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ABSTRACT

The purpose of this article is, on the one hand, to shed light on some significant aspects of Ricardo's theory of value and on the other hand to show that Ricardo's insights about the explanatory power of the relative labour times on the movement of relative prices were in the right direction. For this purpose, Ricardo's theory of value is cast rigorously and in modern terms such that by using detailed intertemporal data from input-output tables of two major economies to show that Ricardo's insights are absolutely consistent with the facts.

Keywords: David Ricardo; Value and distribution, Price-value deviations

JEL codes: B12; B14; B16; D24; D46, D57

1. INTRODUCTION

The purpose of this article is twofold: on the one hand to discuss Ricardo's theory of value as an interpretation of relative prices through relative labour times expended in production; and on the other hand, to test this theory using data from real economies. In spite of the fact that Ricardo makes clear and bold statements about his theory of value, nevertheless, he is usually misinterpreted in the literature for reasons that have mainly to do with the temptation of economists to read in his writings their own theory of value (Stigler, 1958). For example, Marshall (1920) or S. Hollander (1985) attribute to Ricardo a (neoclassical) partial and general equilibrium approach, respectively. Most of the neoricardians (the modern followers of Ricardo's approach) focus on those sections of the *Principles* that refer to the invariable measure of value which is presented as an unsuccessful effort to construct something akin to Sraffa's standard commodity while Ricardo's theory of value is treated merely as a cost of

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production theory without including rent as a constituent component of price (Steedman, 1982). Marxists, usually attribute to Ricardo a theory of value very similar to Marx's and then, not surprisingly, find inconsistencies. A careful reading of the *Principles*, however, reveals that Ricardo's meaning of the word value by no means is the same with Marx's meaning of the same word (Tsoulfidis, , 2010, ch.4).

The remainder of the paper is structured as follows: Section two refers to Ricardo's statements on the theory of value and his insistence for an explanation of the variations of relative prices through the relative labour times spent on the production of commodities. Section three deals with Ricardo's labour theory of relative prices and its modifications, wherein it is argued that this theory is general enough so as to take into account the inter-industry differences in capital-labour ratios, changes in the distributive variables as well as differences in turnover times. Section four shows that the effects of these variables on relative prices not only are minimal compared to the principal cause of variation in relative prices, that is, the relative labour times but also predictable. Section five test empirically Ricardo's theory of value using data from input-output tables of Japan and Germany for meaningfully selected years. Section six summarizes and makes some concluding remarks.

2. RICARDO'S THEORY OF (EXCHANGE) VALUE

Ricardo in his *Principles* straightforwardly states that his purpose is to determine the laws of distribution in the economy but adds that progress in such an endeavour is possible if and only if there is a consistent theory of value, that is, a theory of determination of relative prices (*Works*, I, pp. xiv-xv). Ricardo started from Smith's theory of value based on labour time and advanced it more than any other economist

of his time. However, it was nearly impossible to supersede a series of riddles that even today are regarded hard to deal with.

Ricardo already knew from Smith that market prices are determined by the ephemeral forces of supply and demand; but over time, these same market prices fluctuate persistently around something more fundamental than the simple forces of supply and demand, that is, the "principle of equal profitability". Thus, if in an industry the rate of profit is above the economy-wide average, the inflow of capital would increase the supply of this industry relative to its demand; thereby, reducing the market price to a level that would restore the average profitability. By contrast, if the rate of profit of an industry is below the economy's average, then the outflow of capital will decrease the supply relative to demand and so the price will increase to a point that restores the economy's average rate of profit. Ricardo argued that the principal determinant of the movement in the resulting "natural prices", that is, prices that incorporate an average rate of profit, are their respective labour times. Hence, there is a role for demand and supply; however, these two concepts have entirely different meaning and content from those utilized, for example, by Malthus (cf. *Works* VIII, p. 279-80) and by extension by the usual neoclassical demand and supply schedules each point of which represents a potential equilibrium price and quantity pair. In Ricardo both demand and supply are governed by profitability and by no means should be thought of as neoclassical schedules (Garegnani, 1984).

Ricardo starts his analysis with a discussion regarding Smith's distinction between use value and exchange value and he argues that the use value of a commodity is merely a prerequisite for exchange (*Works*, I, p. 6). Scarcity is important only in the case of non-reproducible goods, such as works of art, rare coins, rare books, and the like, whose value does not depend at all on the quantity of labour which is necessary for their production but depends primarily on the "varying wealth and inclinations of those who are desirous to possess them" (*Works*, I, p. 12). It is

important to stress that the non-reproducible goods whose relative prices are determined by subjective forces are an infinitesimally small percentage of the totality of goods. The overwhelming majority of goods are reproducible and, with regard to them, Ricardo sides with Smith's labour theory of value, according to which the relative prices of goods are determined by the relative quantities of labour that were spent on their production.

> The value of a commodity, or the quantity of any other commodity for which it will exchange, depends on the relative quantity of labour which is necessary for its production, and not on the greater or less compensation which is paid for that labour. (*Works*, I, p. 11).

The trouble with the above definition is that although we do know the relative prices, that is, the visible part of the exchange, the relative quantities of labour times were, by contrast, an unknown in Ricardo's time due to lack of data making exceedingly difficult to infer anything more specific about the movement of relative prices.[2] For example, if the relative price of two commodities change, then if we do not know exactly the relative quantities of labour required in the production of the two commodities, we would not be able to attribute the observed change in their relative price to a specific cause for there would be many possibilities. It is important to note at this juncture that nowadays such difficulties are easily resolved with the use of input-output tables which include detailed accounts regarding the amount of labour required in production, so that we can estimate the relative labour times required in the production of commodities.

The want of data on labour time prompted Ricardo, and by extend the old classical economists, to the search of an *invariable measure of value*, that is, a commodity

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[2] It might be remarked in passing that in the last sentence in the above quotation Ricardo categorically precludes the case of an adding-up cost of production theory of value so frequently attributed to him. Furthermore, the natural or cost price in Ricardo incorporates the economy-wide average rate of profit and is treated as if it were the same with (if not too different from) the market price (*Works* I, p. 382).

whose production would always require the same amount of labour and whose value would remain the same regardless of changes in the distributive variables. In modern parlance, a commodity with the properties of the invariable measure of value must be characterized by (a) zero relative price elasticity with respect to the technical conditions in production, that is, zero substitutability in production and (b) zero relative price elasticity with respect to changes in distribution. These two properties characterize a commodity as an invariable measure of value and as such it could be used as a numéraire to estimate the changes in the relative prices of all the other commodities as well as the precise source of their variation.[3] Ricardo devoted the rest of his intellectual life to the discovery of such a commodity which could be determined either practically or analytically (see *Works* I, pp. 42-44). In effect, he investigated a number of possibilities, however, none of which gave absolutely satisfactory results because the production of all the commodities he thought of was subjected to technological change and therefore required different labour times over time. Ricardo at the end hypothesized gold to be the commodity that could, at least partially, fulfil the role of an "imperfect", but nevertheless the best available "measure of value" the "nearest approximation to truth" (*Works* VIII, p. 279) as he characterized it.

For Ricardo the value of gold was determined in exactly the same way as with the other commodities, that is, by the labour time required for its production, with the difference that the techniques of production of gold (and silver) are subjected to fewer changes and after the passage of reasonably long times (*Works* I, p. 87). Using gold as an approximate invariable measure of value, he also provided himself with a means to integrate the theory of value with the theory of money. Thus, while the labour time spent in the production of gold was supposed to be changing so slowly that it could be

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[3] The invariable measure of value could also possibly be used as a measuring tool for the intertemporal estimations of the wealth and therefore the wellbeing of a society.

regarded as approximately constant, nevertheless this did not prevent Ricardo from engaging in discussions concerning the effects of the supply of money (that is, gold) on the general price level. This separation between the real (theory of value) and the monetary economy as well as their interaction are of critical importance to the interpretation of Ricardo's theory of value, international trade, taxation and public debt (Tsoulfidis 2010, 2013 and 2015).

In spite of the lack of a perfect invariable measure of value, Ricardo argued that the principle according to which the exchange ratios of products are regulated by relative labour times expended in their production is correct not only in "the rude and early stage of society", as Smith thought but also in capitalism where Smith thought that the labour theory of value was no longer applicable. The difference is that in capitalism the previously correctly stated labour theory of relative prices needs several qualifications and modifications. These modifications relate to the presence of factors such as differences in capital-labour ratios, changes in income distribution and differences in the completion of the production process or turnover time. Ricardo's fundamental thesis, however, is that the relative prices of reproducible commodities, are determined by the relative quantity of labour expended on their production. The quality of the expended labour is independent of the subjective evaluations of individual producers; this is an issue that is resolved through the market mechanism. More specifically, the differences in skills or in general qualities of labour are manifested in the market as differential wages. Moreover, Ricardo argued that the value of the product is determined not only by the direct labour expended on its production but also by the indirect labour contained in plant and equipment. He notes:

> Not only the labour applied immediately to commodities affect their value, but the labour also which is bestowed on the implements, tools, and buildings, with which such labour is assisted [...] of the durable implement only a small portion of its value would be transferred to the commodity. (*Works* I, p. 23)

In other words, the exchange ratios of commodities are determined by their respective labour times with fixed capital only transferring its exchange value onto the final product piecemeal through its depreciation. Clearly, Ricardo was fully aware of the depreciation of fixed capital but for simplicity reasons, he hypothesized that depreciation is zero and that fixed capital lasts forever.

3. MODIFICATIONS OF THE THEORY OF VALUE

Let us now focus on a capitalist economy where production takes place with the employment of both labour and capital. Notes Ricardo:

> The principle that the quantity of labour bestowed on the production of commodities regulates their relative value, considerably modified by the employment of machinery and other fixed capital. (Works I, p. 30)

Ricardo argues then that the presence of fixed capital and of the rate of profit affects the relative prices but only in a limited and at the same time predictable way. For this purpose, he constructs a numerical example of two industries ("trades"), the first producing cotton and the second corn; each of the trades employs a 100 workers at a wage rate, w, of £50 per year (see Table 1). He further supposes that the cotton trade unlike the corn trade uses a machine, K, worth of £5,500.[4] The rate of profit, r, for convenience's sake is assumed at 10%, too low for England in Ricardo's time, and total profits, Π, are estimated as the product of the rate of profit times the sum of capital and wages, $r(K + wL)$. Thus, we have:

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[4] Fixed capital in Ricardo's numerical examples is assumed not to depreciate and also there are no materials used up; in short, there is no "constant capital" in Marx's sense.

Table 1 Ricardo's numerical example

	K	$W = wL$	K/W	$\Pi = r(K + wL)$	$P = W + \Pi$
Cotton industry:	£5,500	£5,000	1.1	£1,050	£6,050
Corn industry:	0	£5,000	0	£500	£5,500

From the above Table we get that the relative price of cotton is £6,050/£5,500 = 1.10 which is not far from the relative direct labour time $100/100 = 1$. The 10% deviation is attributed to the differences in the K/L ratios given that the wage rate is uniform across trades.

Thus, the relative prices of production are affected by the presence of capital and rate of profit, but only in a limited way. Ricardo's example is judicious, since he illustrates his thesis under extreme assumptions. For example, instead of taking the two trades with capital-labour ratios close to each other, he shows that, even in the presence of extreme differences in the capital-labour ratios, the deviations between relative prices and labour times remain relatively small, 10% in Ricardo's numerical example.

In effect, the cotton trade uses a capital-labour ratio of 55 and the corn trade a zero capital-labour ratio. Ricardo shows that even under these extreme differences in capital-labour ratios, relative prices are affected only in a limited and, at the same time, theoretically predictable way. In particular, the effect on relative prices is proportional to the differences in the capital-labour ratios of the two trades. It goes without saying that the rate of profit exerts an effect on relative prices but this

diminishes with the passage of time because of the long-run falling rate of profit, a common theme in the old classical approach to which Ricardo was no exception.[5]

Table 2 below modifies somewhat Ricardo's numerical example by examining two commodities A and B and by inserting pragmatism without sacrificing generality hypothesizes that the production of commodities A and B takes place with the employment of both capital and labour. Thus, we have

Table 2: Ricardo's modified numerical example

	K	$W = wL$	K/W	$\Pi = r(K + wL)$	$P = W + \Pi$
Commodity A	£5,500	£5,000	1.1	£1,050	£6,050
Commodity B	**£1,500**	£5,000	0.3	£650	£5,650

The new givens as expected bring somewhat closer the relative commodity prices to the quantities of labour. More specifically,

$$\frac{P_A}{P_B} = \frac{6,050}{5,650} = 1.07 > \frac{L_A}{L_B} = 1$$

where the subscripts A and B denote the two commodities. The differences between the relative prices and the relative labour times spent on the production of the two commodities are derived from differences in the capital-labour ratios (or the value compositions of capital, K/W in Marxian terms). Here, it is important to note that in effect we are dealing with different capital-labour ratios since the wage rate is uniform in the production of the two commodities. If the capital-labour ratio were the same then no deviation would have been observed between relative price P_A/P_B and

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[5] Thus, the effect of different capital-labour ratios on relative prices is secondary, whereas the labour expended is the principal factor exerting most of the influence.

relative labour time L_A/L_B. These results become much more pronounced, if we form the relative price of commodity A, namely

$$\frac{P_A}{P_B} = \frac{wL_A + r(wL_A + K_A)}{wL_B + r(wL_B + K_B)}$$

and factoring out the relative labour time, we get

$$\frac{P_A}{P_B} = \left[\frac{L_A}{L_B}\right] \left[\frac{1 + r\left(1 + \frac{K_A}{wL_A}\right)}{1 + r\left(1 + \frac{K_B}{wL_B}\right)}\right]$$

The above relationship shows that the relative prices of commodities are affected by both the presence of capital and the rate of profit. The numerical example is plausible (if not extreme and thus against Ricardo's thesis) because it hypothesizes far too large differences in capital-labour ratios in the production of the two commodities. Nevertheless, the difference between the relative prices and the relative quantities of labour that went into the production of the two goods is only 7%. Moreover, this difference is predictable, since it depends on the capital-labour ratio provided that the wage rate is the same across sectors and remains constant in the face of hypothetical rates of profit. The assumptions are only made for illustrative purposes and in the next paragraphs we bring into the analysis Ricardo's "fundamental law of distribution", that is, the inverse relationship between the wage rate and the rate of profit (Kurz, 2018). With the above in mind, we differentiate the relative prices with respect to the rate of profit and we get:

$$\frac{\mathrm{d}}{\mathrm{d}r}\left(\frac{P_A}{P_B}\right) = \frac{\mathrm{d}}{\mathrm{d}r}\left[\frac{wL_A + r(wL_A + K_A)}{wL_B + r(wL_B + K_B)}\right] = \frac{w(K_A L_B - K_B L_A)}{(wL_B + rwL_B + rK_B)^2}$$

Since, the denominator of the above fraction is squared and therefore is always positive, it follows that the sign of the above derivative depends exclusively on the term

$$K_A L_B - K_B L_A = \left(\frac{K_A}{L_A} - \frac{K_B}{L_B}\right) L_A L_B$$

Thus we may write

$$\text{sign}\left[\frac{d}{dr}\left(\frac{P_A}{P_B}\right)\right] = \text{sign}\left(\frac{K_A}{L_A} - \frac{K_B}{L_B}\right) L_A L_B$$

The profit rate also affects the relative prices, but only in a limited and theoretically predictable way while its effect lessens with the passage of time if we invoke Ricardo's view of the long-term downward trend in the rate of profit. If, for example, the rate of profit was hypothesized at 5%, then the difference between relative prices and relative quantities of labour is reduced to approximately 3.7% (see Table 3 and Figure 1) and in the extreme case that the rate of profit is assumed zero, there is no deviation between relative prices and the relative quantities of labour, which is another way to say that the labour theory of value holds absolutely. Table 3 below presents selected results of our experiments with different profit rates starting from zero and increasing it each time by 2.5% percent until we reach the 100% taken as a kind of a maximum possible rate of profit. It is important to note that at the time that Ricardo was writing both the assumptions of 10% and 100% rate of profit were rather extreme and the economy's rate of profit should lie somewhere between these two percentages.

Table 3: Relative prices and elasticities for selective rates of profit

r	0%	5%	10%	20%	40%	62.5%	70%	80%	90%	100%
P_A/P_B	1.000	1.037	1.070	1.127	1.210	1.275	1.293	1.31	1.332	1.192
e		0.026	0.053	0.086	0.114	0.119	0.118	0.117	0.115	0.112

In Figure 1 below we show graphically the relation between the rate of profit and the path of relative prices
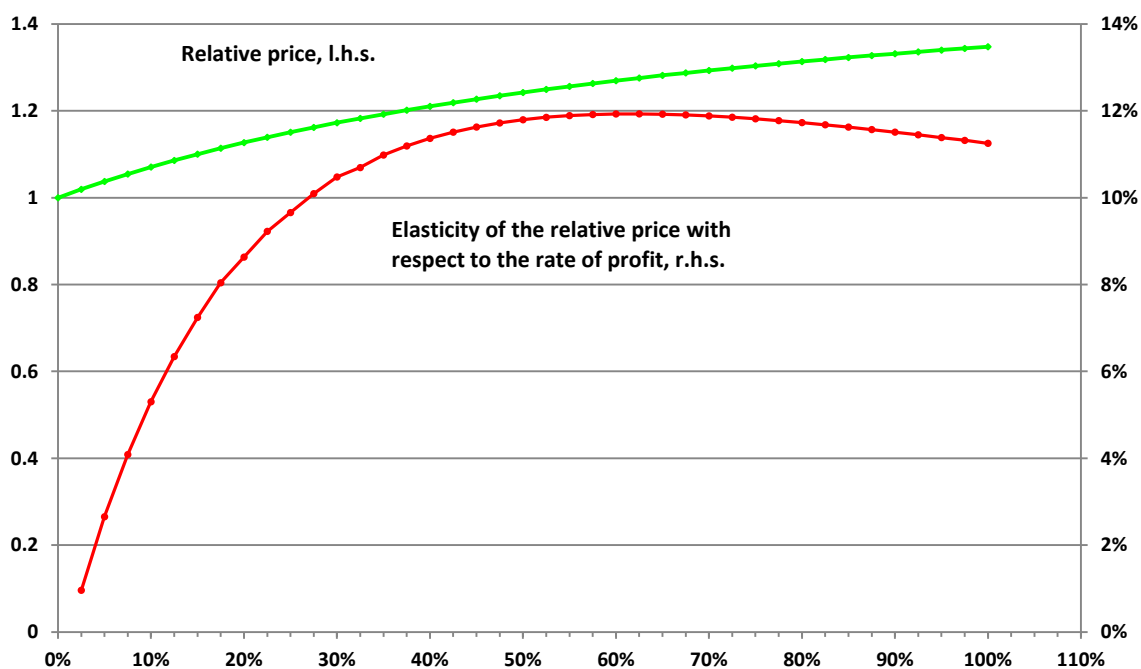

Figure 1: Relative price, elasticity and rate of profit

We observe that the deviations between relative labour values and relative prices, shown on the left hand side (l.h.s.) axis, are directly related to the rate of profit shown on the horizontal axis; the deviations start from zero, when $r=0\%$ and $P_A/P_B =1$ and as the rate of profit rises the deviations also increase but at a decreasing rate. For example, when the rate of profit doubles (say from 10% increases to 20%), the deviation between relative prices and relative labour times increases from 7% to 12.7% (see Table 3 and Figure 1). From the results displayed in Table 3 and Figure 1 it becomes abundantly clear that past a point the relative price becomes increasingly less sensitive to changes in the rate of profit. In effect, the second derivative of relative price with respect to the rate of profit gives

$$\frac{d^2 \left(\frac{P_A}{P_B}\right)}{dr^2} = -\frac{2w(K_A L_B - K_B L_A)(wL_B + K_B)}{(wL_B + rwL_B + rK_B)^3}$$

Clearly, if the capital-labour ratio in the production of commodity A is greater than that of commodity B, therefore, it follows that the second derivative will be negative, which is another way to say that the relative price path will be concave.

Thus, it comes as no surprise that the elasticity of relative price with respect to the rate of profit, e, displayed in Table 3 is smaller, in fact, much smaller than one.[6] In particular, we have,

$$e = \frac{d \left(\frac{P_A}{P_B}\right)}{dr} \cdot \frac{r}{\left(\frac{P_A}{P_B}\right)} = \frac{w(K_A L_B - K_B L_A)}{(wL_B + rwL_B + rK_B)^2} \cdot \frac{r}{\frac{wL_A + r(wL_A + K_A)}{wL_B + r(wL_B + K_B)}}$$

$$= \frac{w(K_A L_B - K_B L_A)}{(wL_B + rwL_B + rK_B)} \cdot \frac{r}{(wL_A + rwL_A + rK_A)} < 1$$

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[6] The estimation of elasticities is based on the application of midpoint formula.

As a consequence, the elasticity of the relative prices with respect to the rate of profit measured on the right-hand side (r.h.s.) axis of Figure 1 increases each time by a decreasing rate until the attainment of a maximum and then for very high and at the same time unrealistic rates of profit turns to a downward direction. The results in Table 3, as well as those shown in Figure 1, are not far from those one expects to find in actual economies and therefore are realistic and lend overwhelming support to Ricardo's intuition.

Our analysis implicitly addresses the issue of changes in the other distributive variable, that is, the wage, which are not hard to figure out. The idea is that an increase in the wage rate causes a decrease in the rate of profit and thus the estimated relative prices come even closer to relative labour times. The converse is true if the wage falls. In both cases, Ricardo argues, the effect of a changing wage is minimal and predictable as we showed above.

In terms of the numerical example of Table 1, Ricardo argues that a rising wage results in a fall in the usual rate of profit. Hence, the price of corn will remain the same, since we only have a redistribution between wages and profit, their sum remaining unaltered. In the case of the price of cotton, the manufacturer estimates a profit on his machine equal to 9% instead of 10%. The final price, therefore, will be £5,995, and the relative price will be 1.09. We observe, firstly that a fall in the rate of profit by only 1% made the relative price of production to come even closer to their respective labour times. Secondly, a significant reduction in profits by £155 (=10% X £1,550 total profits) leads to a change in relative prices by only 1%. Ricardo, after a kind of sensitivity analysis, concludes:

> The greater effects which could be produced on the relative prices of these goods from a rise of wages, could not exceed 6 or 7 per cent.; for profits could not, probably, under any circumstances, admit of a greater general and permanent depression than to that amount. (*Works* I, p. 36)

In terms of our more general example with capital employed by the two sectors and further assuming that $r = f(w), \frac{\partial r}{\partial w} < 0$ and $\frac{\partial K}{\partial w} = 0,$ we get

$$\frac{\partial \left(\frac{P_A}{P_B}\right)}{\partial w} = \frac{\left[\frac{\partial r}{\partial w} w - (r + 1)r\right](K_A L_B - K_B L_A)}{(wL_B + rwL_B + rK_B)^2}$$

A result which is very similar to the one derived above with a constant wage and a variable rate of profit. Since the bracketed term is negative and the denominator is positive the direction of price movements depends on the capital-labour ratio. In this particular case, it is not hard to show the concavity of the trajectory of relative prices as well as the inelastic nature of relative prices with respect to changes in wages.

Ricardo continues by introducing a third and final modification to his theory of value, that is, the differences in the time that elapses between the beginning and the completion of the production process when the product becomes available for sale. Ricardo sets up an example of two commodities A and B and stipulates a uniform rate of profit (r=10%). In industry A we have an investment of £2,000 (40 workers times a £50 annual wage) where £1,000 is invested in the first year and the rest in the second year. At the end of the second year the exchange value of the commodity must be £2,310 and it is estimated as follows:

$$P_A = \underbrace{1,000 * (1 + 0.10)}_{\text{First year}} + \underbrace{1,000 * (1 + 0.10)^2}_{\text{Second year}} = \text{£2,310}$$

The idea is that the estimation of the price in the second year must account for the fact that the producer should have estimated a 10% profit rate for his capital in the first year that he did not invest and 10% for the investment in the current year. By

contrast, in industry j all the money is invested in the first year so the exchange value of the commodities will be:

$$P_B = \text{£}2,000 * (1 + 0.10) = \text{£}2,200$$

We observe that the same quantities of labour give rise to two different prices. The deviation arises precisely because of the assumption of a given rate of profit and also of different turnover times, which make relative prices to differ from relative labour times.[7]

> This case appears to differ from the last, but is, in fact the same. In both cases the superior price of one commodity is owing to the greater length of time which must elapse before it can be brought to market. […] one commodity is more valuable than the other, although no more labour was employed on its production. The difference in value arises […] from the profits being accumulated as capital, and is only a just compensation for the time that the profits were withheld. (*Works*, I, p. 37)

It follows that the inclusion of turnover time modifies the initial principle. We observe, once again, that deviations of relative prices from relative labour times, despite the significant differences in turnover times, are negligible. In terms of Ricardo's numerical example, the deviation will be £2,300/£2,200=1.05, that is, a 5% deviation

$$\frac{P_A}{p_B} = \frac{L_A(1 + r)^{t_A}}{L_B(1 + r)^{t_B}}$$

where t_A and t_B refer to turnover times of commodities A and B, respectively. We observe that the turnover times, as in the previous cases, play a secondary role in the

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[7] This assumption led Marshall to the conclusion that Ricardo like neoclassical economists accepts a cost of production theory of value, which includes 'time or waiting as well as labour' (Marshall, 1920, p. 672)

determination of relative (equilibrium) prices, since there cannot be huge differences in turnover times between industries so as to affect relative prices in any significant way. By taking the derivative of relative price with respect to the turnover time of industry A we arrive at the following expression:

$$\frac{\partial\left(\frac{P_A}{p_B}\right)}{\partial t_A} = \frac{L_A}{L_B}\left[(1+r)^{(t_A-t_B)}\right]\ln(1+r)$$

The above formula indicates that the relative labour times continue to be the most important determinant of the relative prices and that the relative prices are not that responsive to changes in the turnover times. As a matter of fact the elasticity of the relative prices with respect to the turnover of commodity A will be

$$\frac{\partial\left(\frac{P_A}{p_B}\right)}{\partial t_A}\frac{t_A}{\left(\frac{P_A}{p_B}\right)} = t_A\ln(1+r) < 1$$

which in terms of Ricardo's numerically sensible example is equal to 0.0199, that is, the elasticity of relative price of commodity A with respect to the turnover time is highly inelastic.

From the above discussion it follows that Ricardo's insights were reasonable, however, it was impossible for him to make the next step, that is, to test the validity of his propositions empirically. Nowadays, economists have access to a wealth of relevant data which with the currently available quantitative methods can subject to empirical testing Ricardo's theoretical insights. As a matter of fact, time and again it has been shown that the estimated natural prices are closely related to labour time contained in commodities. The available old econometric studies and observations on

the movement of prices lend overwhelming support to Ricardo's insight.[8] More recently, the input-output studies show that the relative prices of production and the relative labour times are surprisingly close to each other and that both are close to market prices (Shaikh, 1984 and 2016; Tsoulfidis and Maniatis, 2002, Tsoulfidis 2008, *inter alia*).

4. RICARDO'S PRINCIPLE OF RELATIVE PRICES TESTED

Ricardo's labour theory of relative prices is not necessarily cross sectional but intertemporal in the main (see also Shaikh, 1984, 2016 and Kurz, 2018). In fact, Ricardo argued that changes in relative prices over time are explained not by changes in wages (and therefore we do not have a cost of production theory) but rather by changes in the labour time required for their production. Ricardo after emphasizing the limited effect of changes in wages on the relative prices, states emphatically:

> In estimating, then, the causes of the variations in the value of commodities, although it would be wrong wholly to omit the consideration of the effect produced by a rise or fall of labour [i.e., wages] it would be equally incorrect to attach much importance to it; and consequently, in the subsequent part of this work, though I shall occasionally refer to this cause of variation, I shall consider all the great variations which take place in the relative value of commodities to be produced by the greater or less quantity of labour which may be required from time to time to produce them. (*Works* I, p. 34)

We do know that the results of the various measures of price-value deviations are not too different and also point to the same conclusion. For example, if the mean absolute weighted deviation is relatively small, the much celebrated (Steedman and Tomkins, 1999) bias-free of numéraire d-statistic of deviation does not show something quite different (see Mariolis and Tsoulfidis, 2016, ch. 4). Furthermore, we expect that if the

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[8] The first econometric studies that test the explanatory power of relative labour times on relative prices at the industry level have been conveniently summarised in Semmler (1984, ch. 5).

Ricardian relative prices and relative labour times are close to each other in cross-section data, this closeness does hold also in intertemporal regressions. The idea is that the size and direction of deviations remain pretty much the same with the passage of time. In what follows, we just cite some evidence from a host of empirical studies. Our focus will be on the intertemporal comparisons which are no doubt closer to Ricardo's spirit. Thus we may write the following econometric specification:

$$\Delta P_{ij\Delta t} = a + \Delta\lambda_{ij\Delta t}$$

For this purpose, we take input-output data in constant 1985 prices from Japan's economy using a circulating capital model (for further details and estimates, see Tsoulfidis 2008) and by testing the intertemporal hypothesis, we arrive at the following results which are portrayed in the following set of figures, where the price-value deviations of the year 1970 are regressed against each of the years 1980, 1985 and 1990. In each of the panel of four graphs, we display the regression line and the OLS results of the regression. The slope coefficient in each of the four regressions is highly statistically significant. It is interesting to note that it might be true that relative prices deviate from relative values (although not significantly so) in each of the years tested; however, these differences change very slowly over the years. Thus it comes as no surprise that the correlations remain high even though the years under comparison are quite distant from each other. In the case of Japan, for example, the cross-section coefficients of determination of price-value deviations of the year 1970 against those of the year 1990 are spectacularly high even though they are twenty years apart!
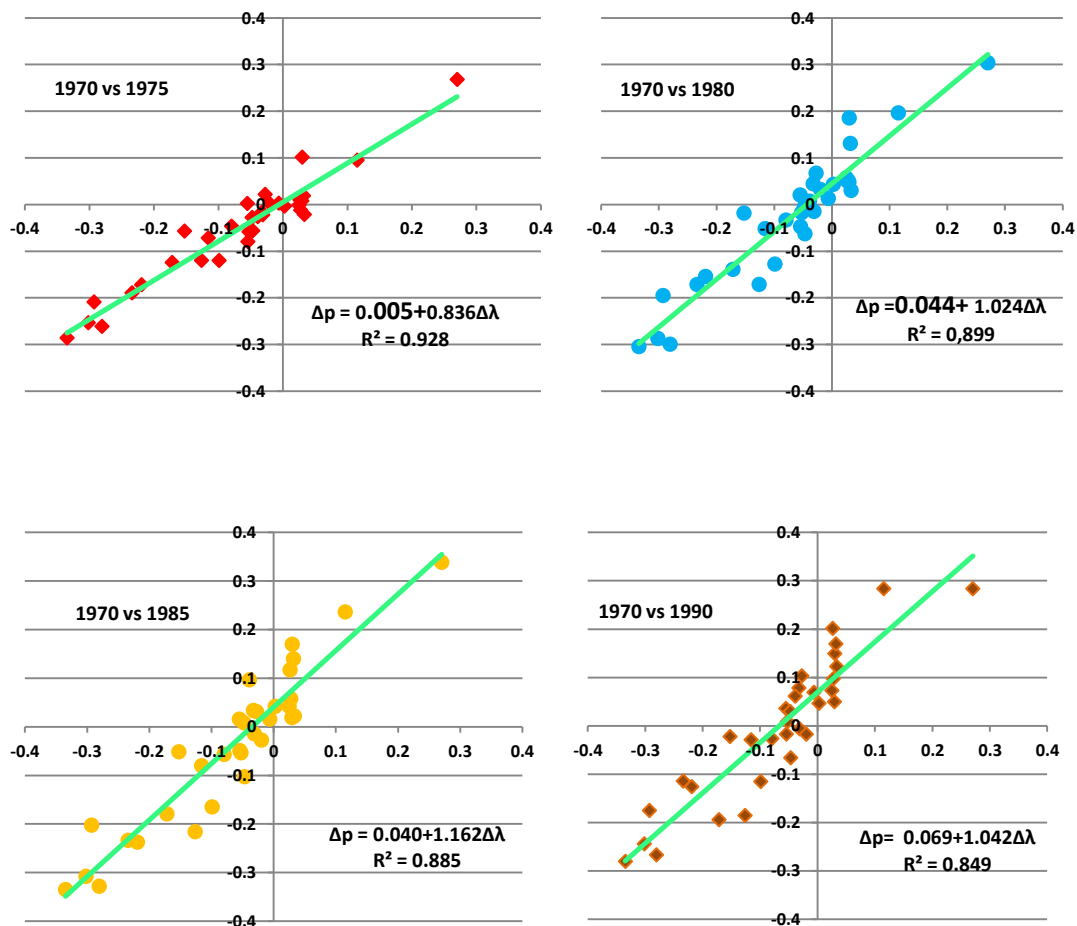
Figure 2 Intertemporal price-value deviations in Japan, 1970-1990

Similar were the results using data from the German economy for the years 1995, 2000 and 2005 using data from the WIOD base (http://www.wiod.org). It is important to emphasize that in these data, unlike the case of Japan, we also used the available data on fixed capital stock. For the construction of the vectors and matrices of capital stock as well as the deflation of the data and other relevant information see Tsaliki et al. (2018) and Tsoulfidis and Paitaridis (2018). In the case of Germany, the regression

results for the three years and using both circulating capital and fixed capital stock are portrayed in Figure 3.
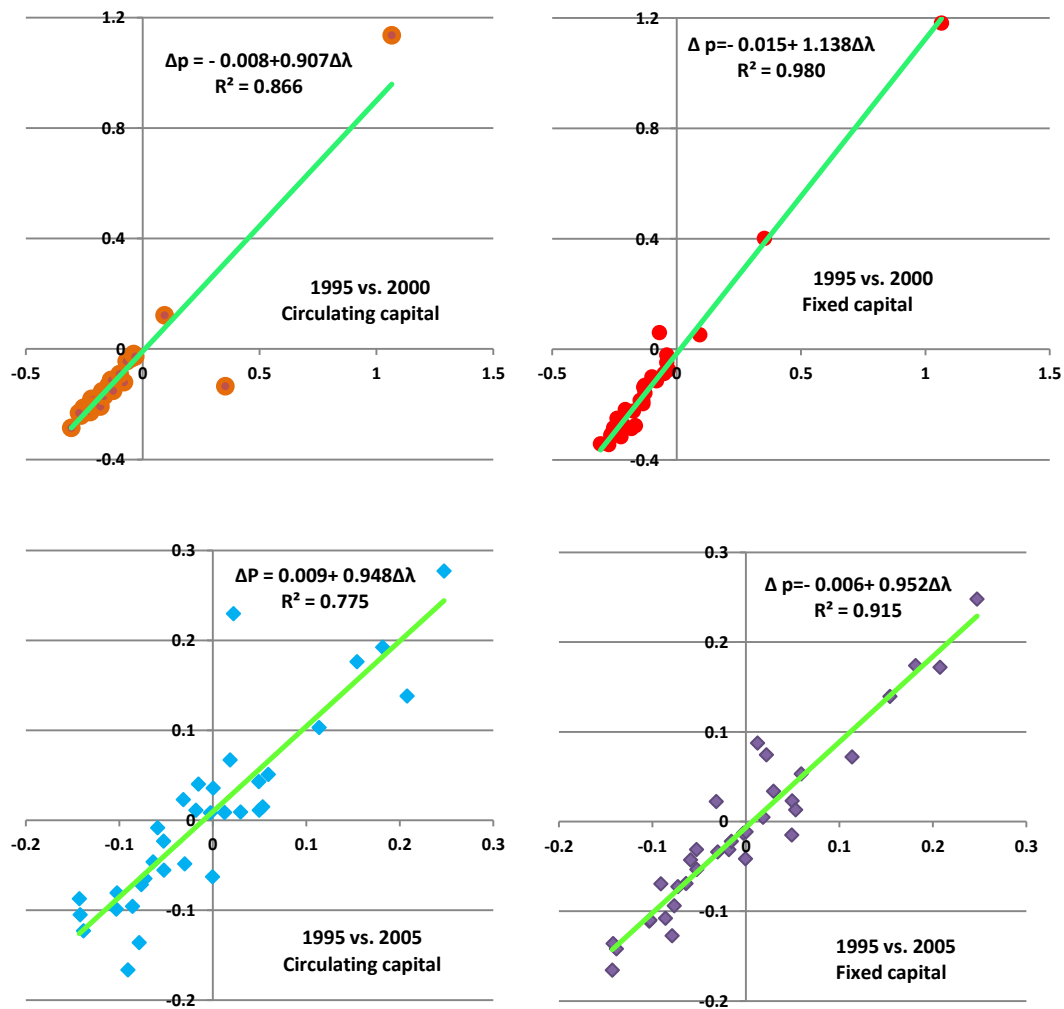

Figure 3 Intertemporal price-value deviations in Germany, 1995-2005

We observe that in both countries the regression results, as time goes by, are getting somewhat weaker with respect to the R-square, however, the fit taking into account

that we are dealing with cross-section data is extremely good and the slope coefficients in all of our regressions are highly statistically significant.

5. CONCLUDING REMARKS

According to Ricardo, labour time is the principal regulator of natural prices, which in turn are theorized as the centres of gravity of ever-fluctuating market prices. The unequal capital-labour ratios between industries, the changes in the income distribution as well as the differences in turnover times affect the relative (natural) prices of commodities, Ricardo argued, but only in a limited and at the same time theoretically predictable way.

In this article we further modelled Ricardo's theoretical insights and showed that one should not expect dramatic changes in relative prices in the presence of fixed capital and in the face of changes in the distributive variables or turnover times. These variables must be thought of secondary importance in determining the relative prices of commodities in comparison to principal determining factor which in Ricardo is the relative labour times. Thus it came as no surprise that Ricardo's major theoretical prediction about the intertemporal change in relative prices as a consequence of change in relative labour times is ascertained in the data from both Japan and Germany, that is, two major economies. Empirical results from a host of other countries cross-sectionally and intertemporally corroborate with Ricardo's great insights.

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