An Empirical Investigation of Paradoxes
(Reswitching and Reverse Capital Deepening)
in Capital Theory

First version. Comments welcome

September 2003

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Summary This paper examines the empirical relevance of the capital controversy between the proponents of the classical and of the neoclassical paradigm in economics. Aggregate capital at the macroeconomic level is regarded as the sum of capital goods employed, measured in terms of normal prices. Hence the price model of Sraffa (1960) and the dual models of the price and quantity systems of von Neumann (1937) become the basis of the investigation. The capital controversy is concerned with consequence of the choice of the cost minimizing technique in the production system for the relationship between distribution and the value of capital. *Theoretical* examples are easily constructed which contradict the fundamental neoclassical hypothesis of an inverse relationship between the rate of profit and the intensity of capital. This paper for the first time presents *empirical* examples. To this end, the quantity system of the von Neumann model is here used to model spectra of techniques, or books of blueprints. 32 input-output tables from 9 countries of the OECD input-output data base serve as data. One input-output table represents one technique (production system). A spectrum of technique, or book of blueprints, consists of two input-output tables from the OECD data base. A technique is chosen by selecting one out of two activities in each of the 36 sectors (each book of blueprints consists of 2^{36} techniques). The linear programming of the quantity system yields $496 = 32 \cdot \frac{31}{2}$ envelopes as choice of technique. Among these, one envelope is found which involves reswitching, considering a subset of the envelopes, and reverse capital deepening is observed in about 11.3 % of these cases.

This seems to confirm the empirical relevance of capital deepening which has been controversial for almost 40 years. From the neoclassical point of view, the presence of these phenomena is „perverse“ and a serious reason to question the validity of the theory.

1. Paradoxes of capital theory

The classical paradigm in economics has influenced modern economic theory since Adam Smith and, although it was pushed into the background in the course of the so-called “marginalistic revolution" at the end of the nineteenth century, it has reached its elaborate, formally self-closed form in the twentieth century. Its modernization and its resuscitation has been carried out by many economists, but it was primarily stimulated by Sraffa (1960). The ensuing debates between classical and neoclassical positions centred mainly on capital theory (the so-called "capital controversy" or "Cambridge-Cambridge controversy").

Central issues in the capital controversy were the phenomena of "reverse capital deepening" and of "reswitching", both at the theoretical and at the empirical level. Both may result from the choice of techniques in self-reproducing linear production systems as in Sraffa (1960). "Capital" here are the commodities used as means of production and valued at normal prices, according to the formula

$$(1+r)\mathbf{A}\mathbf{p}+w\mathbf{l}=\mathbf{p}, \tag{1}$$

where ***A*** is a productive indecomposable input matrix, ***p*** the price vector, ***l*** the labour (input) vector, *r* the rate of interest (here identical to the rate of profit and *w* the wage rate).

From the equation system (1), we can derive the wage frontier, i.e. the wage rate (and prices) expressed in terms of some numéraire. Each wage frontier or wage curve represents a technique. If more than one technique are available, the problem of technical choice arises. The techniques on the envelope of the wage curves are most profitable according to several criteria (Schefold 1997, pp. 30-33). The wage curves will be monotonically falling.

1.1. The Surrogate Production Function and Reswitching

Suppose a spectrum of techniques $\mathbf{A}^{(i)},\mathbf{l}^{(i)}$; $i=1,\ldots,s$; is given, with wage curves $w^{(i)}(r)$. Each technique produces net output $\mathbf{d}$ at activity levels $\mathbf{q}^{(i)}$: $\mathbf{d}=\mathbf{q}^{(i)}(\mathbf{I}-\mathbf{A}^{(i)})$, and $\mathbf{d}$ is also the standard of prices. If the wage curves could all be linear as in Figure 1, their slopes would measure the intensity of capital k_i in a stationary state, since net output per head $y^{(i)}=w^{(i)}+rk_i$, hence $k_i=(y^{(i)}-w^{(i)})/r$, and the wage curves which became eligible successively at higher r would show a uniform diminution of the corresponding intensities of capital. This construction (surrogate production function, proposed by Samuelson 1962) would allow a rigorous construction of neoclassical production functions, as *s* tended to infinity (Schefold 1989, p. 297-298), if the assumptions were tenable.

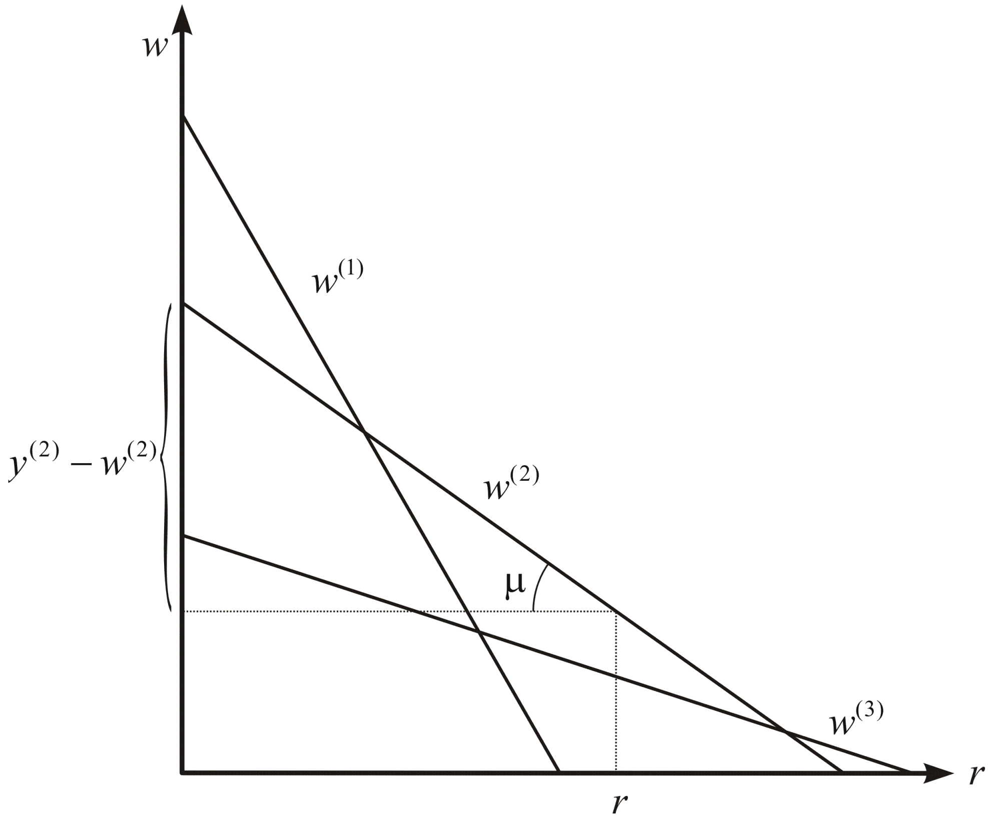

Figure 1: Surrogate production function. The tangent of μ is equal to the intensity of capital of technique 2.

However, simple numerical examples suffice to show that the wage curves are not straight lines – as a matter of fact, straight wage curves are flukes, see Schefold (1976).

Reswitching occurs, if a same technique is chosen in two intervals of the rate of profit, while some other technique(s) are chosen in an interval in between (figure 2). Reswitching contradicts the neoclassical postulate that techniques with lower intensities of capital become eligible at higher rates of profit (for the measurement of the intensity of capital along the wage curve see fig. 2). This critique is relevant not only for the aggregate versions of neoclassical theory but also for intertemporal general equilibrium: reswitching and related phenomena do not contradict the existence of intertemporal equilibria with production, but lead to questioning their stability (Schefold 2000).

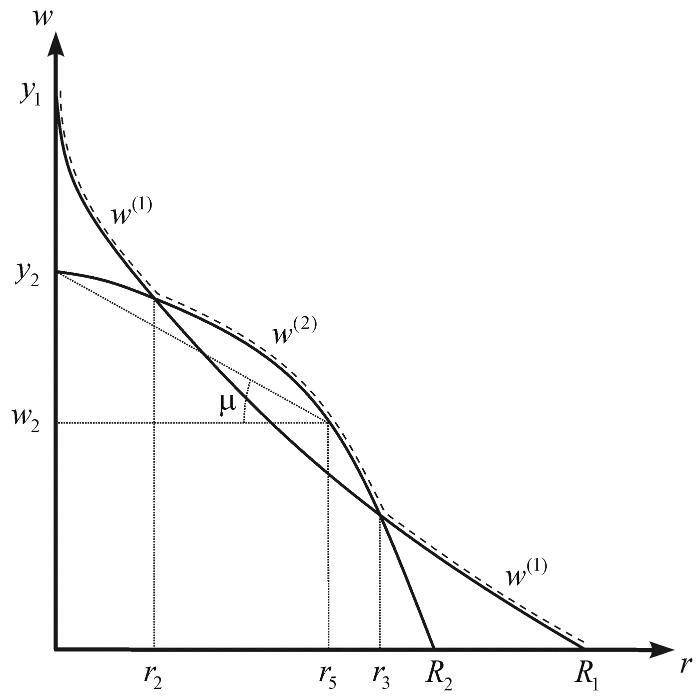

Figure 2: Reswitching: one technique, $w^{(1)}$, returns at r_3 after being dominated by $w^{(2)}$ between r_2 and r_3. The tangent of μ is equal to the intensity of capital k_2 of technique 2 at r_5 in the stationary state, for $y_2 = w_2 + r_5 k_2$. The intensity of capital rises discontinuously as r rises from below r_3 to above r_3.

1.2. Reverse capital deepening

A variety of phenomena results if there are several nonlinear wage curves. The nonlinearity makes it possible for wage frontiers to intersect more than once, so that we get the possibility of multiple switching. A debate on the impossibility of the so-called "surrogate production function" was carried on in the *Quarterly Journal of Economics*, 1966, in a Symposium on paradoxes of capital theory.

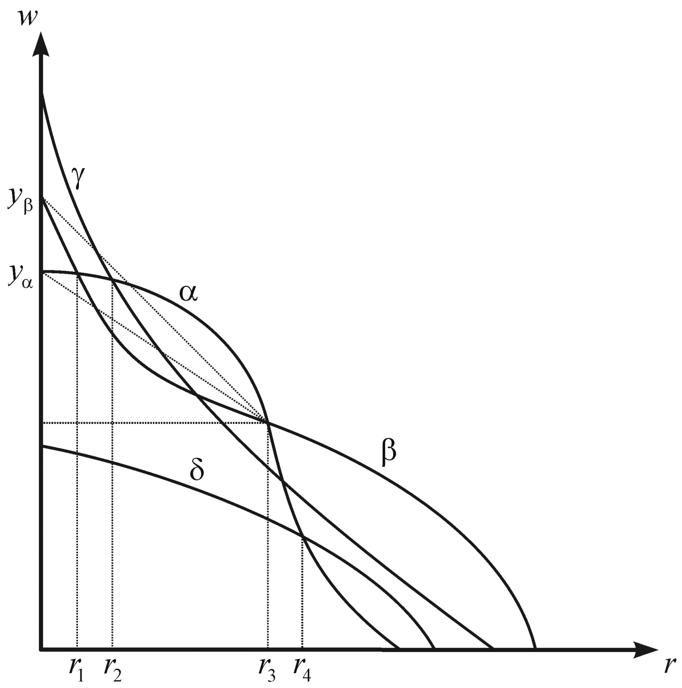

Figure 3: Reverse capital deepening

According to the neoclassical doctrine[1], the substitution should always 'deepen' the intensity of capital, whenever the wage rate w increases relatively to the rate of profit r. Reverse capital occurs, if the exact opposite takes place: A rise in the rate of profit r leads to the adoption of a more capital intensive technique. In this case, it is again not generally possible to order "efficient" techniques in such as way that k becomes a monotonically falling function of the rate of profit. Figure 3 demonstrates that the intensity of capital may rise at r_3 in passing from technique α to β although no reswitching takes place on the envelope (the intersection of α and β at r_1 is not 'visible' on the envelope because of the dominance of technique γ up to $r_2 > r_1$).

There is a 'rapid succession of switches' (Sraffa 1960, p. 85) along the envelope, for if there are e.g. 10.000 commodities in an economy and each can be produced by at least 2 methods, there will be $2^{10000} > 10^{3000}$ wage curves. Yet it can be shown for single product systems that the methods generically are replaced only one at time at each switchpoint: at a switchpoint at some $\bar{r}$ on the envelope, such as r_2 or r_3 in fig. 3, only one method is employed in each industry of the two systems which coexist at equal prices at $\bar{r}$, and in only one of the industries two methods will coexist (Schefold 1989, pp. 178-181; Schefold 1997, pp. 124-126). The same must be true at another intersection of the same two wage curves, even if it is below the envelope: If wage curves α and β intersect at r_3 on the envelope of fig. 3, the corresponding systems differ only with regard to the use of the methods used in one industry, and this will be true also for the intersection of α and β at r_1 below the envelope, where prices of α and β again will be equal. But no such statement can be made regarding other intersections of wage curves below the envelope, such as the one between γ and δ at r_4: in such a case, several, even all methods may be different in the industries of the corresponding two systems. We call a change of technique piecemeal, if, as on the envelope of single product systems, methods generically change only one by one. Whether the actual change of technique is piecemeal is also an empirical question examined below.

Capital theory in single product systems is concerned with the question whether the piecemeal change of techniques, as the rate of profit rises, is associated with a (in switch points) discontinuous monotonic fall of the intensity of capital. Reswitching and reverse capital deepening prove that this monotonicity is not a theoretical necessity. Reverse capital deepening is a necessary consequence of reswitching, but reswitching is not necessary for reverse capital deepening – a second intersection of the wage curves which necessarily exists in the case of reverse capital deepening at a lower rate of profit (such as the intersection at r_1 in fig. 3) is below the envelope. Clearly, reverse capital deepening is the relevant phenomenon in the capital controversy since it is more general, and one feels intuitively that it must be more frequent.[2] Yet in the past reswitching seems to have interested economists more than reverse capital deepening, so that the impression has been created that reswitching is crucial for the capital controversy. For example Stiglitz (1973) formulated conditions under which reswitching is ruled out; Krelle (1976) tried to test the empirical relevance of reswitching with German data and found no instance of reswitching. So it was argued that the neoclassical doctrine could be defended after all.

[1] Samuelson (1962) emphasized the stylized character of the argument by speaking of a "parable".

[2] It is important to note that reverse capital deepening at switch points is independent of the numéraire and is not related to Wicksell effects, since the comparison is made at a given wage rate.

2. Models of empirical investigation of the paradoxes

Schefold (1976) showed that the mathematical probability of reswitching is larger than zero.[3] But even neoclassical economists who accepted the logical possibility of reswitching phenomenon and its theoretical consequence have raised doubts as to its empirical relevance, see Bruno, Burmeister and Sheshinski (1966); Samuelson (1966); Ferguson (1969). A recent survey of the aggregation problem for neoclassical production functions is Felipe and Fisher 2003).

Some economists have tried to test the positive probability of reswitching: Sekerka, Kyn and Hejl (1970; Czechoslovakia), Krelle (1976; Germany), Ochoa (1987; USA), Hamilton (1986; Korea), Özol (1984; USA), Cekota (1988; Canada), Petrovic (1991; Yugoslavia) and Silva (1991; Brazil) derived wage frontiers from input-output-tables and reported that no indication of reswitching was found. Mark Blaug argues for this reason in an online discussion at the HES network (History of Economics Society; www.eh.net/HE/HisEcSoc) in July 2001: "…any attempt to bypass the reswitching conundrum by purely theoretical arguments must obviously fail. The only argument, as I have endlessly but fruitlessly contended, is an empirical one: no one has ever shown that reswitching actually occurs in any even quasi-realistic model. The analogy with positively sloped demand curves is perfect!"[4] It seems therefore to be appropriate to clarify the empirical relevance of the paradoxes (including reswitching), although some economists argue that the empirical relevance of the capital controversy should be separated from the logical and inner consistency of the economic theory which the capital controversy questions, see Helmedag (1986); Kalmbach and Kurz (1986).

2.1. Derivation of the envelope

The authors of the empirical investigations meant that they had investigated the choice of technique on the relevant "envelopes". However, they did not succeed in deriving those envelopes correctly so that their conclusion missed the target. The following simple example with two sectors will clarify this.

[3] For the more recent discussion on the likelihood of reswitching see section 4.3 below.
[4] www.eh.net/lists/archives/hes/jun-2001/0025.php.

We suppose that two input-output-tables are available for the technical choice, namely 1980 and 1990. Each input-output-table has only two sectors, I and II. Let the symbol [*i*, *j*] represent a wage frontier which engages the production process for the sector I from input-output-table *i* and the production process for the sector II from input-output-table *j*. The principle followed in the conventional studies referred to above corresponds here to the construction of the envelopes from two wage frontiers, namely [1980,1980] and [1990,1990] (see figure 3). The other technique is still profitable at low wages, as traditional theories predict.

However the real envelope consists of *four* wage frontiers, that is [1980,1980], [1980,1990], [1990,1980] and [1990,1990]. For if the analysis is meant to represent a choice of technique (if there was no choice there would only be one wage curve), taking place in 1990, the composition of the technology of 1980 can still be remembered and could be used in 1990. But if this is true for the methods employed in both sectors, it must also be true for those methods individually. The decision to construct a modern motor-car today according to the standard of 2000 is a decision not to construct a horse-drawn carriage according to the standard of 1880 (which is still known). So the envelope looks as in figure 5. And it will be seen that the example of figure 5, with reverse capital deepening taking place in the transition from technique [1990,1980] to technique [1980,1980] while there is only one switch between technique [1980,1980] and [1990,1990], is not fanciful. Attempts to test the paradoxes on the basis of an "envelope" as in figure 4 are inconclusive.

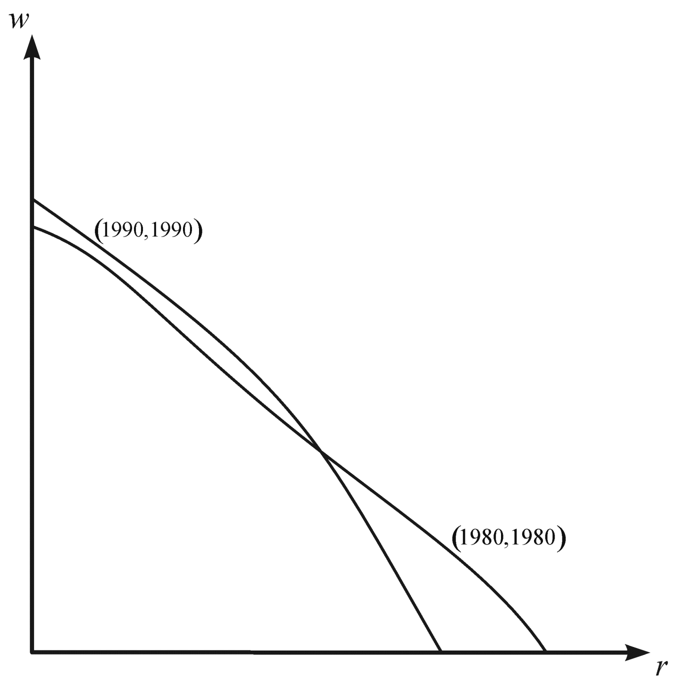

Figure 4: conventional „envelope“

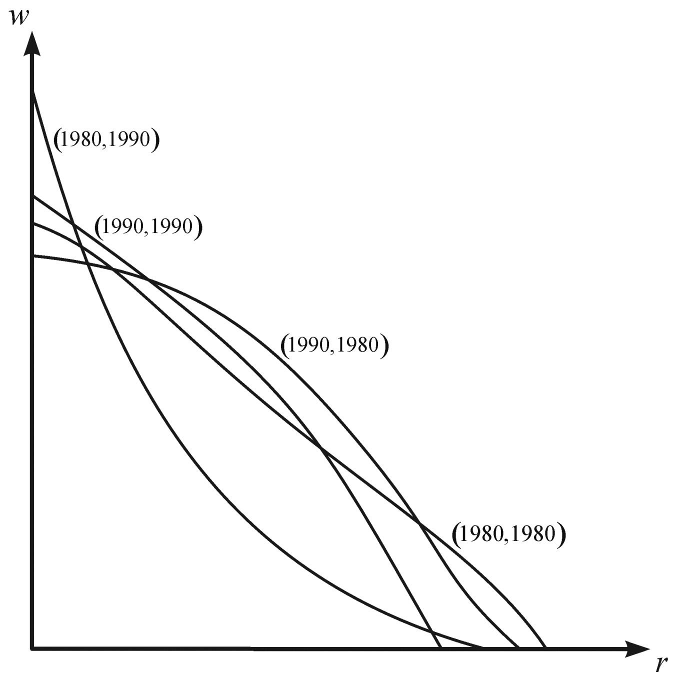

Figure 5: real envelope

2.2. Von Neumann model

The way to derive the envelope from the wage frontiers as in figure 5 has a practical limit, however, if the available input-output-tables have many sectors. We must construct 2^n wage frontiers for the case that two input-output-tables have n sectors respectively. If we have three input-output-tables available for the technical choice, the number of wage frontiers to be formed rises to 3^n.

We therefore use linear programming as an alternative method to construct the envelope; one can show that the same envelope results as according to Sraffa's method (1). This procedure can also be related to the model of von Neumann (1937). Several studies show the formal equivalence of Sraffa's model and that by von Neumann for the case of single product systems; for production systems with fixed capital and for joint production, see Steedman (1976); Schefold (1980); Salvadori (1982); Kurz and Salvadori (1995).

Consider the following programme and its dual:

$$Min\ \mathbf{ql}\ S.T.\ \mathbf{q}(\mathbf{B}-(1+r)\mathbf{A}) \geqq \mathbf{d}, \mathbf{q} \geqq \mathbf{o}, \quad (2)$$

$$Max\ \mathbf{dp}\ S.T.\ (\mathbf{B}-(1+r)\mathbf{A})\mathbf{p} \leqq \mathbf{l}, \mathbf{p} \geqq \mathbf{o}, \quad (3)$$

where the rows of $(\mathbf{A},\mathbf{B},\mathbf{l})$ denote the methods available in the book of blueprints or spectrum of techniques, where the goods are in the columns of **A** (inputs) and **B** (outputs) and where joint production is admitted. According to the usual economic interpretation, the solution describes a steady state golden rule path, at a rate of profit equal to *r* equal to the rate of growth, where a net output vector **d** is produced or overproduced (overproduced goods receive zero prices) and where the normal rate of profit *r* is not exceeded (less profitable activities are not used). It can then be shown under simple and general assumptions (especially regarding the productivity of the system) that solutions exist for all *r* between zero and a finite maximum (Schefold 1978). Prices are here prices in terms of the wage rate ($w=1$), hence, with $\mathbf{dp}=\mathbf{ql}$ by virtue of duality, $1/\mathbf{ql}$ is the real wage; under suitable regularity assumptions, $1/\mathbf{ql}$ will fall continuously and strictly monotonically from $r=0$ to a maximal $r=R$. In essence, one then finds, except in a number of critical points, that the solution to the linear programme is 'square' (the number of positive prices in the solution is equal to the number of activities used), and the solution is a superposition of 'square' solutions in the critical points (Schefold 1997, 128). The solutions can therefore be regarded as subsystems $(\overline{\mathbf{A}},\overline{\mathbf{B}},\overline{\mathbf{l}})$ (so-called truncations) of $\mathbf{A},\mathbf{B},\mathbf{l}$. The commodities in the subsystem have prices forming a truncated price vector $\overline{\mathbf{p}}$ with

$$(1+r)\overline{\mathbf{A}}\overline{\mathbf{p}}+\overline{\mathbf{l}}=\overline{\mathbf{p}}, \tag{4}$$

and if the corresponding truncated vector $\overline{\mathbf{d}}$ of **d** is the standard of the real wage of the truncation,

$$\overline{w}(r)=1/\overline{\mathbf{d}}\overline{\mathbf{p}} \tag{5}$$

is the wage curve of the truncation. The point is that the envelope of the wage curves (5) of the truncations of $(\mathbf{A},\mathbf{B},\mathbf{l})$ is the solution to the programme (2) and (3).

In our case, with single production, the rows of **B** consist of unit vectors. The envelope is calculated using (2), formally the minimization of the labour requirement to produce net output at rate of growth r. But the economic interpretation is based on the theoretical result embodied in (4): except at critical points (where wage curves intersect on the envelope), the solution yields a (square) single product system with positive prices at rate of profit r. In the case of joint production, one cannot be sure that a truncation which appears with positive prices on the envelope at r will still have positive prices at some $r'\neq r$, and the solution will crucially depend on the composition of $\mathbf{d}$. But, with single product systems, well-known theorems ensure that the solution does not depend on the composition of $\mathbf{d}$, and prices will remain positive, if r is lowered to zero or raised to the maximum rate of profit of the system (all input matrices are here assumed to be indecomposable).

To summarise: We assume a spectrum of techniques such that each technique is a productive indecomposable Sraffa system with a wage curve that is monotonically falling. The most profitable technique is chosen at each rate of profit by adopting the system with the highest real wage, hence it is found on the envelope of all the wage curves resulting from the spectrum. Exactly the same envelope is also obtained by solving (2). Hence there is a formal equivalence between a 'Sraffa-approach' and a 'von Neumann-approach'(von Neumann, 1937); their conceptual difference (Schefold 1980) does not concern us here.

3. Methodical problems in empirical modelling

3.1. Alternative techniques at various times and places

Strictly speaking, the available spectrum should be defined for a given time and place. Kurz and Salvadori (1995, p.450) reject the recent empirical studies (national comparisons of the input output tables) because they refer to different times. But all methods in a book of blueprints (except for those actually realised) are removed to some extent from actual realisation, yet their costs are compared with those of actual methods. The prospects for using future 'potential' methods (like the costs of extracting oil from oil sands) influence present decisions (like where to extract oil, i.e. at what cost). Methods used in the past are probably better known than those conceived for the future. Therefore one starts out from the assumption that the time series of the input output tables of a national economy represent also alternative techniques: in a backward-looking perspective. What is used today, can be used tomorrow, and what was used yesterday, might be used again, and more easily in most cases than what we plan for the future.

One expects productivity and wages to rise with time. Hence one might expect that older methods would be profitable today if wages were lower, hence one might expect old techniques to appear still at high rates of profit on the envelope. In particular one expects that old machines could still be used if wages were lower (repair work cheaper). It has been shown (in analogy with reswitching) that this hypothesis is not generally correct in fixed capital models (Schefold 1997, pp. 229-231). But the very consideration of the problem shows that the comparison of present with past techniques is, contrary to Kurz and Salvadori, a standard procedure.

This paper proposes to compare techniques internationally, too. The comparison of techniques in different time periods and that of technologies from different countries are analogous. The observed technology (input output table) of a national economy represents the realized technology for the country at the given distribution (w and r), in a given economic condition, defined by international economic opportunities and national institutions. In another economic and historical constellation, another technique would be chosen, and the techniques of other countries offer such alternatives. The assumption that the technique in use of country A is in the book of blueprints of country B is easy to defend from a theoretical point of view: This paper attempts to prove that the paradoxes of capital are empirically relevant and that the empirical applicability of neoclassical theory therefore is in question. Neoclassical authors often adopt the assumption in empirical work that technology is internationally transferable (between developed countries), and they formalize the assumption by assuming that the production function (i.e. the book of blueprints ordered according to neoclassical principles) is the same for all countries. Does this assumption not mean, *at least*, that single methods actually realized in one country could be regarded as potential methods in another?

It is true that the transfer of methods of production does not always take place where one might expect it, given similar opportunities and institutions. In the discussion about the so-called 'intra-industry trade', various cases have been analyzed in which two countries, despite identical books of blueprints, realize different techniques: because of incomplete competition in connection with the so-called QWERTY theory or theory of 'strategic complementarity', or because of location problems in connection with increasing returns to scale, so that slightly different goods are produced and traded within a product group (or in a 'homogeneous' sector) by two economies, see Krugman (1987). The theory of 'bounded rationality' could also contribute to the explanation why one technology, which is often neither significantly technically better nor lower in price, is realized for no rational reasons instead of many other technical alternatives (see for example Simon 1982). Countries are thus more dissimilar than standard theory assumes. Nevertheless, the hypothesis that distribution and prices govern the choice of techniques and therefore also the international transfer of techniques is shared not only by neoclassical economists. Hence the assumption is made, and the task is to ascertain whether the presumed relation between the prices of factors (rate of profit) and their employment (intensity of capital) is empirically valid.

3.2. Data

Even though input-output-tables have been set up all over the world since Leontief (1953), they were not solidly comparable internationally till recently, in particular because the industry structures of the respective countries are not identical. Moreover, each country adopted a different method of compilation, and some efforts to unify at least the criteria for compilation were not successful, in spite of the importance of input-output statistics both in national accounts and in economic analysis. Really comparable input-output-tables were not published until the late 1990s, when the OECD input-output-table databank[5] or European input-output-tables from the EUROSTAT became available.

We use 32 OECD input-output-tables with 36 sectors from 9 countries, referring to the periods from 1968 till 1990. This databank is suited both for national comparisons in time series and for international comparisons. All tables have 36 sectors from ISIC (International Standard Industrial Classification), version 2. This establishes a satisfactory base for the comparison of the 32 input-output-tables even though the OECD data in its current form are subject to certain inconsistencies: Some sectors in some countries have not been compiled; basic price indices for compilation are different from country to country; the entries for the public goods sector (sector 31) are zero because of U.S conventions. An improved version of the OECD databank (with ISIC version 3) has been announced.

3.3. Unit of the input output table: monetary or physical?

A technique is specified in a book of blue prints in physical terms, but in practice and as a rule one finds only monetary input output tables in official statistics, that is the input output table expressed in the currency of the country concerned. This is particularly problematic if one is looking for the price system (1) or (3). Pasinetti (1977, p.60) suggests to derive physical coefficients from the input output table by dividing the monetary coefficients by the price index. Petrovic (1991) shows theoretically that the form of an original (physical) wage curve is not influenced, if one introduces monetary coefficients.

[5] www.oecd.org/document/6/0,2340,en_2825_495684_2672966_1_1_1_1,00.html. More detailed descriptions of each country's input-output-tables are given in the *Country Notes* ; http://www.oecd.org/dataoecd/48/43/2673344.pdf.

The price indices are not reported in the OECD input-output-table databank so that Pasinetti's proposal cannot be realized; hence Petrovic's suggestion is followed and the monetary coefficients are used as if they were physical. The same method has been adopted in other empirical investigations, e.g. Krelle (1976), Özol (1984), Hamilton (1986), Cekota (1988).

3.4. The closedness of the price system and international trade

Sraffa's price system (1) assumes a closed national economy, but it may be expanded to represent a 'small' open economy (see Kurz and Salvadori 1995). If a national economy depends on trade, the prices of its products depend on imports. The competition of imports therefore is more complicated than that of exports, compilation-technically as well as price-theoretically. Imports are reported in the OECD input-output-table databank in the category "value added" and exports in the category "total final demand". In addition, matrices of imported intermediate inputs are compiled, but not for all countries. Procedures used to construct the import matrix data vary between countries, but every country in the OECD database more or less makes use of the 'import proportionality' assumption in the construction of their import matrices. It is assumed that each industry uses an import of a particular product in proportion to its total use of that product. For example: If the motor vehicles industry uses steel in its production processes and 10 per cent of all steel is imported, it is assumed that 10 per cent of the steel used by the motor vehicle industry is imported.

If there was no competition for imported goods in domestic markets and if countries imported to a great extent from each other, the compilation of comparable input-output-tables would be impossible. But if imported commodities have domestic competitors in inland markets, the distortion of the price system by imported goods is reduced, and in spite of imports, the input-output-tables are internationally comparable. The theory of 'intra industry trade' focuses on such constellations. The practical conclusion is that imports are priced on the basis of the pricing of domestically produced goods.

3.5. Rank of input matrix A

The technique represented by input matrix **A** with 36 sectors i.e. system (1) as obtained from (2), theoretically should consist of 36 different homogeneous sectors, representing 36 different production processes for 36 different 'commodities'(each in effect being an aggregate). Formally, the rank of matrix **A** should be 36; the production processes should be linearly independent. However, the maximal rank of matrix **A** is 34 in the OECD input-output-table databank; sector 34 '*Producers of government services*', devoted to public goods[6], is added to column '*Government consumption*' in '*Final demand*' and is subsequently set to 0. Sector 36 expresses merely '*Statistical discrepancy*' and does not represent a production process. Sometimes, sector 36 is simply set to 0.[7] Moreover, some countries do not show full entries for all of the first 33 sectors so that the rank of the technique matrix is different from country to country. The calculations inevitably reflect these deficiencies: the prices of 'goods' pertaining to sectors, where all entries vanish, are set equal to zero and the tables below exhibit only the first 'significant' 33 sectors.

3.6. Technical progress and growth

Rapid technical progress can make national input-output-tables of one country, compiled at different dates, incomparable within 20 years, because of the problem of new goods: there was no personal computer or handy 20 years ago. The comparability between countries suffers if the growth rates are very different. Nevertheless, the chosen 9 OECD countries in the input-output-table databank may be considered as relatively homogeneous "industrialized countries" concerning technical development and growth rate (Australia, Canada, Denmark, France, Germany (West), Italy, Japan, UK, USA). Moreover, Vaccara

[6] The formation of prices of public goods must differ from that of private goods. The modern classical theory (Sraffa and von Neumann) is agnostic with regard to the pricing of public goods. Samuelson (1954) analysed the price determination of public goods within the neoclassical framework.

[7] For this reason the sectors 34 and 36 are used to construct the "correction items" together with sector 35, *other producers*, the product of which is not homogeneous between countries. Hence, the sectors 34,35 and 36 go into the solution of linear programming as correction items or for statistical correction, but they are not to be interpreted as "production processes" that are subjected to a choice of the technique. On the other hand, if we got rid of sectors 34,35 and 36, the magnitude of the surplus and hence the maximum rate of profit would be distorted. This interpretation (that sectors 34, 35, 36 are relevant for the magnitude of the surplus but that they do not represent processes) is supported by the fact that some countries show other inputs but no labour input for sector 35.

(1970) shows that the macroeconomic influence of technical progress on the whole economy is expressed in a slow and gradual transformation of the input-output coefficients.

3.7. Joint production and fixed capital

Joint production systems are generalisations from single product systems. Joint production, which is found to be a ubiquitous phenomenon in real economies, changes some properties of wage curves and their envelope in the theory (see Schefold 1989). The input-output tables used here represent single product systems; they are based on statistical procedures that eliminate joint production, primarily through aggregation. The use of input-output tables that include joint production for the derivation of wage curves may become possible in the future.

Fixed capital is regarded as a special case of joint production system in Sraffa (1960), while Leontief (1953) introduces fixed capital as “stocks” in his input-output model in order to analyze the dynamic implications. The advantage of the joint production approach to fixed capital is based on the possibility of treating the old machine leaving a production process as a different good from the one entering it, so that depreciation can be determined simultaneously with prices. This approach is also found in von Neumann (1937)[8], because he remarks that capital goods should appear both in the input and in the output matrix and should be considered as different goods at each stage of their utilization.

One can show that fixed capital systems (where other forms of joint production and the trade of used machines is excluded) behave very much like single product system (see Schefold (1989)), above all, in so far as only the prices of old machines may turn negative. Negative prices signal an inefficiency; old machines with negative prices can be eliminated by means of “truncation” (see Nuti 1973).

Fixed capital could be taken account of in the empirical model by introducing stocks. Suitable data for depreciation and a capital stock matrix (not vector) would be necessary.

[8] Von Neumann (1937, pp. 453-463) repudiates the other representation, sometimes erroneously ascribed to him, of wear and tear as a diminution of the physical stock of fixed capital when he writes (our

Some empirical studies integrated fixed capital, see Krelle (1976); (Petrovic) 1991; Ochoa (1987) on the basis of national data for depreciation and capital stocks. For the purpose of international comparison, we would need data according to unified criteria compiled for depreciation and capital stock matrices for 33 sectors of the countries considered according to the second version of ISIC. Unfortunately, these data are not available in the OECD input-output-table databank, and it probably will remain unavailable in the near future. So we have to be content with single product models.

4. Results

4.1. Empirical procedure

The choice of technique in (2) is carried out by comparing techniques in pairs from the OECD input output data bank.[9] Each sector then has two production processes available. Thus one can represent the 'hypothetical' choice of technique in the sense of the capital controversy on the basis of actual, existing techniques.

The maximum range of the rate of profit, where the choice of technique takes place, should be determined by the maximum rate of profit R of the envelope. This is one of 2^{36} R's from 2^{36} possible techniques. Since it would be too cumbersome to determine this R, the empirical investigation is carried out only up to the smallest maximum rate of profit of all pairs of input-output-table techniques. This never exceeds the maximum rate of profit of the envelope, so we merely explore a part of the whole range of technical choice.

The rates of profit in table 1 increase horizontally in steps of 0.01 (1%) so that a column is assigned to each value of the rate of profit. The result of the choice of technique for a given rate of profit, in other words the selected technique, is positioned in a column, so that each column represents a solution vector **q** of model (2). Rows represent the use of production processes for sectors at different rates of profit. If in table 1 the German production process is chosen (or dominant) for sector 1 in the range of the rate of interest

translation): "Wear and tear of a capital good is to be described by introducing its various stages of wearing down and by ascribing a special P_i [price] to each."

0.62-0.63, the corresponding cells have entries of positive real numbers, namely the intensity levels or gross products[10], while the Canadian production process is not chosen and the cells have entries of zero. A change of the chosen technique implies a switch point on the envelope. However, not the exact location of the switch but only an interval within which the switch point must lie is reported. For example, a switch point for sector 10 in table 1 lies between the rates of profit 0.64 and 0.65.

All pairs of the input-output tables are considered. Each pair is a book of blueprints and yields an envelope. In all, we get $\binom{32}{2}$ = 496 envelopes.

The change of a chosen production process on an envelope is indicated by the change of a cell with a positive real number into a cell with a zero on the row considered. Reswitching means that a change of a chosen production process takes place twice on one row (that is we have two switch points for a sector) *and* that there is no change of method in any other sector between these two switch points.

Since switch points below the envelope were not observable, reverse capital deepening could only be analysed by comparing intensities of capital. If the individual wage curves were available, reverse capital deepening could also simply be observed by asking whether, in passing from one technique given by wage curve $w^{(1)}$ to a wage curve $w^{(2)}$ at a rate of profit $\bar{r}$, one had $w^{(1)}(0) > w^{(2)}(0)$ – this would be a normal switch such as the one at r_2 in fig. 2 – or $w^{(1)}(0) < w^{(2)}(0)$: this could be reverse capital deepening such as the switch at r_3 in fig. 3 or reswitching such as the switch at r_3 in fig. 2. However, the programme only calculates the envelopes. Hence reverse capital deepening between two techniques $(\mathbf{A}^{(1)}, \mathbf{l}^{(1)})$ and $(\mathbf{A}^{(2)}, \mathbf{l}^{(2)})$ had more laboriously to be determined by means of the formula $k^{(i)} = \mathbf{q}^{(i)}\mathbf{A}^{(i)}\mathbf{p}^{(i)} / \mathbf{q}^{(i)}\mathbf{l}^{(i)}$, where $\mathbf{q}^{(i)}$ resulted from the following modification of linear programme (2):

$$Min\, \mathbf{q}^{(i)}\mathbf{l}^{(i)} \; S.T.\, \mathbf{q}^{(i)}(\mathbf{B}^{(i)} - \mathbf{A}^{(i)}) \geqq \mathbf{d}, \mathbf{q}^{(i)} \geqq \mathbf{0}, \qquad (6)$$

[9] MATLAB 5.1 was used for the computing the linear programming. The correctness of computing was tested by EXCEL SOLVER (in EXCEL 97) for important results.

[10] Because of the zero columns of the input-output tables, the solutions of quantity system (2) are degenerate.

amounted to calculating the desired $\mathbf{q}^{(i)}(\mathbf{I}-\mathbf{A}^{(i)})^{-1}\mathbf{l}^{(i)}$, where $\mathbf{I}$ is the unit matrix of order 36. The prices $\mathbf{p}$ at the switchpoint in the formula for $k^{(i)}$ are common to both techniques according to (3), and $(\mathbf{A}^{(i)},\mathbf{l}^{(i)})$ is the technique employed, $i=1,2$. The rates of growth, used to calculate $\mathbf{q}^{(i)}$, were thus assumed to be zero. The comparison of stationary systems at different rates of profit corresponds to the usual procedure in most theoretical expositions of the matter. It is here pragmatically justified by the fact that the actual rates of growth are on average much lower than the rate of profit at which prices are compared.

All envelopes were searched to find examples of reswitching. Only books of blueprints arising from national comparisons of input-output-tables were searched for reverse capital deepening; to analyse the international comparisons as well would have taken too much time.

As a result, one case of reswitching[11] (see table 1) and 8 cases of reverse capital deepening, about 11.3% of the considered switch points, are observed (see table 2 as one example); for details, see Han (2003). Returns of processes are frequent, i.e. it happens frequently that a process is used in two separate intervals of the rate of profit I_1 and I_3, separated by another interval I_2 where it is not used. This is no reswitching, however, unless all other processes in I_1 and I_2 are also the same. Mere returns of processes (i.e. returns of processes not associated with reswitching or reverse capital deepening) are not in conflict with the macroeconomic neoclassical hypothesis of an inverse relationship between the intensity of capital and the ratio of the rate of profit to the wage rate. They do, however, question the meaning of a microeconomic ordering of processes according to capital intensity or the generality of the identification of certain techniques as more labour intensive, more apt for use at low wages, etc.

[11] We observed a “switch point” for the row (sector) 35 between two switch points in row (sector) 10. However, sector 35 is to be treated as a correction sector and not as a production process (see footnote 6).

Choice of technique				1.Switch		Sector 10; Rubber & plastic products				2.Switch
Sector	rate of profit	0.62	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.7
1		3.511252	3.601584	3.696017	3.810631	3.704383	3.795216	3.88984	3.988488	4.066091
2		0	0	0	0	0	0	0	0	0
3		3.411198	3.486491	3.565194	3.633069	3.70899	3.788962	3.872275	3.959135	4.064183
4		0	0	0	0	0	0	0	0	0
5		0	0	0	0	0	0	0	0	0
6		0	0	0	0	0	0	0	0	0
7		0	0	0	0	0	0	0	0	0
8		0.554215	0.55541	0.556657	0.5553	0.546193	0.547076	0.547994	0.548949	0.552075
9		3.158615	3.239866	3.324937	3.371977	2.9816	3.051095	3.123568	3.199201	3.297651
10		0	0	0	2.461271	2.186287	2.226775	2.268783	2.3124	0
11	G	0	0	0	0	0	0	0	0	0
12	E	0	0	0	0	0	0	0	0	0
13	R	0	0	0	0	0	0	0	0	0
14	M	3.076424	3.144464	3.215347	3.25355	2.893329	2.95122	3.011278	3.07363	3.151229
15	A	3.184765	3.234528	3.286298	3.422733	3.113789	3.157558	3.202894	3.249891	3.198739
16	N	0	0	0	0	0	0	0	0	0
17	Y	3.158076	3.213187	3.270484	3.375319	3.139367	3.189939	3.242309	3.296581	3.292294
18		2.058542	2.084339	2.110893	2.136093	2.033621	2.056954	2.080878	2.105419	2.126095
19		0	0	0	0	0	0	0	0	0
20		0.551174	0.552475	0.553837	0.55418	0.541444	0.542317	0.543226	0.544173	0.545542
21	1	2.331731	2.360263	2.389925	2.463191	2.287789	2.312614	2.338305	2.364911	2.340048
22	9	0	0	0	0	0	0	0	0	0
23	9	1.564474	1.574143	1.584166	1.595284	1.541126	1.549397	1.557934	1.56675	1.571923
24	0	0	0	0	0	0	0	0	0	0
25		0	0	0	0	0	0	0	0	0
26		0	0	0	0	0	0	0	0	0
27		6.200891	6.354484	6.514797	6.657964	5.738784	5.867369	6.001025	6.140056	6.256037
28		0	0	0	0	0	0	0	0	0
29		0	0	0	0	0	0	0	0	0
30		0	0	0	0	0	0	0	0	0
31		5.318301	5.463244	5.614688	5.772254	5.255204	5.3882	5.526625	5.670806	5.787988
32		9.932538	10.22308	10.52674	11.15212	10.87115	11.16954	11.48022	11.80393	11.80613
33		0	0	0	0	0	0	0	0	0
1		0	0	0	0	0	0	0	0	0
2		5.245089	5.393609	5.548844	5.658972	5.254697	5.393671	5.538376	5.68916	5.871257
3		0	0	0	0	0	0	0	0	0
4		3.808719	3.870855	3.935368	3.945223	3.87852	3.939331	4.002285	4.067502	4.186273
5		1.770759	1.801723	1.834078	1.865942	1.697768	1.723779	1.750836	1.779003	1.800342
6		3.832672	3.938094	4.048318	4.086323	2.839649	2.906814	2.976725	3.049545	3.136526
7		6.571829	6.760763	6.958363	6.770677	6.512286	6.689964	6.875177	7.068386	7.640276
8		0	0	0	0	0	0	0	0	0
9		0	0	0	0	0	0	0	0	0
10		2.206526	2.251295	2.297937	0	0	0	0	0	2.228868
11	C	1.272612	1.301387	1.331436	1.389109	1.312353	1.340399	1.369579	1.399963	1.400124
12	A	2.078662	2.129778	2.183028	2.250776	2.08236	2.129939	2.17931	2.230575	2.259947
13	N	2.840994	2.898212	2.957728	3.032196	2.886322	2.941116	2.997904	3.056802	3.094542
14	A	0	0	0	0	0	0	0	0	0
15	D	0	0	0	0	0	0	0	0	0
16	A	4.943005	5.001767	5.06224	5.137328	5.036	5.094013	5.153565	5.214726	5.25594
17		0	0	0	0	0	0	0	0	0
18		0	0	0	0	0	0	0	0	0
19		1.055151	1.057048	1.059024	1.060507	1.043887	1.045223	1.046605	1.048036	1.04918
20		0	0	0	0	0	0	0	0	0
21	1	0	0	0	0	0	0	0	0	0
22	9	2.288165	2.309762	2.332069	2.35816	2.303948	2.323619	2.343833	2.364617	2.379196
23	9	0	0	0	0	0	0	0	0	0
24	0	1.892703	1.912211	1.932512	1.9883	1.876426	1.894006	1.912226	1.931125	1.90998
25		3.272317	3.359152	3.449918	3.544854	3.333773	3.416314	3.502262	3.591822	3.670842
26		3.103484	3.176322	3.252545	3.337998	2.942481	3.005642	3.071487	3.140179	3.183061
27		0	0	0	0	0	0	0	0	0
28		1.824918	1.855779	1.888038	1.925589	1.47105	1.489169	1.508025	1.527665	1.520757
29		4.87675	5.015503	5.160622	5.254907	2.896054	2.96438	3.035519	3.109642	3.123614
30		1.705468	1.739015	1.774036	1.799489	1.686151	1.716402	1.747851	1.78057	1.818227
31		0	0	0	0	0	0	0	0	0
32		0	0	0	0	0	0	0	0	0
33		2.476134	2.526854	2.579882	2.615222	2.162596	2.200417	2.2398	2.280841	2.318687

Table 1; Reswitching at comparison of German technique 1990 and Canadian technique 1990

(vector d ; Total final demand)

Switch point between 0.52 and 0.53 at choice of technique from British IOT 1979 vs. 1984

Capital intensity=xAp/xl

	r=0.79			r=0.80			
Sector	xAp	Ap	Ap	xAp	Price r=0.80	Intensity r=0.79	Intensity r=0.80
1	124.409512	3.39978963	3.39978963	124.450482	6.22574163	2.2120903	2.18961439
2		0.65057542	0.65057542		1.24890315	4.29128456	4.31043456
3		4.07409209	4.07409209		7.49204031	2.24845694	2.2331955
4		**2.90616122**	**2.92384541**		5.54366083	2.07827704	2.05308517
5		2.65931538	2.65931538		5.05846406	1.71026133	1.71427139
6	xl	1.85287065	1.85287065	xl	3.6764876	3.23159979	3.23254269
7	19.4976156	2.41463742	2.41463742	19.4638427	4.51233004	3.81367807	3.83816707
8		1.7587887	1.7587887		3.41520007	1.13746336	1.1373233
9		1.24191125	1.24191125		2.25585311	2.38659749	2.40995018
10		2.34043125	2.34043125		4.51362699	2.06842255	2.05591105
11	xAp/xl(1)	1.57852791	1.57852791	xAp/xl(2)	3.11333871	1.63603837	1.63861377
12	6.38075519	2.05566519	2.05566519	6.39393179	3.94757158	3.3756466	3.38173454
13		2.1359719	2.1359719		3.98514508	2.44380899	2.44443406
14		2.06724319	2.06724319		4.01980804	1.83575223	1.83862068
15		1.89258385	1.89258385		3.76094786	2.42588539	2.41594769
16		1.80396689	1.80396689		3.46685448	1.18125565	1.18147372
17		1.93903663	1.93903663		3.82482727	1.71301475	1.7121987
18		1.77146491	1.77146491		3.53539619	2.07648103	2.07560683
19		1.70843016	1.70843016		3.55050636	1.23035897	1.23116861
20		1.74361758	1.74361758		3.58416382	1.14164211	1.1426045
21		2.37295726	2.37295726		4.57135526	1.38019956	1.3818246
22		2.23295285	2.23295285		4.38912505	1.33335319	1.33375946
23		1.67550552	1.67550552		3.40083659	1.14936258	1.1486589
24		2.18641696	2.18641696		4.22256976	1.13344327	1.13486851
25		1.20914656	1.20914656		2.37504477	2.50394029	2.50598539
26		1.92021924	1.92021924		3.67162485	1.72074164	1.72287681
27		1.09321189	1.09321189		2.37428061	3.14702603	3.16072626
28		1.88616258	1.88616258		3.82773551	1.07065706	1.07532622
29		1.37335372	1.37335372		2.83791478	3.59900135	3.65255143
30		0.71335781	0.71335781		1.76709073	1.79325716	1.79450206
31		0.94813535	0.94813535		1.95212644	1.90019234	1.88801339
32		0.4469039	0.4469039		1.2665855	2.88809141	2.86911847
33		0.66428134	0.66428134		1.63707148	1.85644773	1.91089254

Table 2: Reverse capital deepening (vector *d*; (1,…,1)); United Kingdom 1979 and 1984

Apart from reverse capital deepening, defined as an increase of the intensity of capital, i.e. of $k^{(i)} = \mathbf{q}^{(i)}\mathbf{A}^{(i)}\mathbf{l}^{(i)} / \mathbf{q}^{(i)}\mathbf{l}^{(i)}$, at a switch point, as w is lowered, there is also the simpler possibility that the lowering of w leads (against neoclassical intuition) to the introduction of a process with a labour coefficient lower than that of the process being replaced at the switch. We call this a labour-reducing switch. We then have four possibilities, and we add in brackets the frequency of the case observed (in per cent) in our sample:

(a) capital intensity-reducing, labour-increasing (80.2%)

(b) capital intensity-reducing, labour-reducing (8.5%)

(c) capital intensity-increasing, labour-increasing (1.4%)

(d) capital intensity-increasing, labour-reducing (9.9%)

(a) is what is to be expected in neoclassical perspective. (d) in comparison with (c) shows that reverse capital deepening seems primarily to be associated with the counterintuitive 'microeconomic' phenomenon of the introduction of labour-saving process at a lower wage. (b) is, like mere returns of processes, a microeconomic puzzle for neoclassical theory, not a macroeconomic one.

4.2. Other aspects of the result

The structure (i.e. the distribution of zero coefficients reflecting the choice of techniques) of the solution intensity vector $\mathbf{q}$ found at r according to (2) – not to be confused with $\mathbf{q}^{(i)}$ – is independent from the composition of the final demand vector $\mathbf{d}$. This is what the non-substitution theorem suggests (see table 3).[12] In table 3, the intensity levels are different depending on the vector $\mathbf{d}$, but the decision, which production process is to chosen and which not, remains unchanged.

For all 496 results of technical choice, no input-output table turned out to be superior for all 33 sectors throughout the considered range of the rate of profit, and no input-output table was in the whole range and for all sectors inferior (dominated).

The property of the envelope that a switch point represents the change of the production process merely in one sector,[13] therefore that two different techniques (systems) are different merely in one sector at a switch point, i.e. the property that the choice of techniques generically is 'piecemeal', can not be verified immediately at all switch points. At more than 100 switch points, the production processes change in more than two sectors. But if the steps, by which the interest rate changes, are made smaller, the processes change one by one at switch points, and the theory is confirmed (see table 4 and table 5).

As a matter of fact, at least three switch points are registered on each of the 496 envelopes. This is in accordance with the theoretical expectation that the chosen technique

[12] The intensities in tables are computed with the vector $\mathbf{d}$ of arithmetical means of "Total final demand" in OECD input-output-table databank.

[13] see Bruno, Burmeister and Sheshinski (1966, p.542); Schefold (1989, p.122).

should change as the distribution (wage or rate of interest) varies. But we obtain some implausible results from the input-output tables of the 1960' and 1970': According to these data, old production processes often dominate than the production processes of later periods. This suggests that these data were compiled incorrectly.[14] The input output-tables of 1980' and 1990' show more plausible results. And only plausible results of national technical choice were used in the investigation of reverse capital deepening. They defined the sample for which changes in capital intensity and of labour coefficients were compared.

4.3. Empirical relevance in capital controversy

Some economists have examined the probability of reswitching and reverse capital deepening phenomena on theoretical grounds. They predicted that these phenomena do not appear frequently, but that their probability of occurring is positive, see Schefold (1976); D'Ippolito (1987); D'Ippolito (1989); Mainwarning and Steedman (1995); Petri (2000). The examination in this paper supports such prognoses. The observed cases of reswitching and reverse capital deepening do not appear to constitute a majority, but they seem to suffice to undermine the neoclassical production and distribution theory, both in a stochastical and falsificatorical[15] sense.

It may be too early to speculate on what has to follow if this conclusion is, as we expect, confirmed by other studies which develop the new method proposed in this paper further. We only want to point out that it would be too facile simple to rely on the fact that reverse capital deepening happens to occur less often than the 'normal' case, to introduce future neoclassical treatises by an assumption which excludes reverse capital deepening (perhaps characterized as 'rare') and to continue otherwise as if nothing had happened. What really matters from the point of view of practical political economy (as opposed to the question of whether pure theory predicts a perfect functioning of an unadulterated market system) are the elasticities of the demands for factors. The book of blueprints should be used to measure them. The problem then reappears as to how to measure the 'amount of capital'

[14] Inconsistencies in data collection are not the only possibility: Cheap old techniques can disappear from the book of blueprints at later times because quality improvements, which are not represented in the input output table, lead to higher costs and because regulations change, in particular if more severe environmental standard are enacted and drive up costs. An example of the effect of environmental factors on the choice of technique is Albin (1975).

[15] See Popper (1935); Lakatos (1970). See Lutz and Hague (1961, p.305-306) on the empirical methodology of Sraffa.

when labour is varied. If it is measured according to (6), our results might be taken to indicate that the wage elasticity of the demand for labour, given the ‘amount of capital’, is neither negative nor zero. It is positive, but possibly low. If so, the state of unemployment in the closed economy cannot significantly be reduced by depressing the general wage level and the alternative becomes either to wait and see or to pursue more active policies of growth (including adjustments of relative wage rates, if necessary).

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Choice of technique from German 1990 vs. Canada 1990

Zielzelle (Min)

Cell	Name	start value	solution
E10	xl	18.91097274	2.675753512

		rate of interest:	r=0,64	r=0,64	r=0,64
Veränderbare Zellen		d vector	d=final demand	d=(1,1,...,1)	d=consumtion
Cell	**Name**	**start value**	**solution**	**solution**	**solution**
C2	x-vector	1	0.36980169	0.577317265	0.189590754
D2	x-vector	1	0	0	0
E2	x-vector	1	0.356519445	0.488219358	0.215663393
F2	x-vector	1	0	0	0
G2	x-vector	1	0	0	0
H2	x-vector	1	0	0	0
I2	x-vector	1	0	0	0
J2	x-vector	1	0.055665721	0.10609361	0.026500695
K2	x-vector	1	0.332493658	0.496865864	0.160285946
L2	x-vector	1	0	0	0
M2	x-vector	1	0	0	0
N2	x-vector	1	0	0	0
O2	x-vector	1	0	0	0
P2	x-vector	1	0.321534698	0.467128655	0.087657946
Q2	x-vector	1	0.328629776	0.377743365	0.065793379
R2	x-vector	1	0	0	0
S2	x-vector	1	0.327048404	0.403236204	0.087179378
T2	x-vector	1	0.211089297	0.228393984	0.033431642
U2	x-vector	1	0	0	0
V2	x-vector	1	0.055380654	0.106354756	0.023541111
W2	x-vector	1	0.238992462	0.258285691	0.076356221
X2	x-vector	1	0	0	0
Y2	x-vector	1	0.158416634	0.148233988	0.04714056
Z2	x-vector	1	0	0	0
AA2	x-vector	1	0	0	0
AB2	x-vector	1	0	0	0
AC2	x-vector	1	0.651479737	0.888055712	0.271706218
AD2	x-vector	1	0	0	0
AE2	x-vector	1	0	0	0
AF2	x-vector	1	0	0	0
AG2	x-vector	1	0.561468794	0.8095629	0.241548917
AH2	x-vector	1	1.052673576	1.490479636	0.41301272
AI2	x-vector	1	0	0	0
AM2	x-vector	1	0	0	0
AN2	x-vector	1	0.554884364	0.891276366	0.191543904
AO2	x-vector	1	0	0	0
AP2	x-vector	1	0.393536811	0.405493524	0.239650307
AQ2	x-vector	1	0.183407625	0.265882911	0.074183909
AR2	x-vector	1	0.404831822	0.611763057	0.153242207
AS2	x-vector	1	0.695836263	1.024845283	0.264225675
AT2	x-vector	1	0	0	0
AU2	x-vector	1	0	0	0
AV2	x-vector	1	0.229793686	0.338237937	0.082916969
AW2	x-vector	1	0.133143627	0.267366246	0.046700703
AX2	x-vector	1	0.218302781	0.395538594	0.052130364
AY2	x-vector	1	0.295772806	0.430672987	0.058964193
AZ2	x-vector	1	0	0	0
BA2	x-vector	1	0	0	0
BB2	x-vector	1	0.506224033	0.322903448	0.056015052
BC2	x-vector	1	0	0	0
BD2	x-vector	1	0	0	0
BE2	x-vector	1	0.105902421	0.111871862	0.00659788
BF2	x-vector	1	0	0	0
BG2	x-vector	1	0	0	0
BH2	x-vector	1	0.233206902	0.232504342	0.01549137
BI2	x-vector	1	0	0	0
BJ2	x-vector	1	0.193251229	0.204131919	0.093003351
BK2	x-vector	1	0.344991791	0.541358384	0.152680694
BL2	x-vector	1	0.325254523	0.452377416	0.108926238
BM2	x-vector	1	0	0	0
BN2	x-vector	1	0.188803803	0.246686405	0.114014647
BO2	x-vector	1	0.516062201	0.768360802	0.209025196
BP2	x-vector	1	0.177403638	0.266801213	0.088009832
BQ2	x-vector	1	0	0	0
BR2	x-vector	1	0	0	0
BS2	x-vector	1	0.257988165	0.347835991	0.11707299

restrictions
none

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Zielzelle (Min)

Cell	Name	start value	solution
E10	xl	18.91097274	2.735209757

			r=0,65	r=0,65
Veränderbare Zellen			d=final demand	d=(1,1,...,1)
Cell	**Name**	**start value**	**solution**	**solution**
C2	x-vector	1	0.381063113	0.593321738
D2	x-vector	1	0	0
E2	x-vector	1	0.363306909	0.49740719
F2	x-vector	1	0	0
G2	x-vector	1	0	0
H2	x-vector	1	0	0
I2	x-vector	1	0	0
J2	x-vector	1	0.055529998	0.105877799
K2	x-vector	1	0.33719768	0.503076795
L2	x-vector	1	0.246127137	0.361469232
M2	x-vector	1	0	0
N2	x-vector	1	0	0
O2	x-vector	1	0	0
P2	x-vector	1	0.325355036	0.471674736
Q2	x-vector	1	0.342273317	0.396929568
R2	x-vector	1	0	0
S2	x-vector	1	0.337531927	0.417524162
T2	x-vector	1	0.213609301	0.23061735
U2	x-vector	1	0	0
V2	x-vector	1	0.055417973	0.106392464
W2	x-vector	1	0.246319116	0.268488532
X2	x-vector	1	0	0
Y2	x-vector	1	0.159528401	0.149528649
Z2	x-vector	1	0	0
AA2	x-vector	1	0	0
AB2	x-vector	1	0	0
AC2	x-vector	1	0.665796396	0.906938182
AD2	x-vector	1	0	0
AE2	x-vector	1	0	0
AF2	x-vector	1	0	0
AG2	x-vector	1	0.577225379	0.830789075
AH2	x-vector	1	1.115211947	1.578452257
AI2	x-vector	1	0	0
AM2	x-vector	1	0	0
AN2	x-vector	1	0.565897237	0.906273461
AO2	x-vector	1	0	0
AP2	x-vector	1	0.394522317	0.40509682
AQ2	x-vector	1	0.186594211	0.270236003
AR2	x-vector	1	0.40863226	0.61602543
AS2	x-vector	1	0.677067706	0.995180189
AT2	x-vector	1	0	0
AU2	x-vector	1	0	0
AV2	x-vector	1	0	0
AW2	x-vector	1	0.138910858	0.275643664
AX2	x-vector	1	0.225077595	0.404912516
AY2	x-vector	1	0.303219633	0.440794529
AZ2	x-vector	1	0	0
BA2	x-vector	1	0	0
BB2	x-vector	1	0.513732806	0.329921582
BC2	x-vector	1	0	0
BD2	x-vector	1	0	0
BE2	x-vector	1	0.106050689	0.112063752
BF2	x-vector	1	0	0
BG2	x-vector	1	0	0
BH2	x-vector	1	0.235816011	0.235706887
BI2	x-vector	1	0	0
BJ2	x-vector	1	0.198830001	0.211941307
BK2	x-vector	1	0.354485372	0.554399115
BL2	x-vector	1	0.333799816	0.464242246
BM2	x-vector	1	0	0
BN2	x-vector	1	0.192558855	0.251811054
BO2	x-vector	1	0.525490708	0.780686078
BP2	x-vector	1	0.179948901	0.27001564
BQ2	x-vector	1	0	0
BR2	x-vector	1	0	0
BS2	x-vector	1	0.261522195	0.352420602

restrictions
none

Table 3: Non-substitution theorem

Intensity vector x **Five switch points between rates of interest 0.11 and 0.12**

Sector	r	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
1		1.03	1.05	1.06	1.13	1.15	1.16	1.18	1.2	1.22	1.24	1.26	1.28	1.29	1.31	1.34	1.36
2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3		1.66	1.67	1.69	1.72	1.74	1.76	1.78	1.8	1.82	1.84	1.86	1.88	1.9	1.92	1.94	1.96
4		1.77	1.79	1.8	1.81	1.83	1.84	1.86	1.87	1.89	1.91	1.93	1.95	1.94	1.96	1.98	2
5		0	0	0	1	1	1.01	1.02	1.02	1.03	1.04	1.05	1.05	1.04	1.05	1.05	1.06
6		1.41	1.44	1.47	1.48	1.51	1.54	1.57	1.6	1.63	1.67	1.7	1.74	1.6	1.64	1.67	1.71
7		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8		0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
9		1.43	1.45	1.47	1.49	1.51	1.53	1.56	1.58	1.61	1.63	1.66	1.68	1.69	1.72	1.75	1.77
10		0.99	1	1.01	1.02	1.03	1.05	1.06	1.07	1.08	1.1	1.11	1.12	1.08	1.09	1.1	1.11
11	G	0.7	0.71	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.79	0.81	0.82	0.82	0.83	0.84	0.85
12	E	2.87	2.96	3.05	3.09	3.18	3.29	3.39	3.5	3.62	3.74	3.87	4.01	0	0	0	0
13	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18		1	1.01	1.02	1.02	1.03	1.04	1.05	1.05	1.06	1.07	1.08	1.09	0.95	0.95	0.96	0.97
19		1.06	1.05	1.05	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0	0	0	0
20		0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.41	0.41	0.41	0.41	0.41	0.41
21	1	1.4	1.41	1.42	1.42	1.43	1.44	1.45	1.45	1.46	1.47	1.48	1.49	1.51	1.52	1.53	1.54
22	9	0	0	0	0	0	0	0	0	0	0	0	0	1.51	1.51	1.52	1.52
23	8	0	0	0	0	0	0	0	0	0	0	0	0	1.26	1.27	1.27	1.27
24	6	0	0	0	0	0	0	0	0	0	0	0	0	1.13	1.14	1.14	1.15
25		1.41	1.43	1.45	1.48	1.51	1.54	1.56	1.59	1.62	1.65	1.68	1.71	1.63	1.66	1.69	1.72
26		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27		2.26	2.3	2.33	2.39	2.43	2.47	2.51	2.55	2.59	2.63	2.68	2.72	2.7	2.74	2.78	2.83
28		1.01	1.01	1.01	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.08	1.09	1.09	1.1
29		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30		0.78	0.78	0.79	0.8	0.8	0.81	0.81	0.82	0.83	0.83	0.84	0.85	0.84	0.85	0.85	0.86
31		1.42	1.44	1.47	1.51	1.53	1.56	1.58	1.6	1.63	1.66	1.68	1.71	1.77	1.8	1.83	1.85
32		2.46	2.51	2.55	2.65	2.7	2.75	2.8	2.85	2.91	2.96	3.02	3.08	3.1	3.16	3.22	3.27
33		1.23	1.24	1.26	1.25	1.26	1.28	1.3	1.31	1.33	1.35	1.37	1.39	1.32	1.33	1.35	1.37
1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2		1.68	1.72	1.76	1.8	1.84	1.88	1.93	1.98	2.02	2.07	2.13	2.18	1.95	1.99	2.03	2.08
3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5		1.11	1.12	1.13	0	0	0	0	0	0	0	0	0	0	0	0	0
6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7		2.21	2.26	2.3	2.35	2.4	2.44	2.49	2.54	2.59	2.64	2.69	2.74	2.68	2.73	2.79	2.84
8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12		0	0	0	0	0	0	0	0	0	0	0	0	1.69	1.73	1.76	1.79
13		1.48	1.5	1.52	1.54	1.57	1.59	1.61	1.63	1.66	1.68	1.71	1.73	1.55	1.57	1.6	1.62
14		1.04	1.05	1.06	1.06	1.07	1.08	1.09	1.11	1.12	1.13	1.15	1.16	1.14	1.16	1.17	1.18
15		1.64	1.66	1.67	1.68	1.7	1.71	1.73	1.74	1.76	1.78	1.79	1.81	1.75	1.77	1.78	1.8
16		1.55	1.55	1.56	1.56	1.56	1.57	1.57	1.57	1.58	1.58	1.58	1.59	1.61	1.61	1.61	1.62
17		1.35	1.36	1.37	1.4	1.41	1.42	1.43	1.44	1.46	1.47	1.48	1.5	1.51	1.53	1.54	1.55
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	9	0	0	0	0	0	0	0	0	0	0	0	0	1.19	1.2	1.2	1.2
20	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22		1.49	1.5	1.5	1.51	1.51	1.52	1.52	1.53	1.54	1.54	1.55	1.55	0	0	0	0
23		1.27	1.27	1.27	1.28	1.28	1.28	1.28	1.29	1.29	1.29	1.3	1.3	0	0	0	0
24		1.06	1.07	1.07	1.11	1.11	1.12	1.12	1.13	1.13	1.14	1.14	1.15	0	0	0	0
25		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26		1.3	1.32	1.33	1.35	1.36	1.38	1.39	1.4	1.42	1.43	1.45	1.47	1.47	1.49	1.5	1.52
27		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29		1.71	1.74	1.77	1.76	1.79	1.82	1.85	1.88	1.91	1.95	1.98	2.02	1.94	1.97	2	2.04
30		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4: Five switch points between 0.11 and 0.12 (Germany 1986 and UK 1979)

only one switch point for a rate of interest between 0.11 and 0.12

Sector		0.11	0.111	0.112	0.113	0.114	0.1142	0.1144	0.1146	0.1148	0.115	0.116	0.117	0.118	0.119	0.12
1		1.28	1.28	1.29	1.29	1.3	1.296	1.296	1.296	1.291	1.285	1.288	1.29	1.292	1.295	1.293
2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3		1.88	1.88	1.9	1.9	1.9	1.901	1.902	1.902	1.894	1.888	1.89	1.893	1.895	1.9	1.896
4		1.95	1.95	1.96	1.96	1.96	1.959	1.96	1.96	1.934	1.936	1.938	1.94	1.942	1.938	1.943
5		1.05	1.06	1.07	1.07	1.07	1.073	1.073	1.073	1.07	1.048	1.048	1.049	1.05	1.043	1.04
6		1.74	1.74	1.73	1.73	1.73	1.735	1.736	1.737	1.583	1.58	1.583	1.586	1.59	1.571	1.604
7		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8		0.44	0.44	0.44	0.44	0.44	0.442	0.442	0.442	0.442	0.442	0.442	0.442	0.442	0.442	0.442
9		1.68	1.69	1.67	1.68	1.68	1.679	1.679	1.68	1.66	1.661	1.664	1.667	1.669	1.666	1.692
10	G	1.12	1.12	1.12	1.12	1.12	1.125	1.125	1.126	1.113	1.105	1.106	1.107	1.109	1.068	1.075
11	E	0.82	0.82	0.82	0.82	0.82	0.824	0.824	0.824	0.823	0.827	0.828	0.83	0.831	0.836	0.819
12	R	4.01	4.02	3.85	3.86	3.88	3.88	3.883	3.886	4.152	4.037	4.05	4.064	4.078	3.83	0
13	M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18		1.09	1.09	0.97	0.98	0.98	0.976	0.976	0.977	0.975	1.018	1.019	1.02	1.02	0.943	0.948
19		1.06	1.06	1.06	1.06	1.06	1.062	1.062	1.062	1.061	0	0	0	0	0	0
20	1	0.41	0.41	0.41	0.41	0.41	0.407	0.407	0.407	0.406	0.406	0.406	0.406	0.406	0.405	0.406
21	9	1.49	1.49	1.49	1.49	1.5	1.496	1.496	1.496	1.496	1.493	1.493	1.494	1.495	1.5	1.514
22	8	0	0	1.5	1.5	1.5	1.504	1.504	1.504	1.503	1.503	1.503	1.504	1.504	1.504	1.506
23	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1.261	1.263
24		0	0	0	0	0	0	0	0	1.153	1.123	1.123	1.124	1.124	1.142	1.134
25		1.71	1.71	1.71	1.71	1.72	1.716	1.716	1.717	1.701	1.691	1.694	1.698	1.701	1.69	1.634
26		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27		2.72	2.73	2.72	2.72	2.73	2.728	2.729	2.73	2.69	2.642	2.646	2.651	2.655	2.645	2.695
28		1.06	1.06	1.08	1.08	1.08	1.081	1.081	1.082	1.089	1.083	1.084	1.085	1.085	1.09	1.083
29		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30		0.85	0.85	0.85	0.85	0.85	0.848	0.849	0.849	0.843	0.832	0.833	0.834	0.835	0.839	0.84
31		1.71	1.71	1.76	1.76	1.77	1.768	1.769	1.77	1.79	1.755	1.758	1.761	1.764	1.799	1.771
32		3.08	3.09	3.16	3.17	3.18	3.177	3.178	3.179	3.235	3.124	3.13	3.136	3.142	3.213	3.102
33		1.39	1.39	1.36	1.36	1.36	1.363	1.363	1.363	1.314	1.314	1.316	1.317	1.319	1.278	1.316
1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2		2.18	2.19	2.17	2.17	2.18	2.179	2.18	2.181	2.15	2.134	2.139	2.145	2.15	2.128	1.949
3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7		2.74	2.75	2.74	2.75	2.75	2.754	2.755	2.757	2.68	2.662	2.667	2.672	2.677	2.663	2.682
8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.693
13		1.73	1.74	1.74	1.75	1.75	1.75	1.751	1.751	1.473	1.446	1.448	1.45	1.452	1.464	1.551
14		1.16	1.16	1.19	1.2	1.2	1.198	1.198	1.199	1.25	1.146	1.148	1.149	1.151	1.149	1.145
15		1.81	1.81	1.76	1.76	1.76	1.76	1.761	1.761	1.787	1.691	1.692	1.694	1.696	1.703	1.749
16		1.59	1.59	1.6	1.6	1.6	1.605	1.605	1.605	1.605	1.585	1.586	1.586	1.586	1.604	1.607
17		1.5	1.5	1.57	1.57	1.57	1.572	1.573	1.573	1.575	1.488	1.489	1.49	1.492	1.523	1.514
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	9	0	0	0	0	0	0	0	0	0	1.189	1.189	1.189	1.19	1.19	1.194
20	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22		1.55	1.55	0	0	0	0	0	0	0	0	0	0	0	0	0
23		1.3	1.3	1.3	1.3	1.3	1.297	1.297	1.297	1.29	1.28	1.281	1.281	1.281	0	0
24		1.15	1.15	1.16	1.16	1.16	1.156	1.156	1.156	0	0	0	0	0	0	0
25		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26		1.47	1.47	1.47	1.47	1.47	1.473	1.473	1.474	1.477	1.473	1.475	1.477	1.478	1.483	1.47
27		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29		2.02	2.02	2.02	2.02	2.03	2.028	2.029	2.03	1.981	1.96	1.964	1.968	1.971	1.946	1.937
30		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5: Five different switch points between 0.11 and 0.12