Management and Business Administration Doctoral School

SUMMARY OF THESES

to the Ph.D. dissertation of

Nándor Kaliczka

titled

Examination of Phenomena Affecting the Depreciation of Fixed Assets

Supervisors

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Rezső Baricz, CSc
emeritus professor

Budapest, 2013

Financial Accounting Department

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1 Project antecedent and justification of the theme

The concept of depreciation and the measurement of its value have long been a prominent issue in economic and accounting literature, the relevance of which is demonstrated by the great number of open questions related to the subject.

The concept of depreciation is virtually inseparable from the concepts of capital and income, which appeared as individual measures in the economic literature of early last century. One of the key issues in the determination of capital and income is how to measure the contribution of fixed assets to the corporate operational processes. The primary attribute of these fixed assets is that their service lifetime spans over several reporting periods. *Preinreich* [1937] differentiates between two major categories of fixed assets on the basis of the services these provide. One of the groups is constituted by assets providing services of a limited quantity; while in the case of the fixed assets belonging to the other group, only the possibility to use these services is limited. However, different approaches are needed to grasp the consumption of these two categories of fixed assets; consequently in my dissertation I will only analyse the consumption of assets serving the company's activity during several periods, created by man, with a finite service lifetime, and with quantitative limitations concerning usability.

Income as the measure of economic performance

In economic and accounting literature, income means excess capital generated during a period and available for consumption, always determined from the point of view of a person or a group. Economists determined the income of a period t as the sum of consumption and saving, the saving being conceived as the variation of the individual economic capital within the period; i.e. $S_t = K_{t+1} - K_t$. On the basis of the above, individual economic income may be expressed as:

(1) $Y_t^e = C_t + K_{t+1} - K_t,$

where K_{t+1} and K_t means the end-of-period and beginning-of-period capital, respectively (*Bélyácz* [2002]).

The economic income concept presented above is also suitable for the measurement of corporate economic performance. As owners constitute a group which is homogeneous in respect of the company, the owners' income (i.e. the company's income) may be determined in analogy with individual income (*Lee* [1986]):

(2) $Y_t^a = D_t + R_{t+1} - R_t.$

Business income is composed of the dividend paid or payable to the owners and of the changes in the business capital over the period; this change shall not include the effects of any eventual capital investment or disinvestment effectuated during that period. Dividend may be construed as the consumption of business capital by the owners, which once paid does not serve the operation of the company's value creating processes any longer, and consequently may be entirely correlated with consumption determined in relation to economic income.

Equation (1) and (2) shows that the value of the income is principally a function of the difference between the beginning-of-period and end-of-period capital. Namely the beginning of period t both represent the wealth of the owner of the income, the recognition of which in the determination of the income also ensures that any profit arising from economic processes may not be considered as income as long as the capital operators have not undertook to maintain or replace the beginning-of-period capital value $\mathrm{K_t}$ or $\mathrm{R_{t.}}$ This guarantees that the intactness of capital is safeguarded.

Capital maintenance concepts influencing income

Virtually all authors discussing capital and income theory agree that the output produced during the operation of the capital provides income to the capital operators, and that out of any output produced in a given period, only that part may be considered as income which is not necessary for the maintenance of the capital at a constant level (*Bélyácz* [1994a]). The close relationship between the concepts of capital maintenance and income is also shown by the fact that *Hicks* [1978] built up the three widely accepted categories of incomes around different concepts of capital maintenance.

Break [1954] discussed several aspects of capital maintenance in detail, whom capital maintenance concepts are clearly delimited according to their intention to maintain either the quantity or the value of capital. A great number of debates have dealt with the applicability of the physical concept of capital maintenance for the purposes of income definition.

The facts described above show that the method of capital maintenance is closely related with the concept of capital, and consequently exerts a fundamental effect on the definition of income itself. It also follows from the diversity prevailing in the field of capital maintenance that there is no single, generally accepted income concept universally suitable for each market player; this is confirmed by the variety of incomes derived for various kinds of persons and groups in line with different capital maintenance concepts.

Identification of asset consumption

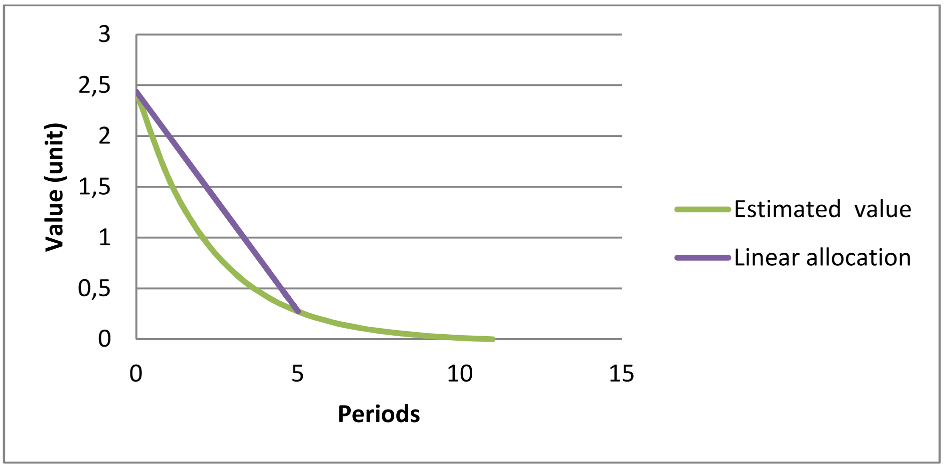
Changes in the value of capital R_t occurring within a period t (excluding any additional capital investment or disinvestment effectuated during that period) constitute a significant part of business income. *However, the value of business capital R_t is equal to the total of the net assets of the company, i.e. the value of its total assets minus the value of the liabilities of the company.* A certain part of the company's net assets is constituted by the fixed assets, labelled as "fix" because they serve the activity of the business during several periods; as a consequence, the physical and price impacts occurring during those periods shall influence the assessment of the asset's future usefulness, i.e. its value.

Academic opinions on income and capital seem to concur in the view that at the end of each period, a certain portion of the value of the fixed assets as of the beginning of the period should be split up to the debit of the income of the period, for fixed assets get exhausted and deteriorate (or else become obsolete) during the business cycle, and their values expressed in current prices change in line with actual inflation. These impacts collectively result in the gradual consumption of the asset value; this consumption influences the change in capital $R_{t+1} - R_t$ as determined in equation (2), fundamentally affecting business income in the given period.

The recognition of the costs stemming from the consumption of fixed assets in the calculation of the income also ensures the conservation of the value of the fixed assets as of the beginning of the period through the fact that the owners' income (profit) may not be established before the costs representing asset consumption appear (and assert their reductive effect) in the income calculation. The relevant academic literature identifies three fundamental theoretical approaches to recognising the consumption of fixed assets during the reproduction process. *Bélyácz* [1993] summarises these three approaches as follows: (1) distributing the initial purchase value, reduced by the residual value, in a discretionary proportion along the estimated service lifetime; or (2) setting aside a constant amount every year which (together with its accumulating interests) constitutes a fund, segregated from the income, for any replacement due by the end of the lifetime of the asset; or (3) changes in the value of the equipment during the given period.

Nevertheless, the methods proposed for the allocation of historical asset costs faced much criticism in academic literature. Some of the critics censure the arbitrariness of allocation, which in the present case refers to the fact that there is no evident causality between the consumption of the thus computed asset value and the evolution of income in time (*Bélyácz* [1994b]), which undermines the applicability of allocation in economic science, as first pointed out by *Hotelling* [1925]. Nevertheless, the method is still popular and widely used, owing primarily to the fact that it makes it possible to calculate the consumption of the asset value occurring during the given period at a low cost and with relatively little computing effort – although it does not necessarily closely reflect reality.

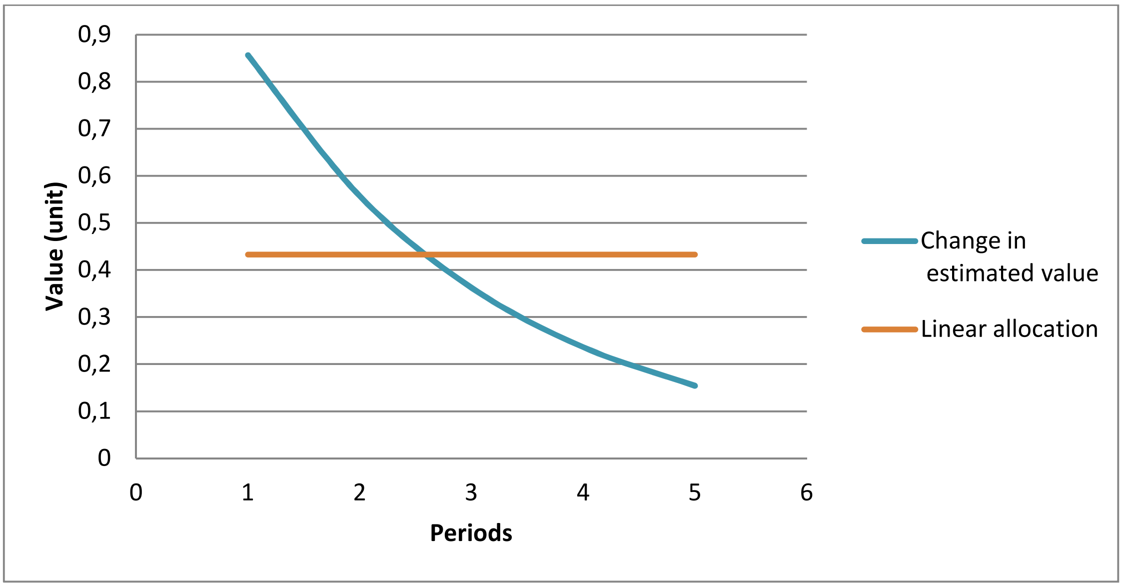
Consequently, the simple cost allocation mechanism is quite probably unsuitable to compute the actual end-of-period asset value and, as a result, does not ensure the maintenance of the business capital as outlined in Chapter 2.2, either in the nominal or in the real sense. We may illustrate the problem with the following example: Let us assume that our company purchases a machine for 2.4 units. The company plans to use the machine during 5 periods, its estimated scrap value at the end of period 5 being 0.27 units. However, using the estimation methodology of the machine's scrap value, it is possible to estimate the asset value at the end of each operating period. In the next graph, this asset value function based on our estimates is represented in green.



Graph 1: Relationship between the asset values as estimated and calculated using the linear allocation method. (Source: own elaboration)

The graph also shows the end-of-period net asset values as calculated using the linear cost allocation method: it is evident that the asset value estimates relating to the individual periods and the asset values resulting from linear allocation do not coincide. The asset value calculated by linear allocation gives higher values throughout the operating period of the asset. Consequently, if single line cost allocation does not coincide with our estimates of the end-of-period asset values, it evidently distorts the image of the company's financial situation.

The linear allocation concept of the example above does not only influence the end-of-period asset value but also impacts on the business income determined in equation (2). This effect is illustrated in the following graph.



Graph 2: How the choice of linear allocation or the 'change in the value' method to compute depreciation impacts on income. (Source: own elaboration))

The graph shows that in this example, linear allocation used to determine asset consumption first under-, then overrates the depreciation computed on the basis of the estimated change in the asset value, which not only distorts the business income of the individual periods, but is also unable to maintain the value of the beginning-of-period capital either in the nominal or in the real sense.

A frequently cited argument on the side of the systematic allocation of the historical cost points out its objectivity, its independence from the person applying the method. However, the objectivity of allocation methods is undermined by the fact that the usage period and scrap value of the assets are established in an ex ante manner; this estimate is virtually always a result of a subjective judgment, which fundamentally challenges the objectivity of historical cost allocation.

At the same time, the single line allocation of historical asset cost also yields questionable results from the viewpoint of the accounting principles. As the mechanical measurement of asset consumption is very frequently quite out of touch with the actual consumption, it does not make it possible to match the appropriate expenditures with the receipts of the period, which infringes the matching principle, and reflects a distorted image of the financial and income situation of the firm.

Through the above mentioned weaknesses led to the creation of the theoretical basis, founded by Hotelling and widely accepted today, determining asset consumption in a given period through the difference between the value of the asset at the beginning and end of the period. *Hotelling* [1925] defined asset consumption over a period as the change in the value of the asset, and considered depreciation as the rate of the decrease of the asset value in a given period. Hotelling turned away from the time-based concept of allocation, used in cost allocation as well as in the replacement fund model.

He defined asset value as the discounted present value of the future rents ('theoretical rentals') and the scrap value of the asset at the end of its service lifetime. He considered the rent of the asset as the value of the maximal quantity of outputs produceable with the asset in the given period, calculated at an anticipated sales price, decreased with the operating costs of the asset, and He recognised that depreciation is related to the value of the outputs produced with the asset, deducting operating costs.

On the basis of the above definition, by 'depreciation' Hotelling means the change occurring in the value of the assets from one period to another. Therefore, the determination of depreciation is inseparable from the underlying value theory. in *Wright's* [1964] formulation: depreciation theory [1] *could not exist without valuation theory*.

The end-of-period value of the fixed assets used may be calculated using the market prices of these assets or on the basis of the discounted present value of their future returns, where the return of the asset is usually identified as its theoretical rental. However in the case of both methods, the end-of-period value of the assets is identified on the basis of market prices, which is rather problematic because in reality such markets hardly ever exist. As a consequence, the end-of-period asset value is determined using estimated depreciation rates calculated with due regard to the phenomena influencing the asset value.

Phenomena affecting asset value

It is clear that the value of used assets is shaped by the physical and economic phenomena occurring in them and in their surroundings. *Griliches* [1963] defines these phenomena and processes in the following way:

- *Exhaustion: with aging, there follows a decline in the life expectancy of the asset; that is, at the end of the period in question, the expected service lifetime of the asset will be shorter than at the beginning of that period.*
- *Deterioration: with aging, there is a decline in the physical productivity of the asset within the individual periods; i.e. the services rendered by the asset become poorer by the end of the period than they were at the beginning*.
- *Obsolescence: as a result of technological progress, the services provided by assets using an older technology will be worth less than those of assets with the most recent technology: this represents a decline in the relative market return for the productivity of these assets, also influenced by other relative price changes*.

[1] Depreciation as defined by *Hotelling*.

Triplett [1996] regarded the concept of exhaustion as defined by Griliches as the last phase of deterioration; nevertheless, Triplett considered it expedient to differentiate between the two effects.[2]

On the other hand, deterioration is connected with the value of the service rendered by the asset, which decreases insomuch as the older asset is only able to provide poorer or less service in the subsequent periods than it could when it was younger.

Jorgenson [1971] considers the above definition of the phenomenon of deterioration as a mortality distribution, and *Triplett* [1996] explains it with two additional factors, the decay and retirement of the assets. Triplett considers decay as the decrease in the productive efficiency of the surviving capital services, while he defines retirement as the loss of capital services. In *Triplett's* [1996] opinion, as a consequence of decay, the efficiency of the asset decreases as its age increases, so that it can render ever less or poorer service in the periods to come. The phenomenon of decay may also be examined from the aspect of input and output; *Feldstein and Rothschild* [1974] establish the difference between these two phenomena very clearly. In their understanding, input decay means that as it grows older, an asset uses more input to render an identical capital service than a newer unit. On the other hand, output decay means that as it gains in age, an asset will be able to render less and less capital service in each future period. *As a second component of deterioration, Triplett [1996] identifies the loss of service resulting from the retirement of the assets; which however may only be construed for a group of assets only, for in the case of one asset, retirement (reaching the end of usability) also entails the end of the valuation*.

The next phenomenon influencing the changes in asset value is obsolescence, also mentioned by Griliches. When a new asset using a new, more developed technology appears on the market, the value of the existing assets using a less developed technology will decrease as a result: *Hulten and Wykoff* [1996] call this decrease obsolescence. The phenomenon of obsolescence appears primarily as a result of the intensive innovation and technological development characteristic of capitalism, a phenomenon which in the economic sense was baptised "creative destruction" by *Kornai* [2010], in the wake of Schumpeter. In connection with the above mentioned technological advance, *Hall* [1968] recognises two further phenomena: embodied and disembodied technological progress, a phenomenon also identified earlier by *Jorgenson* [1966]. In the case of embodied technological progress, the new, more developed technology is embodied in a specific asset which becomes available to market players. Contrarily, in the case of disembodied technological progress, no asset of a more developed condition appears, but the services of the existing asset lose value as a result of the general development of other technologies: in other words, the change occurs in the exchange rate of the asset. Building on the findings of Jorgenson and Hall, following the pattern of

[2] To illustrate the difference between exhaustion and deterioration, let us take the example of a coal mine, where the service provided by the mine is the quantity of coal mined in a given period. Let us furthermore assume that the heating value of the coal situated in the lower layers is lower than that of the coal in the upper layers. In this case, by the end of a period, the coal stock remaining in the mine will be smaller than it was at the beginning of the period: according to the terminology above, this represents the "exhaustion" of the mine. However, in the subsequent periods, coal is extracted from lower and lower layers, which (in line with our assumption) will yield coal of ever lower heating value; this means that period after period, the services rendered by the mine will become poorer and poorer, corresponding to "deterioration" in the above outlined nomenclature.

technological progress, *Diewert és Wykoff* [2006] differentiate between embodied and disembodied obsolescence:

- *Disembodied obsolescence: where there are no new and improved models introduced on the market, but the value of the capital service of the asset declines over time due to shifts in demand or other exogenous factors.*
- *Embodied obsolescence: where new and improved models of the capital good appear on the market over time, as a result of which—under the assumption of Hulten and Wykoff [1996]—the value of the asset with the older technology will decrease.*

Age and date effects exerted by phenomena influencing changes in the asset value

If the above mentioned phenomena exert an influence on the value of the asset, this influence also needs to appear in the market value of the asset. However relatively few used assets have an active competitive market which could provide information serving as a basis to determine the end-of-period value of the asset in use. Therefore we need to estimate the change in the value of the asset in use on the basis of the phenomena affecting the asset value as of the beginning and the end of the period; a possible model to do so was presented in the dissertation.

The impacts of exhaustion, deterioration and obsolescence, estimated in the future, change not only with the age of the asset, thus influencing the current value of the asset, but also because we perform our estimations for the future at different moments in time, i.e. at different dates, and the change in the date of the estimation also impacts on the asset value. According to the organisation described above, these effects are called ‘age and time effect’ in academic literature. As, however, age effect is primarily based on time, I will hereinafter designate the phenomenon identified by academic literature as time effect by the term of ‘date effect’.

Breakdown of changes in the value of fixed assets

For the above mentioned breakdown of the change in value, we need to consider the change in the value $P^I_{t,s}$ of the asset of age s from moment t to moment t+1, which may be formulated as follows:

(3) $$\Delta_{t,s} = P^I_{t,s} - P^I_{t+1,s+1}$$

The change in the value $\Delta_{t,s}$thus defined may be examined in respect of the change in the service value $P^K_{t,0}$ of the new asset as well as in the light of assumptions concerning certainty and exact knowledge about the future. The research aims to clearly differentiate, in the theoretical sense, between any age effects appearing in the changes in the value of the assets on the one hand, and the elements related to revaluation and capital gain/loss constituting date effect, on the other hand.

It is apparent from equation (3) that the changes in the values in question result partly from the alteration of the moment *t* of valuation and partly from the fact that the asset becomes a period older, i.e. its age grows from *s* to *s+1*. These two effects together cause the change in value — called ‘time series depreciation’ by *Hill* [1999] in the event of certainty and exact knowledge of future conditions.[3] *Hulten and Wykoff* [1981a] illustrate the discrete system of value change with a matrix providing a separate display of asset values $P^I_{t,s}$ according to the date of valuation (columns) and the increase in the age (rows).

t=	***1***	***2***	***3***	…
s = 0	$P^I{}_{1,0}$	$P^I{}_{2,0}$	$P^I{}_{3,0}$	…
1	$P^I{}_{1,1}$	$P^I{}_{2,1}$	$P^I{}_{3,1}$	…
2	$P^I{}_{1,2}$	$P^I{}_{2,2}$	$P^I{}_{3,2}$	…
3	$P^I{}_{13}$	$P^I{}_{2,3}$	$P^I{}_{3,3}$	…
…	…	…	…	…

Graph 3: Breakdown of the change in asset values according to age and time factors. (Source: based on Hulten and Wykoff [1981a])

Graph 3 shows that if asset values are represented in the dimensions of the date of valuation and age, the time series depreciation defined in the present matrix as the difference of two cells which represent a transversal movement to the right. This diagonal shift in the matrix expresses a collective change in the age of the asset and in the date of valuation; therefore the time series depreciation expressed as the root of the change in these two factors. *Following Diewert and Wykoff's [2006] train of thought, time series depreciation may be broken down to age effect and date effect in two different ways depending on the order of the shift in the matrix: i.e. first to the right and then down, or first down and then to the right. Therefore age and date effect may be expressed according to the different orders of the shifts as follows:*

(4) $\Delta P^I_{t,s} = [P^I_{t,s} - P^I_{t+1,s}] + [P^I_{t+1,s} - P^I_{t+1,s+1}] = G_{t,s} + D_{t+1,s}$

(5) $\Delta P^I_{t,s} = [P^I_{t+1,s} - P^I_{t+1,s+1}] + [P^I_{t,s+1} - P^I_{t+1,s+1}] = D_{t,s} + G_{t,s+1}.$

where $D_{t,s}$ and $D_{t+1,s}$ designate the changes in the value resulting from the increase in the age *s* of the asset at moments *t* and *t+1*, i.e. the age effects; whereas $G_{t,s}$ and $G_{t,s+1}$ represent the changes in the value of assets of ages *s* and *s+1* due to the change in the moment *t* of valuation, i.e. the date effects [4]. *Hill* [1999] uses the term 'revaluation effect' to designate the change in the value resulting from a change in the date of valuation, assuming certainty and exact knowledge about the future.

[3] This corresponds to the concept of 'depreciation' as defined by *Hotelling*. *Hotelling* also defined depreciation on the condition of certainty and exact knowledge about the future (*Hotelling* [1925] p. 343).

[4] *Hulten and Wykoff* [1981a] use the term 'discrete time effect' to designate the effect thus defined. Discrete time effect, or date effect, represents the difference between the value of a three-year-old asset as of 31 December 2010 and the value of a similarly three-year-old asset as of 31 December 2011.

Formulas $D_{t,s}$ and $D_{t+1,s}$ incorporating age effect, express the difference between the values of two assets of ages s and $s+1$ at a given moment t or $t+1$.[5] To designate this effect, *Hulten and Wykoff* [1996] use the term '(economic) depreciation' and *Hill* [1999] uses the expression 'cross-section depreciation'.

It is clear from equations (4) and (5) that the overall change in the asset value (assuming certainty and exact knowledge about the future), i.e. time series depreciation $\Delta P^I_{t,s}$ is not affected by the order of the 'directions' of computing. As a result, the order of calculating cross-section depreciation and revaluation is based on tradition and conventions. As illustrated in equations (4) and (5), cross-section depreciation $D_{t+1,s}$ and $D_{t,s}$ may also be expressed using a cross-section depreciation rate:

$$(6)\ \delta^C_{t+1,s} = 1 - \left(P^I_{t+1,s+1}/P^I_{t+1,s}\right) = D_{t+1,s}/P^I_{t+1,s};\ ahol\ P^I_{t+1,s} \neq 0$$
$$(7)\ \delta^C_{t,s} = 1 - \left(P^I_{t,s+1}/P^I_{t,s}\right) = D_{t,s}/P^I_{t,s};\ ahol\ P^I_{t,s} \neq 0.$$

Following the same logic, the revaluation rates $\theta_{t,s}\ and\ \theta_{t,s+1}$ corresponding to revaluations $G_{t,s}$ and $G_{t,s+1}$ of assets of age s and $s+1$ may be expressed as follows:

$$(8)\ \theta_{t,s} = 1 - \left(P^I_{t+1,s}/P^I_{t,s}\right) = G_{t,s}/P^I_{t,s};\ ahol\ P^I_{t,s} \neq 0$$
$$(9)\ \theta_{t,s+1} = 1 - \left(P^I_{t+1,s+1}/P^I_{t,s+1}\right) = G_{t,s+1}\ /P^I_{t,s+1};\ ahol\ P^I_{t,s} \neq 0.$$

Using the above defined cross-section depreciation and revaluation rates, the time series depreciation rate $\delta^T_{t,s}$ *of an asset of age s for period t may be expressed as follows*:

$$(10)\qquad \delta^T_{t,s} = 1 - \left(P^I_{t+1,s+1}/P^I_{t,s}\right) = 1 - \left(1 - \theta_{t,s}\right)\left(1 - \delta^C_{t+1,s}\right) = 1 - \left(1 - \delta^C_{t,s}\right)(1 - \theta_{t,s+1});ahol\ P_{t,s} \neq 0.$$

Given uncertainty and lack of exact knowledge about future, the asset values measured at different moments t differ from each other partly as a result of the phenomena described above, but also *because our estimates made at earlier moments t may deviate from the actual realised values on the one hand, and from our estimates for the future based on more recent knowledge, on the other hand*. As a result, realised or unrealised 'heaven-sent' profits or losses are incurred[6] (*Bélyácz* [2002]), which *Hill* [1999] considers to be *capital gains or losses* and definitely isolates from revaluation effect $G_{t,s}\ and\ G_{t,s+1}$ ensuing from the nominal change in the value of the new asset or in the service value of the asset. So in the absence of exact knowledge concerning the future, the change in the asset value, and the value of an asset of age s at moment t, may be established with less uncertainty on the basis of information available at moment $t+1$ than it could be on the basis of information available at moment t.

[5] *Hulten and Wykoff* [1981a] use the term 'discrete age effect' to designate the effect thus defined. Discrete age effect represents for instance the difference between the value of a three-year-old asset as of 31 December 2011 and the value of a four-year-old asset as of 31 December 2011.
[6] To which I have made reference earlier, in connection with the *ex post* and *ex ante* determination of service values $P^k_{t,s}$.

The role of cross-section and time series depreciation in the determination of the change in the asset value of the end-of-period asset value

The fixed assets used by companies hardly ever have an active and transparent market which would enable us to measure the end-of-period value of the assets. Therefore, in practice, the values of fixed assets used by companies are established using depreciation rates. The $\delta_{t,s}^{T}$ time series depreciation rate is consist of the ex post real change $\ddot{\imath}_t^*$ of the service value of the new asset in the given period, the ex post periodical inflation $\ddot{\rho}_t$ and the cross-section depreciation rate $\delta_{t+1,s}^{C}$ of the asset as determined at the end of the period:

$$\textit{(11)} \qquad \delta_{t,s}^{T} = 1 - (1 + \ddot{\imath}_t^*)\,(1 + \ddot{\rho}_t)\big(1 - \delta_{t+1,s}^{C}\big).$$

The real price change rate $\ddot{\imath}_t^*$ and the periodical ex post inflation $\ddot{\rho}_t$ may be established in an ex post manner based on the changes occurring within period *t* (i.e. at moment *t+1*) in the service values $P_{t,0}^{I}$ of new assets available on the market. In order to determine the cross-section depreciation rate $\delta_{t+1,s}^{C}$ of the asset, however, it is necessary to estimate its *exhaustion*, *deterioration* and *embodied and disembodied obsolescence* occurring in period *t* and anticipated for the future. At the same time, these effects are substantially influenced by the specific features, usage and maintenance characteristics of the asset, as well as by a number of further circumstances related to its use.

In certain cases it is possible to determine the cross-section depreciation rate using an empirical method, which also provides a useful testing for the cross-section depreciation rate used. *These empirical examinations are almost in every case based on market prices: consequently, they not only reflect embodied and disembodied obsolescence but also the 'average' condition (wear) of the asset, which—although not likely to correspond to the cross-section depreciation of the individual asset—provides guidance for the determination of that rate.*

The empirical examination of cross-section depreciation rate

The empirical measurement of cross-section depreciation rate $\delta_{t+1,s}^{C}$ is typically performed on the basis of *second-hand market prices and the theoretical rentals prevailing on the rental market of the assets*, however the main problem concerning this approach is that fixed assets typically do not have a transparent and active rental market which would make it possible to observe the services values (i.e. the rents) of assets of different ages.

Mainstream literature discussing the empirical determination of depreciation rates often uses second-hand market asset prices to estimate the cross-section depreciation rate $\delta_{t+1,s}^{C}$ corresponding to moment *t+1*. Asset values $P_{t+1,s}^{I} and\ P_{t+1,s+1}^{I}$ are in this case identified with the second-hand market prices of assets of age *s* and *s+1* observed at moment *t+1*, from the proportion of which it is possible to estimate the cross-section depreciation rate $\delta_{t+1,s}^{C}$ of an asset of age *s*. However the cross-section depreciation values thus computed are also distorted by the fact that the assets found on the second-hand market are all 'surviving assets', a problem first addressed by *Hulten and Wykoff* [1981a] in their empirical research. The main problem is that t*he scrapped assets will not be represented on the second-hand market, and will therefore be excluded from the analysed sample, which distorts the determination of* *depreciation rate on the basis of second-hand market prices.* Consequently the surviving asset of a given vintage present on the second-hand market will not be representative of the 'average' asset of that vintage but of the 'surviving' assets of the vintage in question. At the same time, 'average' assets are more relevant to the measurement of asset value than the assets of the given vintage which 'survive' for the longest time (*Hulten and Wykoff* [1981a]).

2 Used methodes

I considered asset age as an explanatory variable of depreciation expressing the exhaustion, deterioration and obsolescence of assets. In the case of cars, another factor to observe is mileage, which I assume to be an independent explanatory variable of the ‘average’ deterioration and exhaustion of cars in the calculation of depreciation.

In Hungarian accounting practice, the cost allocation model (and especially the linear allocation method) prevails in the calculation of depreciation. Linear cost allocation is, however, probably unable to reproduce the change in the asset value, which not only reflects a distorted image of the company’s financial and income situation, but also leads to the incorrect pricing of the company output. Therefore, it is particularly important, that the depreciation model used by companies should not fail to consider the effects of exhaustion, deterioration and obsolescence, these effects also determine the shape of the depreciation function, constituting the subject matter of my Hypotheses 1 and 2:

H1: The cross-section depreciation of used passenger cars of the same category follows a geometric pattern according to the age of the cars.

H2: The cross-section depreciation of used passenger cars of the same category follows a geometric pattern according to the mileage of the cars.

Previously I traced back the cross-section depreciation of fixed asset to four major phenomena: *exhaustion*, *deterioration*, and *embodied and disembodied obsolescence*. Virtually all researchers discussing depreciation agree in their views concerning the impacts of exhaustion and deterioration on the asset value; as opposed to this, the effects of *embodied and disembodied obsolescence* on the asset value constitute a widely discussed issue in academic literature on depreciation, and therefore these are not always taken into account in the calculation of the cross-section depreciation rate, which also results in distorted finance and income figures, and impacts on the pricing of the company output. Therefore, my Hypotheses 3 and 4 relate to the recognition of the phenomena of *embodied and disembodied obsolescence* in cross-section depreciation:

H3: Age has more explanatory power than mileage in the cross-section depreciation of used passenger cars of the same category.

H4: Among used passenger cars of the same category and with identical mileages, the value of older specimens is inferior to the value of younger specimens.

Scope of the research

I will analyse the hypotheses using *quantitative research methods*, on the basis of information from the second-hand car market. As cars do not have a transparent market which would make it possible to observe both the characteristics of the cars and the strike prices, I will conduct my research by observing the market supply of second-hand cars. The second-hand car market supply is available through numerous online selling portals, the individual supplies of which may be contracted using a procedure called ‘crawling’. Considering the opinions of several professional players of the second-hand passenger car market, I will use the Belgian car supply for the purpose of my study, for it is the market where it is the less probable that the mileage of the cars should be manipulated. Lack of manipulation is a very important factor in the present research because *I consider mileage as an independent variable expressing the exhaustion and deterioration of the cars*. For the testing of my hypotheses, I will use the supply data of one of the major Belgian selling sites, www.autoscout24.be, using the entire supply of the portal as of 1 March 2011. The entire supply consists of 75 614 observation units, i.e. cars of different ages and mileages offered for sale: this will serve as a basis for the creation of the database used for the verification of the hypotheses.

It is necessary for the examination of hypothesis that the assets of different ages should be perfectly replaceable between themselves: this means that I need to limit my observation to cars using the same kind of fuel. Therefore I will only use the sample of diesel-powered passenger cars - amounting to a sample of 43 114 items over the entire database - to test my hypotheses.[7] In the observations, ‘market price’ does not signify strike price but supply price. In my research, however, I assume that the surplus manifested in the supply prices as compared to the realised strike prices is constant for all vintages and does not affect the validity of the research conclusions.

After preparation and use the method of clustering I practised the following methodes of the items

[7] For an analysis of a sample of gasoline-powered cars, see *Kaliczka* [2012].

3 The issues of the dissertation

Verification of H1 and H2

I used the *Box-Cox* transformation by *Hulten and Wykoff* [1981a] for the verification of hypotheses H1 and H2, as the flexibility of the function shape it yields makes it possible to identify the most current shapes of cross-section depreciation function (*geometric, linear, 'one-hoss shay'*, as described in the dissertation).

The Box-Cox transformation used to identify the shape of the cross-section depreciation function shall be a specifically transformed version of the linear regression function, i.e.:

$$\text{(12)} \qquad \frac{Y^{\lambda_1}-1}{\lambda_1} = \alpha + \beta\frac{X^{\lambda_2}-1}{\lambda_2} + u.$$

It may be demonstrated that if $\lambda_1, \lambda_2 \to 0$, then the model is simplified to the log-log form $\ln Y = \alpha + \beta \ln X + u$. If $\lambda_1 = \lambda_2 = 1$ we obtain the linear form $Y - 1 = \alpha + \beta(X-1) + u$, whereas if $\lambda_1 \to 0$ and $\lambda_2 = 1$ the model gives the semi-logarithmic form $\ln Y = \alpha + \beta(X-1) + u$ (*Ramanathan* [2002]); this *semi-logarithmic function shape is identical with the depreciation function following a geometric pattern*. Therefore, the different values taken by λ make it possible to determine the shape of the depreciation function and, consequently, the depreciation pattern of passenger cars.

The regression equation adjusted for the Box-Cox transformation may be formulated for the analysis of the cross-section depreciation as follows:

$$\text{(13)} \qquad \frac{P_i^{\lambda_1}-1}{\lambda_1} = \alpha + \beta\frac{s_i^{\lambda_2}-1}{\lambda_2} + u_i,\ i = 1, \dots, N,$$

where P designates the supply price and s designates age as an independent variable.

If the independent variable of the analysis is not the age but the mileage of the car, then the regression equation formulated with the Box-Cox transformation shall be:

$$\text{(14)} \qquad \frac{P_i^{\lambda_1}-1}{\lambda_1} = \alpha + \beta\frac{m_i^{\lambda_2}-1}{\lambda_2} + u_i,\ i = 1, \dots, N,$$

where *P* designates the supply price and *m* designates mileage as an independent variable.

Following *Ramanathan*'s [2002] method of determining the definition of λ_1 *and* λ_2 allowing the best covariance I first formulated the following new variables from the dependent and independent elements of equations (13)- and (14): $P_i^* = \frac{P_i^{\lambda_1}-1}{\lambda_1}$, $s_i^* = \frac{s_i^{\lambda_2}-1}{\lambda_2}$, $m_i^* = \frac{m_i^{\lambda_2}-1}{\lambda_2}$.

Subsequently, I identified the values of λ_1 *and* λ_2 which yield a minimal sum of squares for the residua of linear regressions (15) and (16) i.e. which show the best covariance.

$$\text{(15)} \qquad P_i^* = \alpha + \beta s_i^* + u_i,\ i = 1, \dots, N$$

(16) $P_i^* = \alpha + \beta m_i^* + u_i,\ i = 1, \dots, N$

The following table summarises, broken down to clusters, the values of λ_1 and λ_2 thus obtained.

Cluster	*Cluster centre (kilowatt)*	*Independent variable*	λ_1	λ_2	*ß*	α	R^2
1.	99	*Age*	0.000	0.766	-0.240	10.191	0.619
		Mileage	0.000	0.826	0.000	10.268	0.507
2.	147	*Age*	0.000	0.800	-0.229	10.722	0.624
		Mileage	0.000	0.783	0.000	10.815	0.458
3.	217	*Age*	0.000	0.658	-0.303	11.086	0.822
		Mileage	0.000	0.761	0.000	11.193	0.677
4.	65	*Age*	0.000	0.756	-0.244	9.698	0.687
		Mileage	0.000	0.863	0.000	9.761	0.543

Table 1: Estimated parameters of the Box-Cox transformation. (Source: own elaboration)

Table clearly shows that the values of λ_1 are quite close to zero for both age and mileage, and the values of λ_2 approximate 1. This shows that the depreciation function of cars is semi-logarithmic in respect of both age and mileage, which means that ***the depreciation function follows a geometric pattern in both cases. Based on this fact, I accept hypotheses H1 and H2.***

The effective cross-section depreciation of fixed assets therefore follows a geometric sequence pattern both in respect of age and of the physical performance variable.

The identification of the geometric sequence pattern is a prominently important finding because in Hungarian accounting practice, asset depreciation is typically determined using the linear cost allocation model, which entails - in the light of my present empirical research results - that through the use of the linear cost allocation method, cars become overvalued in the balance sheet. *It also follows from the above facts that the depreciation write-offs corresponding to the individual periods are overestimated in the initial periods and underestimated in the later periods. This distorts the image of the company's income situation and (through the allocated depreciation) the unit cost of the company output, which affects the competitiveness of the company on the commodity and capital markets.*

The decrease in the value of used cars is halted, in each cluster, sometime about the age of 25 years, and subsequently an increase follows, due, presumably, to the fact that the cars in question reach veteran status. However, this so-called 'veteran effect' is not asserted in the case of the same cluster plotted against mileage, which shows that the veteran effect is characteristic of cars older than 25 years but with comparatively low mileages.

Verification of H3

As the results of the Box-Cox transformation show that the depreciation function of the examined cars is semi-logarithmic and follows a geometric pattern, therefore by logarithmising the supply prices, the depreciation function may also be expressed as follows:

$$(17) \qquad \ln P_i = \alpha + \beta s_i + u_i,\ i = 1, \dots, N$$

By logarithmising prices, I have therefore defined a new variable $\ln P_i$ for the regression. I ran the regression by clusters, including the independent variables of age and mileage. Reviewing the descriptive statistics, it appears that the relative deviation of the variables does not exceed 2 in either of the clusters; this means that they are not excessively heterogeneous, and may thus be involved in the model. The correlation matrices show that the independent variables of age and mileage strongly correlate with the logarithmised price variable. We also see a strong correlation between the independent variables of age and mileage in each cluster; this multicollinearity evidently follows from the nature of the variables. In all four clusters, the first variable to enter the regression is age, and no variable exits it in either of the clusters. The value of R^2 only weakly improves with the entry of the mileage variable in the case of clusters 1 and 4 with a higher number of elements: this is a consequence of the strong multicollinearity between the independent variables. In the case of clusters 2 and 3 containing less elements, the multicollinearity between the independent variables is weaker; here the value of R^2 improves by 0.1 with the entry of the mileage variable.

The following table shows the values obtained as a result of the calculation of regression as defined in equation (17) for the individual clusters, with age as the only independent variable.

Cluster	*Cluster centre (kilowatt)*	α	*ß*	R^2
1.	99	10.228	-0.155	0.614
2.	147	10.641	-0.126	0.526
3.	217	10.946	-0.131	0.690
4.	65	9.650	-0.141	0.650

Table 2: Values of the regression based on the variable ‘age’. (Source: own elaboration)

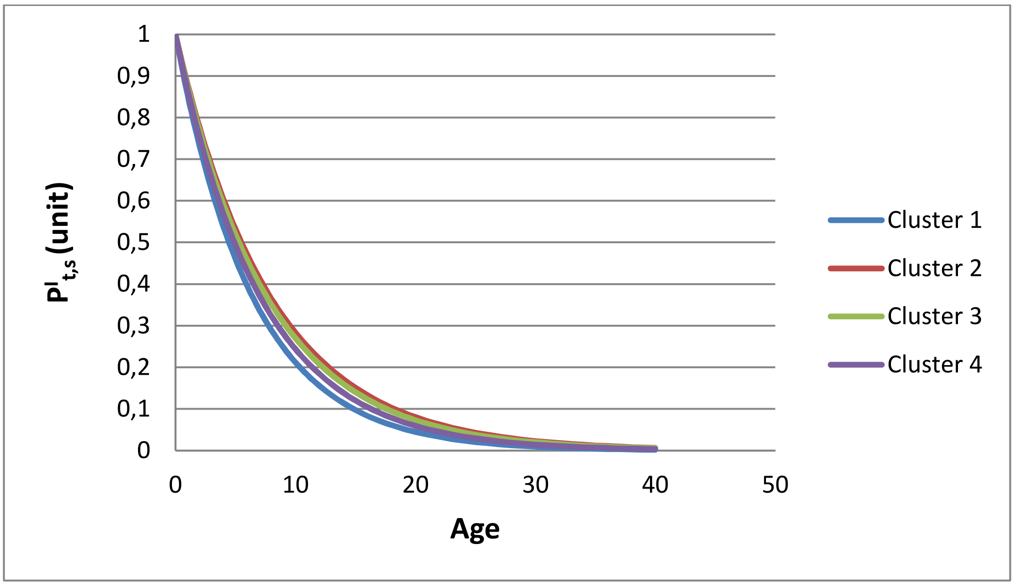
It is therefore clear that the covariance of the regression function is nearly identical with the covariance of the equation determined using the Box-Cox transformation as shown in Table 1.

The histogram of the standardised residuals shows a quasi normal distribution for the four clusters. In the normal probability plot, the points sometimes deviate from the 45° straight line, but there are no major deviations: this shows that the results of the regressions run are suitable for the verification of the hypotheses.

The results show that the independent variable of age has a higher explanatory power than mileage in each cluster; therefore, based on the above results, I accept hypothesis H3.

It seems demonstrated, therefore, that whereas the physical performance variable of fixed assets as such only comports the phenomena of exhaustion and deterioration, the age of passenger cars also incorporates the phenomenon of obsolescence, in addition to exhaustion and average deterioration. Consequently, the calculated value of depreciation will be more precise if the age of the asset is taken into account in the calculation.

The following graph presents the value functions determined for the individual clusters using the computed depreciation rates for a period of 40 years.



Graph 4: Depreciation patterns computed for the individual clusters (Source: own elaboration)

The graph shows that the estimated depreciation of the examined cars follows a geometric sequence pattern, shaped - according to theory - by the exhaustion, deterioration and obsolescence of the cars.

Verification of H4

To verify hypothesis H4 I used the *'hedonic' method* parting from the assumption that the supply price of the examined cars is a result of the characteristics of the individual cars, these characteristics being in the present case *the exhaustion and deterioration resulting from use, and the embodied and disembodied obsolescence resulting from the technological progress*. I constructed the hedonic method used for the testing of hypothesis H4 by classifying the observation units in the individual clusters into 10 groups on the basis of the deciles of the 'mileage' variable, with the result that the observation units belonging to the individual groups would have approximately similar mileages. Subsequently, I defined a new variable from the quotient of the age and the mileage, denoted by '*age/mileage*'. In the case of new cars, I changed the value of mileage from 0 to 1 so as to be able to perform the division for the calculation of the 'age/mileage' variable. Next, I divided the observation units into another three groups on the basis of the 33rd and 66th percentiles of the 'age/mileage' variable, assigning the units with low age/km values to Group 1 and those with high age/mileage values to Group 3. If the value of the 'age/mileage' variable is low, it means that it took a comparatively short time for the given car to perform a distance of a kilometre; if this value is high, then the car took longer to run the same distance. Subsequently I computed the difference of the average prices of Groups 1 and 3 constituted on the basis of the variable 'age/mileage' for each of the 10 mileage groups, in order to be able to say whether among cars with the same mileage, the price of the older cars contains the negative premium due to obsolescence.

Percentiles according to mileage	*Negative premiums by clusters (EUR)*			
	1.	*2.*	*3.*	*4.*
1.	-14861.2	-	-	-1442.2
2.	-5541.3	-11722.2	-9930.8	-2812.0
3.	-6122.6	-14635.8	-33893.6	-3157.0
4.	-6089.6	-8659.2	-24033.7	-3524.0
5.	-5346.6	-10790.5	-23959.9	-3728.8
6.	-5778.8	-11687.9	-17208.8	-4034.3
7.	-5688.9	-9021.8	-16387.5	-4225.3
8.	-5641.0	-11680.0	-18092.0	-3747.5
9.	-4565.5	-12914.2	-13849.0	-2615.3
10.	-3691.5	-7118.0	-6933.3	-1098.6

Table 3: Negative premiums in the individual clusters, broken down by clusters. (Source: own elaboration)

Table 3 clearly shows that in almost each of the groups created on the basis of mileage, a negative premium may be identified in the supply prices of the older cars, which I attribute to the effect of obsolescence. Clusters 2 and 3 did not contain any observation units belonging to Group 1 (among the groups constituted on the basis of the 'age/mileage' variable), probably due to the small number of elements in these clusters.

To demonstrate the existence of the identified negative premium, I also performed a paired t-test on the whole database. The subject of the paired t-test were the supply prices of the observation units in Groups 1 and 3 of the database broken down into three groups based on the 33rd and 66th percentiles of the 'age/mileage' variable. The results of the paired t-test are presented in *Annex 2*. The results clearly show that the value of the F-test is significant, therefore the null hypothesis for the F-test needs to be rejected; the variances of the supply prices of the cars belonging to Groups 1 and 3 are different, which means that the results of the Welch's t-test should be considered as relevant. The results of the Welch's t-test are significant: therefore, by rejecting the null hypothesis, I have demonstrated that the averages of the supply prices of the cars belonging to Groups 1 and 3 are not identical.

Based on the results of the hedonic method and of the paired t-test, I accept hypothesis H4.

Therefore, the depreciation of fixed assets is affected by the embodied and disembodied obsolescence of the services of the asset, in addition to its exhaustion and deterioration; consequently, it is necessary to take these phenomena into account in the calculation of fixed asset depreciation.

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