



## **Keeping Land in Capital Theory: Ricardo, Faustmann, Wicksell, and George**

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### Article citation:

Gaffney, Mason. "Keeping Land in Capital Theory: Ricardo, Faustmann, Wicksell, and George." For annual meeting of History of Economics Society, Grinnell College, 25 June 2006. Draft.

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## **“Keeping Land in Capital Theory: Ricardo, Faustmann, Wicksell, and George”**

Mason Gaffney, for annual meeting of History of Economics Society (H.E.S.),  
Grinnell College, June 25, 2006<sup>1</sup>

Revised, July 2006, for submission to the AJES.

### **ABSTRACT**

Most economists today live in a 2-factor world: there are just labor and capital. Land, so central to classical political economy, has been swallowed into capital and “disappeared”. This paper surveys some of the better historical treatments of land and capital, their interrelations, and how they support modern Georgists and Greens who want land to reappear.

David Ricardo had a theory of land rent, of course, plus a practical understanding of compound interest and the relationship of capital to labor. He wove these together in his theory of value. He saw how the flow of investing into creating jobs and incomes led to higher employment; he was concerned that excessive conversion of working capital into fixed capital would reduce that vital flow. This concern would resurface with Mill, Jevons, the Austrians, Wicksell, and possibly—indirectly—in Keynes.

Martin Faustmann showed how to convert irregular pulses of cost and revenue, as in forestry, into the level annual equivalent, to define and find the regular flow of site rent. He made this a performance standard to maximize. In the process he showed how to find the optimal time to harvest and replace forests. As an important by-product his formula shows that rents vary inversely with interest rates, and this effect tempers the effect of interest rates on financial maturity. An even more important by-product (quantitatively) is to adapt Faustmann to time the salvaging of sites under old buildings by clearing and renewing the sites.

He showed how to convert the infinite flow of such rents into a present value, or Discounted Cash Flow. His site value measure combines the DCF of Generation #1 with the Reuse value of a site, providing a mathematical basis for George’s later observations on the damage done by land speculation. There was a flurry of interest in reviving Faustmann, ca. 1957-76. Economists now neglect it again; some industrial foresters may be subverting it for wrong ends.

Böhm-Bawerk and other Austrians revived Ricardo’s concept of working capital vs. fixed capital, using other terminology while still crediting Ricardo’s priority. J.B. Clark and Frank Knight expurgated the Austrian idea of a “period of production” because it would up-end Clark/Knight’s conflation of land and capital. Knight’s Chicago School dominates academe today, while Austrians survive only in odd corners.

Wicksell improved on Böhm-Bawerk in three ways. He “normalized” the model of tree growth, showing how Austrian capital-intensity works as a relation of co-existence (at any moment of time), not just as a relation of sequence. Second, he restated the misunderstood and maligned “wages-fund” theory as a “wages-flow” theory, a basis for reviving Ricardo’s concern that converting working capital to fixed capital would disemploy labor. Third, he insisted that the wages-flow employs land as well as labor—a finding implicit in Faustmann, also.

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<sup>1</sup> The writer thanks Robert Dimand for generous references to the literature; Mary M. Cleveland for editorial advice; and Marianne Johnson for insightful suggestions about integrating the materials.

Henry George divided land price into two parts: DCF from the current use, plus the DCF from all future Generations of use. He observed that the value derived from the later Generations, discounted to the present, often keeps land from its highest and best use today, because of speculation. This effect, immanent in all land markets, makes landowners collectively act like a universal cartel, pushing labor and capital to lands of lower quality, depressing wage and interest rates.

The policy implications are that George's proposed policy of focusing taxes on land value, and relieving commerce, industry, labor and capital from taxation, would enhance human welfare in many ways.

### **I. How Ricardo's theory of value includes land and capital**

Ricardo opens his *Principles* by noting that "the value of (some commodities) is determined by their scarcity alone", and exceeds the value of labor embodied in them (p.5). One example he offers is "grapes grown on a particular soil, of which there is a very limited quantity". That is, a wine's *terroir* adds to its value. On p.7 he generalizes that the value of a commodity is enhanced by the "additional quantity of labor which the cultivation of inferior land requires". That is, it's the labor required on marginal land that equals value. On better land it takes less labor to produce the same value; so rent enters into value (whether as cause or effect we need not settle here). It is misleading to call that a "labor theory of value", as some do. One need only read Ricardo with reasonable sympathy to see that his value theory is quite sophisticated and comprehensive. He assumes, perhaps too sanguinely, that his readers will see the extended implications of matters he covers only tersely.

As to capital, Sections IV and V of Chapter One, "On Value", are all about the incorporation of imputed interest into value. "Value ... varies with the unequal durability of capital, and by the unequal rapidity with which it is returned to its employer" (p.21).

In Chapter XXXI, "On Machinery", Ricardo picks up these ideas again to show how a reallocation of capital from working capital to fixed capital may disemploy labor. Some later commentators have alleged that Ricardo didn't really mean it, or was aberrant when he wrote it. Yet, it follows from his analysis in Chapter One, Sections IV and V. Ricardo does not mention Ludd, and he carefully avoids endorsing smashing of machinery.

It is common to interpret Jevons as anti-Ricardian. This may be a case of Jevons' protesting too much, in his introduction, to differentiate his product from Ricardo's. It may also be a case of one critic copying from another who copied from another, and so on; for if we read Jevons himself he writes that his views "on this subject are in fundamental agreement with those adopted by Ricardo; (which they are) ... (as opposed to) some later economists" (Jevons, rpt 1957, p.222). He then replicates Ricardo's points as cited above (Chap. VII, "Theory of Capital", esp. pp. 222-45).

Austrian economists picked up on Ricardo's basic idea, and gave him credit by describing their finding as "Ricardo Effect". They invented their own terminology, writing of "higher and lower orders of capital". Their treatment of land is somewhat negligent and incidental; yet their "period of production" idea implies a sharp distinction between capital, which has one, and land, which does not. It was for this underlying reason, according to Stigler, that J.B. Clark and Frank Knight feuded so long and intransigently against Austrians Böhm-Bawerk, Friedrich von Hayek, Fritz Machlup, and others (Stigler, 1941, p.278). Clark and Knight aimed to wipe out any bright

line, or any line at all between land and capital. If libertarianism and anti-Marxism were the dominant issues, Chicagoans and Austrians would merge in mutual admiration and support. Instead, rampant Chicagoans let Austrians survive mainly on the margins of the profession.

## II. Martin Faustmann and other forest economists

Martin Faustmann was a German forest economist, writing in 1849, who undertook to find the annual value of a forest site yielding a periodic future stream of revenues. The aim was to find the “highest and best use” (as we say today) of the site; to make commensurable different uses with different yields over different time periods and with different costs. He called this measure *Bodenrente* (ground rent). Anglophonic foresters call it “soil rent”, but soil per se is only one of several components that make forest sites yield rent: rain, temperature, slope, hours and angle of sunshine, and access to markets are as or more important. I will denote it by “B”, for *Bodenrente*, and Anglicize it as ground rent or site rent.

Faustmann began with the planting cost (P) of a tree at time zero. He compounded this

|     |                               |
|-----|-------------------------------|
| n   | Harvest time                  |
| i   | Interest rate                 |
| SFF | Sinking fund factor           |
| P   | Planting cost                 |
| S   | Stumpage (net sale value)     |
| NS  | Net stumpage = $-Pe^{in} + S$ |
| B   | Ground rent                   |

forward to the time (n) of harvest, using a market rate of interest (i). Compounding P makes it commensurable with the net value of the harvest at time “n” (S, for stumpage, which is the sale value less the cost of harvest). Finally, he annualized (or “levelized”, as some prefer to say) this value by multiplying it times the Sinking Fund Factor (SFF).

Algebraically, we now have:

$$SFF = i/[e^{in} - 1] \quad (1)$$

$$B = [-Pe^{in} + S] \times SFF \quad (2)$$

Note that we now have labor, capital, and land compressed into one expression; and maximizing this expression is a performance standard, i.e. the highest and best use of land subject to market wage rates (included in P and subtracted from S) and a market interest rate (found in “i” and the SFF).

Note also that the SFF accumulates the rent of the forest site, year by year with interest, into the value of the final product, S. This is a point on which the great Knut Wicksell insisted, but which most other economists have omitted. Even Wicksell never expressed it as compactly or correctly as Faustmann in (2). Ohlin hit on it in 1921, but never developed it.

To simplify the notation I will now consolidate the items in the brackets into one, calling it Net Stumpage, or NS. Note, however, that these items may include a lot more than the “P” value I am making invisible. There may be any number of intermediate costs and revenues at times other than time zero and time n, the ones shown explicitly. Just compound each item forward to year “n”, using the appropriate number of years in each case. That makes them commensurable so you may add (or subtract) them together. Furthermore, these intermediate revenues may be falling, rather than rising to a climax as in the forestry case. Thus, the formula can be adapted to apply to factories, office buildings, milk cows, or anything. The idea is to consolidate all intermediate values at one point in time, “n”, and then levelize them into *Bodenrente*. Now we have:

$$B = NS \times SFF \quad (3)$$

This levelized *Bodenrente* applies to years zero to “n”. To capitalize the rent in perpetuity, divide (3) by “i”. Faustmann called this the “Site Expectation Value” (*Bodenerwartungswerte*). (In fact, that is how he originally derived his formula, which one may derive in several ways.) Dividing by “i” cancels the numerator of (1), so we have:

$$\text{Site Value} = NS/[e^{in} - 1] \quad (4)$$

The pesky little “-1” in the brackets in the denominator of (4) makes the difference between the Discounted Cash Flow (DCF) of one Generation of land use, and the DCF of infinite repeating Generations of land use.

Foresters have preserved Faustmann’s Formula in a few texts, but have not taken kindly to it. That is because it contains compound interest, which most foresters (not all) wish would go away. They dislike it because timber culture is so capital-intensive that it needs a low rate of interest to justify itself in competition with rival uses of land and capital—and foresters are in the business of justifying timber culture. Instead they generally prefer another performance standard that Germans call *Waldrente*, and Anglophones call Forest Rent. This is  $NS/n$ , where  $P$  is not compounded forward to year “n” but just subtracted from  $S$  as though they were simultaneous (so  $NS = -P + S$ ). This, of course, results in higher values of forest rent.

We will soon see that this “Forest Rent” is the same as Faustmann’s ground rent where a zero interest rate is applied. I have seen no evidence that foresters derived it that way, or understand the relationship, although surely some do. Many of them, however, disparage Faustmann’s result as coming from putting mathematical or green eye-shade values, which they scorn, above forest values, which many embrace rather too romantically. Let us not scoff, for they are sensitive to collateral forest values that one-dimensional financial “rationality” easily neglects. Rather, let us see what economists can learn from this.

Above all, let us not think foresters put no value on time, just because they use a zero rate of interest. They are not maximizing  $NS$ , but  $NS/n$ , that is  $NS$  *per year*.  $NS$  per acre per year is site rent, once they have dismissed compound interest. In practice the forest management regime that maximizes  $NS/n$  is sometimes fairly close to the one that maximizes Faustmann’s Site Rent, so that rough-and-ready foresters have set aside the differences as nitpicking. This is anti-intellectual and caters to innumeracy, and yet it contains an important lesson for economists. This is, when interest rates are low, rent rises, and stands in for interest as a cost of time. We return to this in heading “C”, below.

Naturally, others can be found who anticipated Faustmann, at least in part. Discussions are found in Samuelson (1976), Scorgi and Kennedy (1996), Gane, Ince, Brazee, Lofgren, and others. Ohlin discovered the principle, apparently independently, in 1921, 72 years after Faustmann, but never developed it. Other good discussions are in Bentley and Teeguarden (1965), Pearse (1967), and Scott (1987). David Klemperer has published several articles using the Faustmann logic.

#### A. Capital distinct from land.

Note how Faustmann’s reasoning distinguishes clearly between capital and land. Ever since J.B. Clark, neo-classical economists have conflated capital with land, denying the classical tripartite division of factors into land, labor and capital. Yet, felling, trimming and bucking trunks, and hauling away logs separates a tree from its former site so visibly and materially it is hard to deny. It is true that the capital in the tree includes stored-up site rent, with interest—that

is inherent in the SFF used in Faustmann's formula. We will see later how Wicksell handled this last point.

### B. Two sources of site value.

Site value is seen to consist of two distinct parts. The first part derives from the present use: call it Generation #1, or  $G_1$ . Discount the NS from  $G_1$  to the present in the usual way. Denote site value as "W" (from *Werte*). Add to that the DCF of all later generations,  $G_2$ , as of time "n". This is also "W" (assuming identical future cycles of planting and growth). Discount it to the present. Now we have:

$$W = [NS + W]/e^{in} \quad (5)$$

Solving for "W", we have (4) again:

$$W = NS/[e^{in} - 1] \quad (4, \text{repeated})$$

Some will object, and rightly so, to the simplifying assumption that future cycles exactly replicate the first one. The formulation in (5) is useful when we want to adapt Faustmann to conditions when the expected value of W at time "n" exceeds the value from Generation #1. It is mnemonic to call "W" from Generation #1 the "possessory" value, and value from later Generations the "R" value, where "R" stands for Resale, Reuse, Regeneration, Renewal, or other "Re"-word meaning a new start on the old site. Some call it "speculative" value, because the uncertainty of specific forecasts rises with their futurity and novelty. Anyone pursuing those threads may adapt Faustmann's formulation to untangle them. It waited on Henry George (q.v.) to pursue them seriously. He was moved by observation and intuition, without benefit of formal capital theory. We will see how theory can throw light on the case that troubled George.

### C. Site rent rises as interest rates fall.

This is a most important result, one that is flouted daily in the business press, in academic literature, and in pleas to redistribute wealth and income from rich to poor by lowering interest rates. In the 2-factor world of neo-classical economists, land is just another form of capital; by implication, rents and interest rates must move in sympathy. This has become the working assumption behind many public policies, some introduced from the "left" and some from the "right", but equally mistaken.

When interest rates rise, Site Rents fall. Equation (2) tells us there are two reasons for this. The more obvious reason is that P, the initial Planting Cost, is compounded forward to year "n", using a market rate of interest, before being subtracted from S (Stumpage) in year "n".

The second reason is less obvious, but equally weighty and general: the SFF is also a decreasing function of "i". This is not obvious, because both the numerator and denominator of the SFF are increasing functions of "i". Both approach zero as "i" approaches zero, so we cannot demonstrate the point by the easy *reductio ad extremum* of letting "i" equal zero. Rather we can tabulate values of the SFF to show how it varies with "i". It approaches a limit of  $1/n$  as  $i \rightarrow 0$ . I begin with very low values of "i", so the top row makes the point.<sup>2</sup> Note that the values are rounded.

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<sup>2</sup> Do not despair of evaluating a ratio that approaches 0/0. One of the Bernoulli's solved this long ago, and named the solution for a wealthy patron, so it appears in many calculus texts as "L'Hôpital's Rule".

TABLE 1: The  $SFF = i/[e^{in} - 1]$  (as a percentage, rounded) with different values of the interest rate ( $i$ ) and the term ( $n$ )

| $i$ (%) \ $n \rightarrow$ | 5     | 10   | 20   | 50   |
|---------------------------|-------|------|------|------|
| .1                        | 19.95 | 9.95 | 4.95 | 1.95 |
| .5                        | 19.75 | 9.75 | 4.75 | 1.76 |
| 1                         | 19.50 | 9.51 | 4.52 | 1.54 |
| 3                         | 18.54 | 8.57 | 3.65 | 0.86 |
| 5                         | 17.60 | 7.71 | 2.91 | 0.45 |
| 10                        | 15.41 | 5.82 | 1.57 | 0.07 |

#### *D. When to terminate investment cycles*

The best forest sites, the ones that are “warm, wet, and flat”, are where timber grows fastest, and where succeeding crops may be replanted soonest. Faustmann therefore focused on finding the optimal harvest time, to maximize Site Rent. This turns out to be the year when the value of timber’s current annual growth just covers the sum of interest on the Stumpage ( $S$ ) and the Site Rent ( $B$ ). (Gaffney, 1957, covers the interesting problem of simultaneously finding the highest and best value of  $B$  while also using it to determine itself.)

From Table 1, when  $n=50$  and  $i=5\%$  or more, the  $SFF$  is negligible compared with interest on  $S$ . Practical foresters often just ignore it. However, when  $n=10$  and  $i=5\%$ , the  $SFF$  is  $8\%$ , and plays a larger role than “ $i$ ” in determining harvest dates. A great deal of timber now matures in less than 20 years, especially in the southeastern United States, where sites are “warm, wet, and flat”, and the Southern Yellow Pine thrives.

When the interest rate falls, easing the pressure to harvest mature timber, site rent rises, partially offsetting and tempering the first effect. So the net effect of interest rates on harvest times is much weaker than the simpler analysis, still found in textbooks, would indicate.

But replacement analysis concerns much more than timber. The greater practical role of Site Rent is in determining when to clear aged buildings and renew the site. Here there is no salvage value, but only a weak and dying cash flow or service flow. Ratcliff (1949) and Gaffney (1964, 1969) have addressed this case.

Here is where Site Rent,  $B$ , is essential to the decision of timing. The salvage value of an old, decrepit, obsolete building is close enough to zero that we may ignore it. Unlike mature timber, it has no growth rate, so we cannot use the simple old formula that capital is mature when its growth rate equals the interest rate. If we were to use that formula for timber, and generalize from it, we would be left with no reason at all to clear and renew sites with old buildings.

The economic reason to tear down old buildings is to salvage their sites for future use, and begin realizing the potential rent. To calculate that rent we pencil out the capital cost of rebuilding, the timing and value of future cash flows, and their likely duration. Then we “levelize” those values, just as Faustmann did for timber (Eqns. 2 & 3).

In this case it is customary and intuitive to make a procedural change from Faustmann. Instead of compounding all values forward to the terminal year, "n", discount all future values to time zero, add them up, and subtract the initial capital cost, P. Then levelize them and convert them into the annual rent by applying the Installment Plan Factor (IPF), which is the same as the SFF multiplied by  $e^{in}$ . Thus the result is identical with compounding each value forward to year "n", and applying the SFF. I bring it up here because it corresponds more closely with the way builders see the matter, just as Faustmann corresponds with how foresters see it.

Recent neo-classical theorists have done little with the question of when it is economical to salvage and renew urban sites. It is a practical and theoretical question of high and growing importance. I can only surmise that this neglect results from recent neo-classical training that suppresses thoughts that entail distinguishing land values from building values. This training, in which moderns are heavily invested, tells them there are only two factors: labor and capital.

Notice, now, how the rate of interest affects Site Rent. Higher interest rates mean lower Site Rents. Thus, instead of speeding the end of life of old capital, higher interest rates retard it, by lowering Site Rents, which are here the only cost of time; the only economic force prompting clearance and renewal. This makes sense in its own right; a builder faced with higher interest rates will perceive their force on his decision in his own way. But if economic theory is to help him, or predict what he will do, it needs the help of something like Faustmann's formula.

#### *E. The flurry of interest in Faustmann, ca. 1957-75*

The revival of Faustmann attracted a good deal of interest after 1957. Jack Hirshleifer circulated it among the economic "elite", while many forest economists saw it as a useful tool. Samuelson endorsed it. Among economists this interest died out after a while. Both Hirshleifer and his colleagues Alchian and Allen later published works in which they regressed to the old winery example where wine is immature so long as its value is growing faster than the interest rate—with never a mention of Site Rent. Samuelson omitted it when holding up his end of the Cambridge Controversy, where it might have helped his case.<sup>3</sup> I can only surmise that this regression resulted from their discomfort, as neo-classical economists, with distinguishing land from capital.

The support of industrial foresters was something of a Faustmannian bargain. Industry economists coopted Faustmann to put a gloss of rationale on rapid cutting, even abusive cutting, such as clearing steep slopes, polluting streams and fisheries, roading erosively, endangering rare species, and so on. They focused their attack on the U.S. Forest Service, using R.F.F., Inc. as a vehicle. Their influence on R.F.F., Inc., is manifest in the list of major contributors, listed in every Annual Report, that kept that organization afloat after the Ford Foundation withdrew its support after 1971. This writer, an R.F.F. Associate researching the undertaxation of forests and forest land, was blandished and courted by timber lobbyists, declined, and soon found it better to accept work elsewhere. Trying to publish such findings in academic journals has been a nightmare: industry tentacles reach deep into the clerisy.

America's schools of forestry have become adjuncts of the industry, as their deans troll for grants and avoid offense. They influence many scholarly journals. A leading Professor of Forestry threatened to retaliate professionally if I wrote that timber owners in 1944 secured

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<sup>3</sup> My esteemed colleague Mary M. Cleveland thinks not, but I have yet to prove her wrong.

preferential capital-gains tax treatment, while troops overseas were receiving 1040 Forms at mail-call—a soldier's meager pay is "ordinary" income. A current incident illustrates the culture of complaisance with industry demands. An apolitical graduate student in the School of Forestry at Corvallis, Daniel Donato, found evidence that certain salvage logging practices retard regeneration. This finding troubled industry officers and allied State legislators. These admonished the Dean, writing in the familiar, insolent tone a king might use with his jester. The Dean and some senior professors joined an effort to stop *Science* from publishing the findings (Boxall and Wilson, 2006).

### III. Eugen von Böhm-Bawerk and other Austrians

Böhm-Bawerk, as is well known, published a weighty tome on capital theory, dueled over it with J.B. Clark, and helped found the Austrian School of economics. He dealt with financial maturity of timber, and discounted cash flow, and other basic elements of finance. In debating Clark, insofar as one can follow their involuted arguments, Böhm-Bawerk insisted that capital has a "period of production", and stated or implied that land has none—a solecism to Clark. George Stigler, echoing Clark and Knight, objects to the Austrian-School concept of a "period of production" because it presumes a difference between capital, which has one, and land, which does not (Stigler, 1941, p.278).

There is no clue that Böhm-Bawerk ever heard of Faustmann, or consulted the vigorous and extensive German literature on forest economics. Like Alchian and Allen later, Böhm-Bawerk simply tells us that timber is immature so long as its value is growing faster than the interest rate. Wicksell archly expressed an expository problem that also stands between Böhm-Bawerk and most readers: "he loves to pile up difficulties in order that he may remove them later".

### IV. Knut Wicksell

Wicksell modestly paints himself as a "Swedish Austrian", a disciple of Böhm-Bawerk. He then proceeds to improve on the master.

One great contribution is his normalizing Böhm-Bawerk's model of growth over time, a relation of sequence, into the corresponding relation of coexistence. His model uses maturing wine as the example, and economists often call it the "grape-juice model" (Lectures, pp. 172-76), but it applies to all growing capital like trees. Here he deftly converts Böhm-Bawerk's model of an even-aged forest into the corresponding normalized or "going-concern" forest, where ages are staggered so there is at any time one tree of every age. The whole life span of a single tree is then represented simultaneously by a cross section of the normalized forest.

Wicksell then shows that the higher capital-content of a longer-lived tree (the accumulated interest over time), which Böhm-Bawerk conceives in the time-dimension, makes the normalized forest equally capital-intensive at every moment in time. A mathematician might sniff that he merely inverted the order of integration. Perhaps that is all he did mathematically and conceptually, but he did it in an economic model, while others were struggling unsuccessfully to fit Böhm-Bawerk's ideas into their neo-classical models from which time had been largely banished—and rejecting or isolating the ideas when they could not fit them into their static, Clarkian models. From 1870-1920, "much of the economics was ... an economic theory of

acapitalistic production. Considerations of capital theory proper ... simply disappear from the picture" (Robbins, 1934).<sup>4</sup>

Wicksell immediately used his normalized model to demonstrate how a lower interest-rate makes for a more capital-intensive economy, as trees (or wines) are replaced slower, so there is more timber outstanding at any given time, while the labor of planting and harvesting remains constant. Conversely, a lower wage rate leads to shorter cycles so that more labor is employed per unit of capital. (Lower taxes on labor would have the same effect.) Factor proportions will adjust to match any given supply of capital with any given supply of labor.

Thus, Wicksell used Böhm-Bawerk to complete Ricardo's and J.S. Mill's and Jevons' cruder demonstrations that factor proportions are malleable, and tend to an optimal equilibrium with full employment of labor and capital, both. Adam Smith's invisible hand had dealt mainly with commodities. Ricardo and Mill extended the idea to comprehend factor proportions, as well. Marshall regressed in this respect toward Smith when he developed supply and demand analysis mainly w.r.t. commodities with limited markets. The profession generally has followed Marshall's commodity-based model. Even Keynes, dealing with aggregate supply and demand, limited demand by a propensity to save (in excess of investing) that allegedly rose with income. Keynes, while crediting Wicksell with some other inspirations, paid no heed to Wicksell's simple "grape-juice" demonstration of the variability of factor proportions. Keynesians for decades brushed such questions aside as mere "structural" issues, unworthy of their time. Latter-day "supply siders" and "growthmen" continue to shunt them aside, focusing on raising GNP with fixed factor proportions as the single-minded goal of thought and policy.

Friedrich and Vera Lutz (1951) repeat Wicksell's normalized model, but then turn around and botch it, in an otherwise flawless book. They use their own rather stilted terminology, from which four-letter words like "land" and "site" are absent. They cite neither Faustmann's nor Wicksell's previous work. Having first arrived at Faustmann's solution with a single-aged stand of timber, they claim the normalized model leads them back to a longer optimal rotation period. In a word, they do this by including land in the single-aged model, then omitting it from their normalized model. The details are in Gaffney (1957).

Wicksell also contributed a correction and revival of the misapprehended "wages-fund" theory. He correctly renamed it the "wages-flow" theory. It is the flow of capital into investing, not a fixed fund of capital, that hires workers and creates incomes. Wicksell showed how the flow/fund ratio rises when capital turns over faster, as in the grape-juice model, so a fixed fund of capital can generate more investing whenever a surplus of labor seeks jobs. Or, by slowing its turnover, it can afford more investment opportunities when the supply of capital is in surplus.

Thus, Wicksell laid the groundwork for a macro-economics, and policy measures derived there from, that would be based on real turnover of real capital, and not just flows of spending money. Earl Rolph, in a stimulating but unpublished ms, tried to show that Keynes' *Treatise on Money* incorporated such ideas—to which Rolph was cool. If Keynes did that then, he dropped it from his *General Theory* which became the basis of standard macro theory, for years. Macro is the poorer for it. Wicksell's turnover of real capital is what could have bridged and still should

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<sup>4</sup> It was Auguste Comte who wrote that all science consists of relations either of coexistence or sequence. Clark confined neo-classical economics into a box that shut out relations of sequence. Wicksell's model neatly combines both kinds of relations.

bridge the chasm between macro and micro, and save macro from the futility and frustration of latter-day devices like the Phillips Curve, growth theory with fixed proportions, rational expectations, and Barro's twist on the Ricardian Equivalence Theorem.

A third Wicksell contribution was to incorporate land into his capital theory. He insists in his "wages-flow" theory that the flow of investing pays not just wages but site rent. This point was already inherent in Faustmann's use of the SFF to define rent, but there is no evidence that Wicksell was any more aware of Faustmann than was the Austrian, Böhm-Bawerk. Faustmann had never related his work to any macro-economic idea like the wages-fund theory. Considering that all were central Europeans who published in German, it was a rueful isolation of related work into airtight compartments, to the impoverishment of all.

A common way to dismiss Wicksell and Böhm-Bawerk is to allege that their theories and models apply only to timber, and a limited range of kinds of living and appreciating capital like timber and wine. My colleague Karl Uhr (R.I.P.), a lifelong student of and leading authority on Wicksell, taught that. Hans Brems, a native Dane steeped in Wicksell, held a related opinion. Assets like timber and wine are now generally called "Point-input, Point-output" assets (PIPO), and treated, if treated at all, as a trivial, exceptional special case.

This is a mathematical error. The PIPO case is the building block for all capital theory, from which its other familiar formulae are derived by summation. Discounted cash flow, sinking fund, compounded cash flow, installment plan factors, capitalization in perpetuity, internal rate of return ... all can be derived, jointly or separately, as summations of geometrical progressions of PIPO cases. What is true for the basic element is likely to hold also for the summations. Earlier, above, (Section II, C) I pointed out how Faustmann's formula, ostensibly dealing with timber growth, can be adapted to deal with all capital assets, with any time-patterns of inputs and outputs whatever.

To respond to the error of isolating the PIPO case, the writer has published a set of models showing how to replicate Wicksell's grape-juice model with depreciating assets, or with a constant-valued asset of finite life-span (Gaffney, 1972). The last, the "cow-sow model", is the easiest to grasp and requires little mathematics or capital theory. A cow is assumed to yield a constant "milk-flow" over 10 years, then suddenly be slaughtered for the hide and meat which are sold for exactly the original cost of birthing and weaning. There is a herd of cows whose ages are staggered. Cut the lifespan to 5 years and the ratio of cows (capital) to the costs of slaughter and birthing (labor) is halved. Let each cow require a fixed complement of land, and the ratio of land to labor is likewise halved.

The "clean-sock" model is even simpler, more homely and intuitive. To have a clean pair of socks every morning, I can have one pair of socks and wash them by hand every night. (Some can recall that situation, as soldiers or students.) If I choose to save labor by washing once a week, I will need seven pairs of socks, with added storage space, a hamper, a washer, and so on. Baumol (1965) makes a similar point, *mutatis mutandis*, with his cash flow model.

Perhaps Gaffney, like Faustmann, published in the wrong place at the wrong time, for his findings went unnoticed by the macro-economists of his day. Or perhaps Gaffney got it wrong: that is for others to judge.

## V. Henry George

George on capital theory is best forgotten. He is best known for his observations on land. The gist of *Progress and Poverty* is that land markets function badly, keeping the best lands from their highest uses and creating an artificial scarcity. He likens this to a universal cartel. George's goal is to break the cartel, thus creating jobs, raising wage rates, raising production and living standards.

We find in *Progress and Poverty* three major reasons why land markets (absent land-value taxation) perform badly. One is "land speculation", conceived as "holding for the rise" and, by strong implication, as a "store of value" without regard to current use. A second is the appetite of the rich for land as an item of consumption for recreation, for amenity, and for show, as exemplified then by English noblemen's "deer parks", and today by the vast manorial holdings of rich Americans in once-rural counties, marina space for their mega-yachts, airspace for their private planes, urban land for grounds around their mansions, trophy golf courses and polo fields, hunting clubs, and so on. A third is that our Solons base taxes on using and improving land, with hardly any on just holding land. The "excess burden" of such taxation takes the form of underusing land. Gaffney (2006) has undertaken to show this excess burden in terms of the capital theory that George lacked.

George's effort to formalize his capital theory is weak. He lacks any mathematics of finance. He flays the wages-fund theory without citing any advocate, or seeming to understand it. He attributes the productivity of capital solely to living things like livestock. Then other uses of capital, which he says are not productive, must pay interest because of arbitrage. Let us forgive him these trespasses; they are isolated from his major thesis. His powers of observation, and his intuitions about land values, were sound and original, and may be formalized in terms that would satisfy a Wicksell or a Faustmann.

We can express his idea of land speculation in terms of Eqn. 5. Recall that  $G_1$ , for Generation #1, derives from the site rent,  $B_1$ , in current use;  $G_2$ , for Generation #2, is the value in subsequent use.  $G_1 = B_1 \times \text{DCFF}_{(1-n)}$  and  $G_2 = B_2/i$ , where each  $B$  is the annual rent corresponding to the respective  $G$ . Now make  $B_2 \gg B_1$ . Divide  $G_2$  by  $e^{in}$  to discount its value to time zero; call the result  $W$ , as before. Now the value of  $W$  is dominated by  $G_2$ .

$$W = B_1 \times \text{DCFF} + B_2/ie^{in} \quad (6)$$

The DCFF falls only gently as " $i$ " rises, for terms less than about 20 years. The second term on the right side of (6), however, the Resale or Reuse value,  $R = B_2/ie^{in}$ , falls steeply as " $i$ " rises. Table 2 shows the sensitivity of the two terms to " $i$ " and " $n$ ".

Table 2: Sensitivities of the DCF and the Resale Factor to interest rates ( $i$ ) and lifespans ( $n$ )

### A. The DCF Factor $(1-e^{-in})/i$

| $i \backslash n$ | 10   | 20    | 30    |
|------------------|------|-------|-------|
| 0.04             | 8.24 | 13.77 | 17.47 |
| 0.08             | 6.88 | 9.98  | 11.37 |
| 0.12             | 5.82 | 7.58  | 8.11  |
| 0.16             | 4.99 | 6.00  | 6.20  |

B. Resale value factor ( $1/[ie^{in}]$ )

| $i \backslash n$ | 10     | Ratio | 20     | Ratio | 30    | Ratio |
|------------------|--------|-------|--------|-------|-------|-------|
| 0.04             | 16.758 | 1.000 | 11.233 | 1.000 | 7.530 | 1.000 |
| 0.08             | 5.617  | 0.335 | 2.524  | 0.225 | 1.134 | 0.151 |
| 0.12             | 2.510  | 0.150 | 0.756  | 0.067 | 0.228 | 0.030 |
| 0.16             | 1.262  | 0.075 | 0.255  | 0.023 | 0.051 | 0.007 |

"Ratio" is the ratio of the resale value factor for 0.04, 0.08, 0.12 and 0.16 to that for 0.04.

To simplify, we are not far off the mark to postulate that a struggling start-up entrepreneur—the kind that gives capitalism its dynamic—can place no value at all on  $R$ , the resale value. This entrepreneur is desperately seeking capital and paying high interest rates that devalue the Resale Value Factor so much he ignores it. At the other extreme a passive investor seeking a store of value that keeps with no care might place little value on the first term, and discount the  $R$ -value at a low rate. The start-up entrepreneur, financed with costly venture capital, would view the passive investor as a “dog-in-the-manger”, as George did. The passive investor would view the newcomer as a nuisance and interloper today, and a possible meal-ticket for tomorrow. Cleveland (1984) has developed this theme at length.

$W$  grows rapidly as time passes and the present approaches “ $n$ ”, where  $B_2$  is to displace  $B_1$ . This annual increment may be high enough to warrant holding the land for its appreciation alone. Of course one could also use it at the same time, and some do; but others hold more land than they have time to bother using, or using well or fully.

As an example, my family and I have lived on the same low hill since 1976, a quarter mile from the City’s major shopping “Galleria” and its many satellites, two major interchanges, a railway station, a large hospital, and dozens of little shops and services. 8 of the neighboring plots have not been used during that 30-year period, while new building proceeds in leaps and bounds dozens of miles further out. There are also many householders whose yards and curtilages include an extra lot or two for future resale. Each owner has his own story and reasons, often of a “passive-aggressive” hue, but meantime the lands have about octupled in value, doubling every 10 years, for an annual return of 7.2%. That is more than one can make in the bank, and it is free of any tax on “ordinary” income, and may never be taxed at all.

To accommodate the inchoate dreams of people like my neighboring landowners, young people getting started are priced out of the land market for homes and businesses. The N.Y. Times of June 13 brings the news that “From 1990 to 2004, the number of 25-to-34-year-old residents in the 52 counties north of Rockland and Putnam declined by more than 25 percent. In 13 counties that include cities like Buffalo, Syracuse and Binghamton, the population of young adults fell by more than 30 percent. In Tioga County, part of Appalachia in New York's Southern Tier, 42 percent fewer young adults were counted in 2004 than in 1990.” New York pays to educate them by taxing sales and incomes, mostly from work; then they take their bodies, filled with human capital and the spirit of enterprise, to greener pastures. This is a recipe for decadence and desuetude in a once-vibrant region.

The market may be topping out—who can be sure?—but 30 years at 7.2%, tax-deferred or tax-free, has been a good run. The real growth rate is less than the nominal rate, due to inflation, but real interest rates are also lower than nominal rates, for the same reason, and fully taxable besides. Purists may say the owners would maximize their wealth by using the land as it appreciates, but they don't, which speaks volumes. Economists need to explain what they observe, not just what their ideology says might or should be. It was just such an observation, in the hills above Oakland, that pricked Henry George, originally an investigative reporter and editor, to write *Progress and Poverty*.

Gale Johnson (1950) and Stephen Cheung (1969) have explained the neglect of land in terms of share tenancy. A share tenant will take as much land as the landlord will allow because there is no fixed cost of taking more. Share-cropping creates an incentive structure that motivates the cropper to substitute land for labor (as much as the landowner allows) until the marginal product of land is zero. Our tax system, except for the property tax on land, operates something like share-cropping. We do not pay a tax for the land we hold, but only for the use we make of it: we “share the crop” with the fisc. The analogy needs modifying, because we pay to buy land, and forego gain by holding it, unlike the share tenant. Yet at the same time we accrue gain “in our sleep”, as Mill said, by just holding it. The market as a whole operates against that fiscal background, which bids us substitute land for capital and labor.

## V. Conclusion

Ricardo, Faustmann, Böhm-Bawerk and other Austrians, and Wicksell all contributed mightily to capital theory. Ricardo, Faustmann, Wicksell, and Henry George also contributed to our understanding of land values and rent. George, the least mathematical but the most observant of the lot, pointed up major flaws in land markets, exacerbated by flaws in tax policy. We can use mathematics and insights from the others to expound more fully what George merely observed, and help evaluate his proposals to raise wage rates, and marginal returns on investing, by perfecting land markets.

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