed at the optimal point in time. For example, delayed harvesting may imply a poorer quality of the crop and thereby lower return for the farmer. The size of the timeliness cost depends on several factors such as soil quality, type of crop and type of field operation.

Investments, in particular replacement investments, are also a result of *depreciation* of capital. Depreciation is caused by both physical and functional factors. Physical depreciation relates to the actual use of an investment whereas functional depreciation is caused by factors such as technological advances and reduced demand for a product. The depreciation thus reflects the decline of usefulness of an asset. The depreciation costs are determined by the initial cost, the useful life of the asset and the residual value.

3.2.3 Financial conditions

Investment decisions are influenced by the cost of investment among which cost of financing play an important role. This relates to the functioning of the financial capital market which is a topic covered by Deliverable 4.3 and will only briefly be discussed below.

Modigliani and Miller (1958) suggested that a firm's capital structure is irrelevant for its value (the Modigliani-Miller theorem). The Modigliani-Miller theorem thus implies that a firm's investment decisions are independent from its financing decisions. However, external and internal financing are usually not perfect substitutes (as external finance is usually more expensive). In the finance literature, this has been explained as a result of asymmetric information leading to problems caused by adverse selection (e.g. Myers and Majluf, 1984) and moral hazard (e.g. Jensen and Meckling, 1976).

Several studies provide empirical evidence for the idea that firm capital structure (liquidity) affects accessibility to credit and investment. For example, Fazzari el al. (1988) finds that liquidity has a positive impact on investment. However, the difficulties of empirically assessing the impact of financial constraints on investments have also been highlighted in the literature. Schiantarelli (1996) provides a critical review of the econometrical evidence and a discussion of various methodological issues.

The accessibility and cost (including transaction costs) of credits in agriculture largely varies among countries, regions and individual firms within the member states. One reason is imperfections on the agricultural credit market which are mainly due to imperfect (asymmetric) information.[8] Because of such imperfections, not all farmers are able to get access to credits even in cases when investment would have been profitable. Imperfect information on the agricultural credit market may also cause moral hazard problems if the loan applicant does not have enough incentives to carry out profitable investment projects or does not act (invest) according to the initial purpose of the loan (Swinnen and Gow, 1999).

In order to mitigate the problem of credit constraints in agriculture, governments have intervened the market through for example credit interest subsidies and credit guaranties. Agricultural credit institutions have also been initiated. An advantage of these is that they are equipped with the special knowledge relevant for agricultural activities and thereby are able to reduce the problems related to asymmetric information (Swinnen and Gow, 1999). However, in the case of transitional economies, Swinnen and Gow (1999) conclude that low farm productivity is a critical factor behind the agricultural and rural finance problems and that intervention on the agricultural credit markets therefore is not enough to solve the problems in those countries.

3.2.4 Firm structure and organization

Farm ownership structure, which significantly varies across the member states, may explain some differences in regional investment behaviour. There is an extensive amount of theoretical and empirical literature dealing with the potential impact of ownership and organizational structure and governance on corporate value and/or investment behaviour. As we saw in section 3.1.6, Jensen and Meckling (1976) suggested that ownership structure affects investment (which in turn affects corporate value). Also several empirical studies have looked at the impact of ownership structure on investments, an often finds that ownership structure influences investment (e.g. Cho, 1998). However, empirical analyses of the impact of ownership structure on investments are often complicated by endogeneity of the ownership variable.

Complexity in organizational structures, dispersion in ownership and delegation of control are examples of ownership/organizational factors that may determine investment behaviours. For example, some innovative technologies have the potential to simplify the production process (e.g. GM crops) which may reduce technical inefficiencies in complex organizations. Therefore, they may be preferred in firms with complex organizational structure. Firms with dispersed ownership structure provide scope for managerial discretion, i.e., high agency costs. To avoid increase in agency costs, owners might prefer less complex investment projects. The effect of ownership structure on investment is further likely to depend on the institutional framework for corporate governance, e.g., protection of property rights, protection of minority owner and functioning of equity markets. Thus, a general conclusion is that differences in farm ownership structure among the member states could explain some differences in technology adoption.

4. Supply of physical capital and other farm assets

This section briefly reviews some general theoretical and practical aspects of supply of agricultural physical capital goods and other farm assets (agricultural land[9] [10]). Because important agricultural production factors such as land is characterized by immobility, the

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[8] Swinnen and Gow (1999) discuss the role of these issues in the case of agricultural credit markets.

[9] We only briefly mention a few aspects related to the functioning of land markets. This topic is covered in other Deliverables such as 14.1, 14.2, 14.3 (for three candidate countries), 15.1 and 15.2.

[10] As noted in section 2.1, land is typically not viewed as physical capital according to its standard definition.

discussion separates between mobile and immobile farm assets. Farm machinery and equipment provide examples of production factors belonging to the former group, whereas land and buildings constitute immobile farm assets. Figure 2 attempts to summarize some market characteristics and price determinants (mainly on the supply side) for farm assets using the categorization described above.

4.1 Mobile farm assets

Farm machinery, such as harvesters, ploughs, combines and tractors, is a typical example of mobile as well as reproducible physical capital goods used in agricultural production. Also different types of equipment used at the farm belong to this category. In general, and in comparison to the immobile assets, the markets for the mobile physical capital goods may be said to be characterized by relatively liquid assets.

In economic theory, supply is generally defined as "the quantity of a product that a producer is willing and able to supply onto the market at a given price in a given time period." According to the Law of Supply, producers supply more of a good when the price of the good rises. In economic text books, this is typically illustrated graphically with an upward sloping supply curve that shows the relationship between price and quantity supplied (assuming that all other factors except price are held constant). The reasons behind the assumption of a positive relationship between the market price and quantity supplied typically include the following; First, when the market price rises (for example as a result of an increase in consumer demand), it becomes more profitable for firms to increase their output. Secondly, when output expands, a firm's production costs rise (according to the law of diminishing returns to scale), and a higher price is needed to cover the higher average unit cost of production. A third reason is that higher prices may create an incentive for other firms to enter the market which in turn leads to an increase in supply.

Several factors may cause a shift in supply, and thus causing an increase or decrease in the total amount supplied at a given price. The traditionally mentioned factors include changed costs of production, currency volatility, technological progress and government intervention (e.g. taxes and subsidies). Lower (higher) costs of production imply that more (less) can be supplied at a given price. A fall in the exchange rate causes an increase in the prices of imported production factors and will (assuming that all other factors remain at constant levels) lead to a decrease in supply. Changes in production technologies may imply changes (increases) in supply and lower prices for the buyer. Agriculture is typically characterized by strong knowledge intensity (technological progress). Shifts in supply are furthermore affected by governmental taxes and subsidies, such as support of energy saving technologies that stimulates its development and supply. Examples of further factors potentially affecting supply include purchasing powers on the demand side (e.g. agricultural cooperatives and other forms of cooperative arrangements that imply coordinated purchase of production factors), financial institutions and (imperfect) institutions and regulations.

4.2 Immobile farm assets

Agricultural land constitutes an immobile production factor used in agricultural production. As physical capital generally can be viewed as a complement to land in agricultural production, a farm's access to agricultural land will influence its investments in physical capital. Other examples of immobile production factors in agriculture include buildings and different types of facilities used in the production that cannot be moved and typically are characterized by asset specificity (i.e. they have been constructed for a specific production purpose at the farm and has a low or non-existing resale value). Immobile capital goods can be either reproducible (such as buildings and facilities) or non-reproducible (land).

The non-reproducibility of agricultural land implies that the quantity (measured by area) of existing agricultural land is fixed. It thereby differs from other capital goods used in agricultural production. Furthermore, as noted by Hurlburt (1958), agricultural land is two-dimensional in its nature. That is, the quantity of land supplied is not only measured by geographical area but also by physical quality (determined by factors such as soil quality and weather). Therefore, according to Hurlburt, the issue of defining effective supply of agricultural land is more complex than for other capital goods.[11]

However, more relevant for land supply in modern European land markets are factors such as (imperfect) institutions and regulations which are discussed in other Deliverables. As is also discussed in other deliverables, a large share of land transfers within the member states takes place on the rental market. Further characteristics of land markets is that the total area of transferred land units each year only constitutes a small share of the total existing agricultural land and new land plots typically only become available on the market when existing firms quite. The latter imply that farms generally only can grow when other farms exit. However, in some member states further land market segments exist as a result of privatization of previously state-owned land. This is the case for the Central and Eastern European Countries were previously collectivized state-owned land are being privatized as a part of their economic transition (this is discussed in other deliverables such as 15.2). For example, the land market in Eastern Germany is influenced by its history of collectivized land. After the German reunification, an organization (the German Trustee Agency) was founded with the legal duty to privatize previously state owned agriculture and forestry property. Today, the Land Utilization and Administration Company (BVVG) have taken over this task in Eastern Germany and apply a public tendering procedure. Thus, individual farms may have the opportunity to acquire (buy or rent) new land through these privatization procedures.

[11] Clearly, there are also several other reasons why the standard theory of supply do not apply to modern land markets.

Figure 2. Examples, market characteristics and some price determinants (mainly supply side) of mobile and immobile farm assets

Farm assets

	Assets labeled as "physical capital" according to its standard definition		
	Mobile	**Immobile**	
	Typically reproducible	**Reproducible**	**Non-reproducible**
Examples	Farm equipment, machinery Market characteristics: - *Relatively* liquid assets (compared to the immobile)	Agricultural buildings, various types of facilities used in agricultural production Market characteristics: - Asset specificity, resale market generally non-existing - Typically only has a value when transferred to another farmer	Agricultural land Market characteristics: - Markets typically characterized by various regulations - Large share of transfers by rentals in the member states - Transfers of ownership often takes place outside the market
Examples of price determinants (When market exists)	General (supply side): - Costs of production - Exchange rate - Technological progress - Taxes and subsidies	Other : - Financial institutions - (Imperfect) institutions and regulations - Market power	

Source: own compilation.

5. Summary

The overall aim of this Deliverable was to identify drivers of agricultural physical capital development. Physical capital is generally defined as an asset that is used in production which is manufactured by humans. Examples of physical capital assets in agricultural production include farm equipment, machinery and agricultural buildings.

A review of some existing theories and modelling approaches related to physical capital adjustments showed that they have moved from being output based to approaches that consider, for example, irreversibility, uncertainty/risk and flexibility in the timing of investment. The aspects considered in the latter models (the new investment theory) should be relevant for investments in agriculture which are typically are characterized by large sunk investments costs and uncertainty in future returns. As is always the case with theoretical models, existing investment models consider one or a few aspects. They should therefore be viewed as complementary to each other in explaining investment behaviour. Particularly in the case of agricultural production, any change in the capital stock has to be seen in relation to other production factors, such as land and labour, which can be viewed as complements as well as substitutes to physical capital. This is especially the case for family farms which have a close links between farm and household.

Investment decisions by agricultural firms can thus be expected to be driven by a large number of determinants, as well as being influenced by subjective beliefs and individual firm strategies. In this Deliverable, it was suggested that the drivers of physical capital adjustments in agriculture can be divided into three main groups, namely: i) expected (risk-adjusted) profit, ii) expected societal benefits and costs, and iii) expected private non-pecuniary benefits and costs. The discussion in this Deliverable mainly focused on the determinants related to the first group (expected profit) and covered aspects related to product market conditions, technological conditions, financial conditions and firm structure and organization. The second group refers, for example, to certain policies that may drive investment if they impose specific technological regulations (such as environmental regulations) and the third group relates to aspects such as reputation or organizational legitimacy gained through compliance with higher quality standards or environmental regulations, which could drive capital adjustment.

As physical capital generally can be viewed as a complement to land in agricultural production, a farm's access to agricultural land will influence its investments in physical capital. Therefore, characteristics of land markets in the member states, including factors such as (imperfect) institutions and regulations which are discussed in other deliverables, will influence farms' physical capital adjustments.

References

Balmann, A., M. Odening, H-P Weikard and W. Brandes (1996), "Path-dependence without increasing returns to scale and network externalities". *Journal of Economic Behavior and Organization*, Vol. 29, pp. 159-172.

Bischoff, C.W. (1971), "The Effect of Alternative Lag Distributions" in Gary Fromm (ed. 1971), pp. 61-130.

Brainard, W.C. and J. Tobin (1968), "Pitfalls in Financial Model Building", *American Economic Review*, Vol. 58, No. 2, pp. 99-122.

Chenery, H.B. (1953), "Overcapacity and the Acceleration Principle", *Econometrica*, Vol. 20, No. 1, pp. 1-28.

Cho, M-H (1998), "Ownership structure, investment, and the corporate value: an empirical analysis", *Journal of Financial Economics*, Vol. 47, pp. 103-121.

Clark, J.M. (1917), "Business acceleration and the Law of Demand: A Technical Factor in Economic Cycles", *Journal of Political Economy*, Vol. 25, No. 1, pp. 235-54.

Clark, P.K. (1979), "Investment in the 1970´s: Theory, Performance, and Prediction". Brookings Papers on Economic Activity, Vol. 1979, No. 1, Brookings Institution, Washington , D.C., pp. 73-113.

Cochrane, W.W. (1958), *Farm Prices: Myth and Reality*, St. Paul, MN: University of Minnesota Press.

David, P.A. (1969), "A contribution to the theory of diffusion", Stanford Center for Research in Economic Growth, Memorandum no. 71, Stanford University, Stanford, CA.

Deardorff's Glossary of International Economics (http://www-personal.umich.edu/~alandear/glossary/).

Dixit, A. and R.S. Pindyck (1994), *Investments under Uncertainty*, Princeton, NJ: Princeton University Press.

Dusenberry, J.S. (1958), *Business Cycles and Economic Growth*, New York, NY: McGraw-Hill.

Edwards, W. M. and Boehle (1980), "Machinery Selection Considering Timeliness Losses". *Transactions of the American Society of Agricultural Engineers*, pp. 810-821.

Eisner, R. and R.H. Strotz (1963), "Determinants of Business Investment", in *Impacts of monetary policy*, Commission on Money and Credit. Englewood Cliffs, NJ: Prentice-Hall, pp. 59-233.

Eisner, R. (1972), "Components of capital expenditure: replacement and modernisation versus versus expansion", *Review of economics and Statistics*, Vol. 53, No. 4, pp. 297-305.

Ellsberg, D. (1961), "Risk, ambiguity and the Savage axioms". *Quarterly Journal of Economics*, Vol. 75, No. 4, pp. 643-699.

Encyclo Online Encyclopedia (http://www.encyclo.co.uk).

Fazzari, S., G. Hubbard and B. Peterson (1988),"Financing constraints and corporate investment", *Brookings Papers on Economic Activity*, Vol. 1, Brookings Institution, Washington, D.C., pp. 141-206.

Grant, S. and J. Quiggin (2007), "Conjectures, Refutations and Discoveries: Incorporating New Knowledge in Models of Belief and Choice under Uncertainty" in D. Abdellaoui, R. Luce, M.J. Machina and B.R. Munier, *Uncertainty and Risk. Mental, formal and Experimental Representations*, Berlin Heidelberg and New York: Springer.

Greenwald, B., J.E. Stiglitz and A. Weiß (1984), "Informational Imperfections in the Capital Market and Macroeconomic Fluctuations“, *American Economic Review*, Vol. 74, No. 2, pp. 194-199.

Hassett, K.A. (2008), "Investment." *The Concise Encyclopedia of Economics*. 2008. Library of Economics and Liberty (http://www.econlib.org/library/Enc/Investment.html).

Hayashi, F. (1982), "Tobin's marginal q and average q: A Neoclassical Interpretation, *Econometrica*, Vol. 50, No. 1, pp. 213-24.

Henry, C. (1974), "Investment Decisions under Uncertainty: The "Irreversibility Effect"“, *The American Economic Review*, Vol. 64, No. 6, pp. 1006-1012.

Holmström, B. (1979), "Moral hazard and observability", *Bell Journal of Economics*, Vol. 10, pp. 74–91.

Huber, O. (2007), "Behaviour in Risky Decisions: Focus on risk Defusing" in *Uncertainty and Risk. Mental, formal and Experimental Representations*. Edited by M. Abdellaoui, R.D. Luce, M.J. Machina, B. Minier, Berlin, Heidelberg and New York: Springer.

Hurlburt, V.L. (1958), "Theory of Supply of Farm Land", *Land Economics*, Vol. 34, No. 2, pp. 161-167.

Investiopedia.com, http://www.investopedia.com, accessed on February 20, 2012.

Jensen, M. and W. Meckling (1976), "The theory of firm: managerial behaviour, agency costs and ownerships structure“. *Journal of Financial Economics*, Vol. 3, pp. 305-360.

Johnson, G.L. (1956), "Supply functions: some facts and notions" in Heady, E.O. et al. (eds), *Agricultural Adjustment problems in a Growing Economy*, Ames, IA: Iowa State University Press.

Johnson, G.L. and L. Quance (1972), *The Overproduction Trap in U.S. Agriculture*, Baltimore, MD: Johns Hopkins University Press.

Jorgenson, D.W. (1963), "Capital Theory and Investment Behavior", *American Economic Review*, Vol. 53, No. 2, pp. 247–259.

Jorgenson, D. (1967), "The Theory of Investment Behavior" in R. Ferber (eds), *Determinants of Investment Behavior*, pp. 129-188.

Jorgenson, D.W. and C.D. Siebert (1968), " A Comparison of Alternative Theories of Corporate Investment Behavior", *American Economic Review*, Vol. 58, pp. 681-712.

Jorgenson, D.W. (1971), "Investment Behavior and the Production Function", *Bell Journal of Econ. Manage. Science*, Vol. 3, No. 2, pp. 220–51.

Koester, U.E. and K.M. Brooks (1997), "Agriculture and German Reunification". World Bank Discussion Paper No. 355. World Bank, Washington, D.C.

Koyck, L.M. (1954), *Distributed Lags and Investment Analysis*, Amsterdam: North-Holland Publishing Company.

Kuh, E. (1963), *Capital Stock Growth: A Microeconomic Approach*, Amsterdam: North-Holland.

Leahy, J.V. (1993), "Investment in Competitive Equilibrium: The Optimality of Myopic Behavior", *Quarterly Journal of Economics*, Vol. 108, pp. 1105-1133.

McDonald, R. and D. Siegel (1986), "The Value of Waiting to Invest", *Quarterly Journal of Economics*, pp. 707-727.

Meyer, J.R. and E. Kuh (1957), *The investment decision: an empirical study*, Cambridge, MA: Harvard University Press.

Modigliani, F. and M.H. Miller (1958), “The Cost of Capital, Corporation Finance and the Theory of Investment“,*American Economic Review* Vol. 48, pp. 261-297.

Myers, S.C. and N.S. Majluf (1984), “Corporate Financing and Investment Decisions When Firms Have Information That Investors Do Not Have”, *Journal of Financial Economics*, Vol. 39, pp. 187-221.

Nwaeze, E.T. (2005), ”Replacement versus adaptation investments and equity value”. *Journal of Corporate Finance*, Vol. 11, pp. 523-549.

Oliner, S., Rudebusch and D. Sichel (1995), ”New and Old Models of Business Investment: A Comparsion of Forecasting Performance”, *Journal of Money, Credit and Banking*, Vol. 27, No. 3, pp. 806-826.

Odening, M., O. Musshoff and A. Balmann (2005), ”Investment Decisions in Hog Production - An Application of the Real Options Approach”, *Agricultural Economics*, Vol. 32, No. 1, pp. 36-47.

Odening, M., O. Musshoff, N. Hirschauer and A. Balmann (2007), ”Investment under uncertainty – Does competition matter? ” *Journal of Dynamics and Control,* Vol. 31, pp. 994-1014.

Pearce, D.W., J. Cairns, R. Elliot, I. McAvinchey and R. Shaw (eds) (1992),. *Macmillan Dictionary of Modern Economics*: Palgrave Macmillan.

Pindyck, R.S. (1991), ”Irreversibility, Uncertainty, and Investment”, *Journal of Economic Literature,* Vol. 34, pp. 53-76.

Rogers, E. M. (1962), *Diffusion of innovation*. New York, NY: Free Press.

Runge, I. (2000), *Capital and Uncertainty: The Capital Investment Process in a Market Economy*, Cheltenham, UK and Northampton, MA: Edward Elgar Publishing.

Samuel, C., (1996), “Internal Finance and investment. Another look.” Policy research working paper 1663, The World Bank.

Schianterelli, F. (1996),”Financial constraints and investment: methodological issues and international evidence”, *Oxford Review of Economic Policy*, Vol. 12, No. 2, pp. 70-89.

Short, C. and K.W.Gitu (1991), ”Timeliness cost for machinery selection”, *Canadian Journal of Agricultural Economics*, Vol. 39, pp. 457-462.

Swinnen, J.F.M. and H.R. Gow (1999), ”Agricultural credit problems and policies during the transition to a market economy in Central and Eastern Europe”, *Food Policy*, Vol. 24, pp. 21-47.

Smit, H.T.J. and L. Trigeorgis (2004), *Strategic investment*. Princeton, NJ: Princeton University Press.

Stiglitz, J.E., and A. Weiss (1981), Credit rationing in markets with imperfect information, Part I, *American Economic Review*, Vol. 71, pp. 393-410.

Sunding, D. and D. Zilberman (2001), “The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector” in B. Gardner and G. Rausser (eds), *Handbook of Agricultural Economics,* Vol. 1A, pp. 207–61. Amsterdam: Elsevier.

Tirole, J. (1988), *The theory of industrial organization,*. Cambridge, MA: MIT Press.

Tobin, J. (1969), “A General Equilibrium Approach to Monetary Theory”, *J. Money, Credit, Banking*, Vol. 1, No. 1, pp. 15-29.

Williamsson, O. (1975), *Markets and Hierarchies: Analysis and Antitrust Implications*. New York: Free Press.

Wossink, A. and S.M. Swintoc (2007), “Jointness in production and farmers' willingness to supply non-marketed ecosystem services”, *Ecological Economics*, Vol. 64, pp. 297-304.

Comparative Analysis of Factor Markets for Agriculture across the Member States

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The Factor Markets project in a nutshell

Title	Comparative Analysis of Factor Markets for Agriculture across the Member States
Funding scheme	Collaborative Project (CP) / Small or medium scale focused research project
Coordinator	CEPS, Prof. Johan F.M. Swinnen
Duration	01/09/2010 – 31/08/2013 (36 months)
Short description	Well functioning factor markets are a crucial condition for the competitiveness and growth of agriculture and for rural development. At the same time, the functioning of the factor markets themselves are influenced by changes in agriculture and the rural economy, and in EU policies. Member state regulations and institutions affecting land, labour, and capital markets may cause important heterogeneity in the factor markets, which may have important effects on the functioning of the factor markets and on the interactions between factor markets and EU policies. The general objective of the FACTOR MARKETS project is to analyse the functioning of factor markets for agriculture in the EU-27, including the Candidate Countries. The FACTOR MARKETS project will compare the different markets, their institutional framework and their impact on agricultural development and structural change, as well as their impact on rural economies, for the Member States, Candidate Countries and the EU as a whole. The FACTOR MARKETS project will focus on capital, labour and land markets. The results of this study will contribute to a better understanding of the fundamental economic factors affecting EU agriculture, thus allowing better targeting of policies to improve the competitiveness of the sector.
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Partners	17 (13 countries)
EU funding	1,979,023 €
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