New goods and the measurement of real economic growth

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1. Introduction

Measured economic growth has slowed in advanced economies since the mid 1970s. A number of explanations have been advanced, one being that the slowdown is an artifact of the statistical system. In particular, one suspected source of error is the way the statistical system deals with the new kinds of 'information' products that are central to the current wave of technical change. These goods are often produced with dramatic and historically unprecedented increasing returns to scale.[1] Hence, their introduction is followed by a considerable period of falling prices, much of which may be going unmeasured given the usual lags before new products enter the commodity baskets on which price deflators are based. In addition, there is a general sense that the pace of technical change has been accelerating. The conjecture is that the benefits of this very novelty and the increased range of choice are going unmeasured, and that these factors are becoming more important over time (Diewert and Fox 1997).

A number of analyses have sought to quantify the extent to which new goods are a source of bias in price measurement, and also, therefore, in the measurement of 'real' (i.e. deflated) economic growth (e.g. Diewert 1996; Grilliches 1996; U.S. Senate (Boskin et al.) Advisory Commission 1996; Crawford 1993). The consensus is that there is an upward bias on the order of half a percent per annum. However, the Boskin commission considered only the 'product cycle' biases arising from unmeasured price declines that occur after a commodity first appears on the market. Their estimates do not include any measure of the novelty of new goods as such, nor the effects due to differential impacts by income group.

To aid our thinking, we have constructed a simplified model of an economy, and then used this to explore the effects of introducing new goods on various measures of real economic growth.[2] Our model -- XEcon, for experimental economy -- includes both utility-loving individuals and profit-motivated firms. XEcon also includes a statistician, who computes several variants of the time series of real GDP, based on alternative empirical price deflators. Finally, XEcon has an omniscient creator, who can measure social welfare and compute 'true' standard of living indices.

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We begin with a review of the theory of real income measurement in the face of new goods. This is followed by an overview of the XEcon model. Then a set of simulation experiments is described. To anticipate the conclusions, serious measurement error is possible. Moreover, even using 'best practice' methods for constructing empirical price deflators, we can devise situations where the statistician's measure of real GDP ranks economies' growth opposite to the creator's ranking based on both social welfare and 'true' standard of living indices. These paradoxical situations are associated with the introduction of new goods. The impacts of these new goods vary systematically by income group.

2. On measuring real income with new goods

The recognition that the appearance of new goods requires special treatment in the theory of price measurement dates back at least to Hicks (1940). The treatment Hicks offers is premised on a key assumption which we follow: "... comparisons of economic welfare must proceed under the hypothesis of constant wants..... In order to compare the positions of a particular individual in two different situations, we must assume his wants are the same in the two situations. If this assumption cannot be granted, the question whether he is better off in one situation or the other loses all economic meaning" (p. 107).[3]

Interestingly, Hicks considered the introduction of new goods a "minor difficulty" (p. 113). In contrast, the most recent System of National Accounts manual (SNA; UN et al. 1993) states that, "... the appearance of new products and the disappearance of old products ... can be the most serious practical problem encountered in the construction of ... price indices" (para 16.7 (d)).

The core of Hicks' framework is shown in figure 1. At time zero, only food is available, so individual choice is constrained (i.e. the choice set is equal) to the positive half of the horizontal axis. Suppose the individual has enough money to buy an amount of food x_0. Shortly thereafter, movies come onto the market. The individual's choice set then expands from one dimension to two, to the positive orthant in figure 1. Then, after some time, food and movie sales settle down at amount x_1, and at a relative price represented by the slope of the budget line x_0x_1b.

According to Hicks, the basic problem is that the period 0 price of the newly introduced good (movies in this case) "become(s) indeterminate" (p. 114). (The period 0 quantity of movies purchased is simply zero.) In this circumstance, a Laspeyres index could still be computed, but the Paasche index is undefined. In turn, the usual propositions to determine whether or not real income has increased, using the Paasche and Laspeyres indices as bounds, cannot be applied.

Nevertheless, Hicks argued that the correct theoretical concept is "the prices, in the I situation that would just make the demands for these commodities (from the whole community) equal to zero" (p. 114, italics and parentheses in original). In our case, movies' reservation price is the lowest relative price movies could

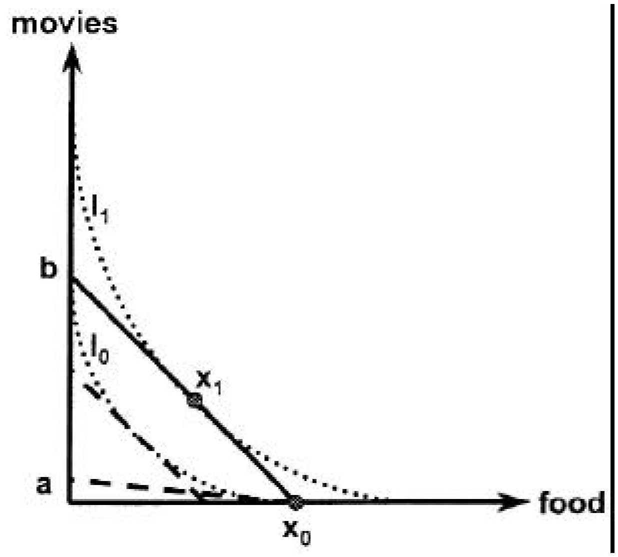

FIGURE 1. Hicksian style indifference curve analysis for a new good

have been at time 0 such that even if they had been available, the individual would still have chosen to consume only food in amount x_0. This is shown in the diagram by the tangent to indifference curve I_0 at x_0, with a slope x_0/a, so that movies at time 0 had a reservation price *b/a* times their price at time 1. Hicks believed "these (reservation or virtual) prices cannot be estimated" (p. 114), since the dashed lines in figure 1 are speculative. The only solid information are the points x_0 and x_1 and the relative price as of time 1.[4]

One simple way to operationalize the Hicksian approach in the context of XEcon is to undertake a sensitivity analysis. Two variants of 'empirical' price indices can be constructed in order to assess the implications of the introduction of new goods. The standard variant ignores the new good in the time interval when it first comes on the market. This was Hicks' original suggestion (followed e.g. by Crawford 1993; Boskin Commission 1996), based on his view that the sales volumes of new goods entering the market are extremely small.

The other variant makes an arbitrary assumption about the size of the relative reservation price (*a/b*), which we can call the 'Hicks new good factor', or HF. Then alternative versions of standard price indices can be computed by arbitrarily setting the price of the new good at the beginning of the interval when it comes on the market to HF times its observed market price at the end of this interval. Even though this implies an HF-fold drop in price of the new good over the time interval when it is introduced, if the market share of the new good at the end of this period is still small, as is widely assumed, the second variant should be close to the first in quantitative terms. (The two variants will show identical changes over time intervals when no new goods come onto the market.)

Additional approaches are also possible in a theoretical world like XEcon, by making reference to the underlying improvement in an individual's utility (i.e. from I_0 to I_1 in figure 1). Two approaches that yield 'true' standards of comparison are explored. The first is based directly on utilities, assuming (conveniently) cardinal comparability - essentially a simple arithmetic average of each individuals' known utility is used as the 'social welfare function'.

The other approach is based on something akin to money-metric utility. Using knowledge of the underlying utility functions (e.g. as in figure 1), the creator asks how far out, on a ray through the origin and x_0, an individual has to go to attain the same level of utility as is provided by x_1 - i.e. the value of $\ddot{e}_0$ such that the point $\ddot{e}_0 x_0$ is on the same indifference curve I_1 as x_1. (At the beginning of XEcon simulations, to be described later, there is only one commodity, food. Thus the ray through the origin will correspond with the food axis. In later periods, when there is more than one commodity available, these rays will generally be interior to the positive orthant.) This $\ddot{e}_0$ value is then a Malmquist (quantity) index of the individual's 'true' change in standard of living from period 0 to 1.[5]

The two 'true' measures of the improvement in economic welfare given an expansion of the choice set serve the added purpose of demonstrating how 'true' economic growth might arise in even the simplest possible case where nominal income is constant when a new good comes onto the market. Figure 2 sketches a very simple time series with constant nominal income divided between two categories of expenditure. At first, there is just food. Then movies become available, and movie consumption eventually stabilizes at about half of total income. For this to occur, we need only assume that movies offer higher utility than food, at least over a non-trivial range of substitution. 'True' economic growth in terms of higher economic welfare will result from a shift to a higher indifference curve with the shift from only food to food and movies.

This scenario could also generate increases in measured real GDP (more precisely, real aggregate consumption) in two ways. One is if the 'novelty' of movies at the time of their introduction were taken into account in constructing the price deflator, say, by using a Hicksian new goods factor. The other is if the price of movies fell over time (while food prices remained relatively stable).

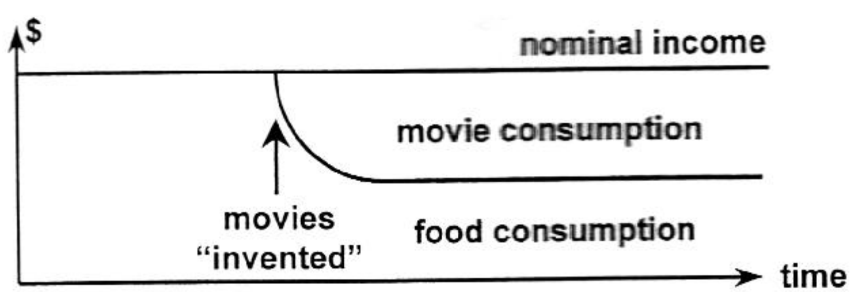

FIGURE 2. An example of real economic growth with constant nominal income

If the new good were a conventional service like live theatre, only the first of these two possibilities would be likely, since live theatre (an 'asymptotically stagnant' industry in Baumol et al.'s 1985 terminology) is typically produced with constant average costs so there is little scope for prices to fall as sales increase. On the other hand, with information goods like movies or videos, both the novelty and the declining price aspects can apply. Movies are 'technologically progressive' (again in Baumol et al.'s 1985 terminology) since their production exhibits decreasing average costs (both in terms of the technology available, and in the evolution of the technology over time).

3. General XEcon methodology

To aid thinking about the possible impacts of the introduction of new goods on both empirical price indices and social welfare, allowing for individual heterogeneity and the kinds of product characteristics just described, we have developed a theoretical simulation model, or 'artificial world,' XEcon. This model has the following attributes:

there are explicit micro foundations - aggregate characteristics of the economy are built up as the sum or aggregation of the characteristics of all the individual agents, principally in their roles of consumers and producers[6];

these agents are heterogeneous along a number of dimensions including their individual histories of transacting (e.g. reservation prices, profit history) and basic capabilities (e.g. individual incomes, cost functions);

agents are not perfectly rational -- they make do, or satisfice, while trying to maximize their utility or profit, based on relatively simple rules of thumb to guide their behaviour; and

there is no a priori assumption of equilibrium - the behaviour of individual agents unfolds in an environment populated by other agents whose behaviour is co-evolving simultaneously; so the economy unfolds in something akin to real calendar time, and transacting at 'disequilibrium' prices is the usual situation.

These features are important to the analysis of the introduction of new goods.

4. Basic characteristics of the XEcon economy

There are two main groups of agents in XEcon: individuals and firms. Individuals receive income in return for providing factor services. Each individual saves 100% of its continuous flow of income, while its stock of commodities is consumed at a steady rate until one runs out. Then the individual checks market prices, revises its consumption plan, goes shopping for the needed commodity, and when a suitable vendor is found, buys a discrete quantity. This transaction induces an instantaneous and simultaneous reduction in the individual's financial saving, and a matching increase in its commodity stocks.

On the other side of the commodity market, there are one or more firms, each selling one kind of commodity to all comers at a posted-offer price. Firms set prices based on their profit histories, which in turn depend on their exogenous (and possibly heterogeneous) cost functions, their histories of sales, and rules of thumb which in stable environments lead them to maximize profits.

For the simulations reported, individuals' incomes are given exogenously. This simplifies interpretation. The only source of divergence between the sum of individuals' incomes and the sum of firms' sales is individual saving. On average, every individual spends all its money on commodities. Since savings provide no utility, while consuming goods does, individuals tend to have constant savings. Individuals' incomes in aggregate tend ex post to equal firms' aggregate sales, so the economy ends up de facto being closed.[7]

5. Commodity characteristics of XEcon

XEcon is designed to include an arbitrary number of commodities with a range of characteristics, including:

- when in calendar time it is 'invented' and comes onto the market, so that new goods can appear after the beginning of a simulation;
- the number of firms producing each commodity, allowing a continuum between atomistically and monopolistically competitive market structures;
- the firm's cost structure, allowing a range from constant to dramatically increasing returns to scale;
- individuals' utility structures, allowing a range from high to zero marginal utility; and
- firm pricing strategies, with potentially varying degrees of 'aggressiveness' in exploiting increasing returns cost structures.

The analysis posits three sets of commodities. The first is 'food', a conventional necessity. It is present at the beginning of a simulation, and is produced with constant returns to scale in an atomistically competitive market. The other two sets comprise new goods that are invented and come onto the market during the simulation. These new goods are forms of entertainment.[8]

After food, the first set of new goods corresponds to traditional services such as dining out and live theatre. These services are characterized by constant average costs. The metaphor is that productive capacity has progressed beyond the necessities, so a portion of the population can leave 'farming' and begin specializing in the production of entertainment. However, these services are labour intensive, the more enjoyable requiring more labour per unit.

The second set of new goods represents newer kinds of information products like movies, videos, and Nintendo.[9] These goods illustrate the information and communications technology (ICT) 'techno-economic paradigm shift' (Freeman and Soete 1993) or 'deep structural adjustment' (Lipsey and Bekar 1995) of the last few decades. The main feature of the ICT 'revolution' for our purposes is dramatically increasing returns to scale in production, or more precisely reproduction. For example, video images provided by cable TV, VCR's or satellite signals represent a sequence of technologies that allow the essence of a theatrical experience to be much more widely disseminated at dramatically diminishing average costs (albeit providing somewhat lower utility). Nintendo represents a yet further (though still nascent) evolution toward interactive movies.

The central question in this analysis is how the highly stylized 'waves of innovation' associated with the appearance of these new entertainment goods affect real economic growth from three perspectives: as conventionally measured in the SNA, as it might be measured with improved empirical price indices, and in terms of (otherwise unobservable) social welfare.

6. Individual utility and social welfare in XEcon

XEcon posits individual utility functions as the basis for behaviour. Each individual's utility function is assumed to be concave, and additively separable both across commodities (which are discrete) and time (which is continuous). Thus, an individual's instantaneous total utility at time t is the sum of utilities $U^i(x_{it})$ derived from the flow rate of consumption of each commodity x_{it}; so that we have overall utility $U_t = (\Sigma_i \alpha_i\ U^i(x_{it})$, where α_i is a constant.

Since XEcon is a numerical simulation model (and computers can only function with fully specified inputs), these utility functions de facto must be cardinal. Specifically, XEcon has been constructed so that each of the U^i is a polynomial of the form $a_i x_i^{bi} + c_i x_i$, with $U^i(0) = 0$ and with the parameters set so that marginal utility is initially positive and declining. Figure 3 illustrates these commodity-specific utility functions (i.e. the U^i) for food, movies, and videos.[10]

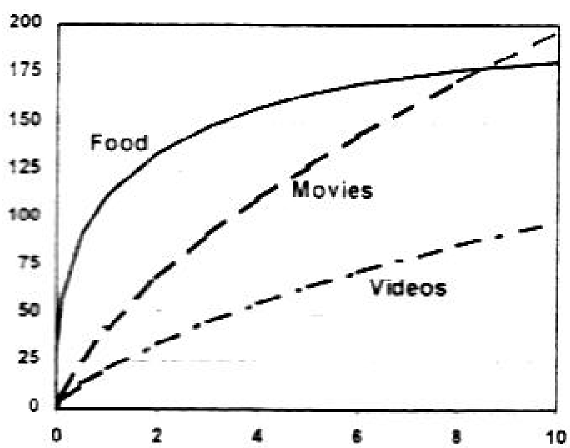

FIGURE 3. Illustrative XEcon utility function components $(U^i(x_i))$

One role of each individual's utility function is to guide its behaviour. These are also used for calculating indices of the overall economic well-being of the XEcon population. Two social welfare indices have been computed: the average over all individuals of each of their utilities at each moment in time,[11] and chained Malmquist 'true' quantity indices for consumption. The former requires cardinality, while both require some assumption of interpersonal comparability.

7. Individual behaviour

Individuals in XEcon are continually trying to maximize their utility, but able to do so only by 'satisficing'. At the beginning of each simulation, individuals are each endowed with a steady flow rate of income, a geographic locale, a utility function, initial endowments of saving and commodity stocks (only 'food' in the simulations to be examined), and a limited memory of prior transactions. In these simulations, individual incomes are drawn randomly from a distribution with a Gini Coefficient of about 0.33, and top and bottom quintile shares of 0.44 and 0.04 respectively, and all individuals have identical utility functions.

Individuals begin by consuming commodity stocks, and accumulating their income flow as financial savings. At some point, they run out of one of the commodities, and have to shop. They shop first to find prevailing prices, and may visit more than one firm to search for an 'acceptable' price. (Firms producing the same commodity don't always sell all of it at the same price.) A price is acceptable if it is below the individual's reservation price, based on prior experience.

Another part of the shopping event is re-evaluating desired flow rates. Metaphorically, the individual starts with its current consumption rate bundle (or vector) x, and 'imagines' consuming at alternative rates $\{x_k^*\}$. The set $\{x_k^*\}$ is generated by a series of random draws in a spherical neighbourhood of x. Since these $\{x_k^*\}$ may either be too expensive or inexpensive, they are transformed into $\{x_k^1\}$ by projection onto the budget constraint, with fixed proportions (i.e. by moving along a ray through x_k^* and the origin of the commodity space to the point intersecting the budget hyperplane). Then utility for each of the (now) feasible consumption rate bundles is evaluated, and the individual changes to the one offering the highest utility. This heuristic process essentially produces utility maximization gradually by a hill-climbing random walk. However, the shape of the hill is also changing, as firms' pricing behaviour co-evolves; so individuals may always be 'chasing' their (evolving) utility optima in an XEcon simulation.

Given the new x_k^1 and a target minimum ratio of savings to total wealth, the individual uses its 'excess' savings to buy more of the needed commodity, updates its 'memory' of successful transactions, 'goes home', and resumes consumption at steady rates until it next runs out of a commodity.

8. Firm behaviour

Firms, like individuals, are also boundedly rational. They seek to maximize their profit, but are only able to adjust gradually. Each firm is endowed at the start of each simulation with a cost function consisting of fixed and variable components, a geographic locale, an initial amount of equity (so it can run at a loss for limited periods, though once this equity is exhausted, it goes irreversibly bankrupt), a ‘remembered’ profit history, and a price-setting rule of thumb.

Firms operate based on posted-offer pricing. They post a price at the beginning of each chronon (the unit of time in XEcon, after A.K. Dewdney’s Wa-Tor 1984), and then sell as much as individuals wish to purchase. In other words, firms have unbounded production capacity, given their cost functions.

The one decision of the firm is its selling price. It is adjusted based on a rule of thumb as follows. The firm has a limited memory of its profit history, plus a knowledge of the share of its total costs that are fixed. The heuristic pricing rule has two parts. One is to “keep on truckin, unless...”. In other words, if a moving average of recent profits is trending upward, keep moving prices in the same direction that they moved last chronon. However, if profits start falling, reverse the direction of price change. If profits are stable, keep prices stable.

The other part of the firm’s heuristic pricing rule is based on the character of its cost function. Basically, the higher the share of fixed costs in total costs, the more the firm lowers its prices in an effort to “walk down its cost curve”. However, firms may vary in the rate at which they do this -- a marker of the ‘aggressiveness’ of their pricing strategy.

The market structure for each commodity is also parametric. In the simulation results presented, food is produced in an atomistically competitive market with 20 firms, while the other entertainment commodities are produced by a single firm, and in monopolistically competitive environments.

9. The statistician and the creator

XEcon, in addition to its individual and firm agents, has two ‘observers’. One is a statistician who tracks nominal GDP, plus ‘household expenditures’ and retail prices. The statistician then uses this information to estimate real GDP based on a GDP deflator. This is a Laspeyres index, with prices collected every chronon and expenditure weights collected every five chronons. Analogous to current practice, new goods are only added to the expenditure basket once they achieve a minimum market share. In the XEcon context, this threshold is set at 5%.[12] Also, in XEcon’s food market, where there are many firms, prices are collected for the ‘standard’ quinquennial Laspeyres index only from those firms with the most sales (specifically the largest firms accounting for 50% of total food sales), and simply averaged (i.e. without weighting by each firm’s sales volume).

XEcon’s statistician also has data from a survey where each individual every chronon provides details on expenditures and prices paid. These data allow the statistician (with ideal data) to estimate a range of new price indices, including two variants of ‘best practice’ annual chain Fisher indices. One uses the conventional assumption of ignoring new goods for the problematic chronon when they first come onto the market. The other makes a ‘Hicks new goods’ adjustment using an arbitrary factor HF.[13]

Finally, there is an all knowing creator. The creator provides a 'gold standard' for assessing the statistician's various measures of real economic growth -- with both a social welfare function, defined as the simple arithmetic average of individual utilities, and chained Malmquist indices.[14] It should again be emphasized that the statistician's price indices are not derived from the underlying utilities (e.g. as in Diewert 1990). Rather, the statistician and creator work independently to construct empirical price indices and utility-based indices respectively. Simulations are used to explore the extent to which these agree.

10. Simulation experiments - overview of base case

We turn now to an exploration of the impacts of new goods on measured economic growth. First, we illustrate the operation of XEcon with a single 'base case' simulation scenario. Then we explore in more detail a range of measures of real economic growth for a base case simulation scenario. Finally, we derive a further set of results by comparisons with other simulation scenarios.

Initially, food is the only good available on the market at time t = 0. This is followed by the exogenous arrival of 'information' type entertainment goods. Movies come on the market at t = 15; videos at t = 35; and Nintendo at t = 65.[15] As new commodities appear, purchases shift to include them (figure 4a). Movies show the most dramatic penetration.[16] The patterns of diffusion of the new goods into individuals' consumption bundles depend on their (endogenous) prices and marginal utilities.

Utility flows (figure 4b) evolve more smoothly than purchases because consumption occurs at constant rates, while shopping and hence purchases are discrete events. Utility from food consumption drops much less than purchases, since this upper income group is closer to satiation in food.

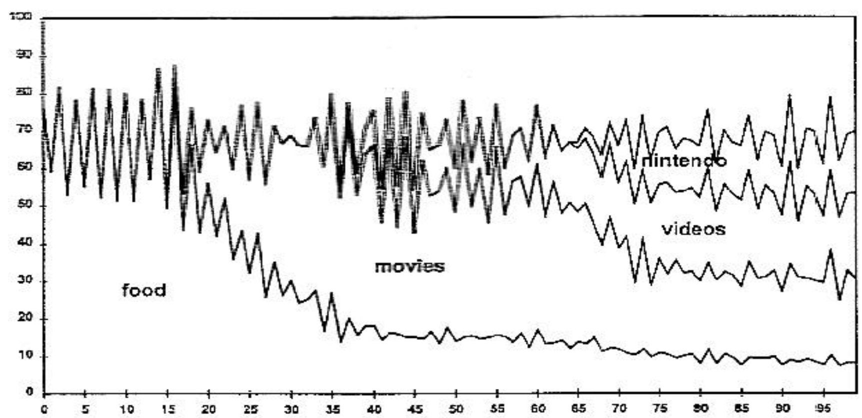

FIGURE 4a. Purchases over time by commodity

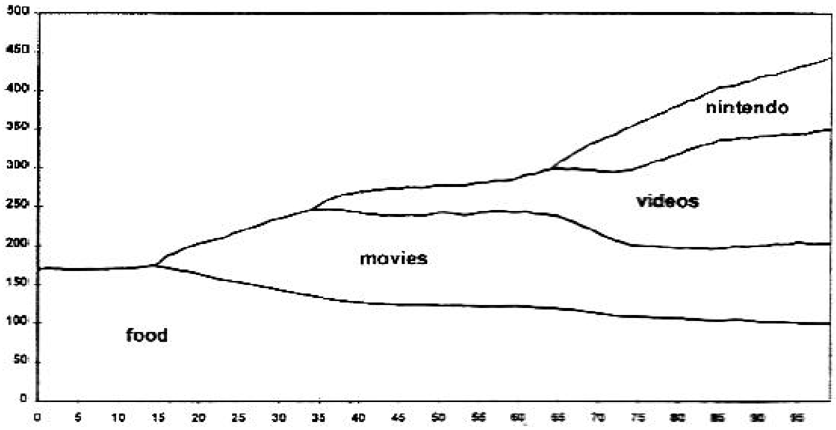

FIGURE 4b. Utility flows over time by commodity

Figures 5a and b show corresponding time series of prices and quantities sold. The patterns indicate that XEcon is producing reasonably typical product cycles for the 'information' kind of entertainment commodities. When these are first introduced, physical unit sales are small, but they then grow. Recall that these information goods are produced with fixed costs that are relatively high in comparison to variable costs. Thus, a firm that prices aggressively can 'walk down its cost curve'.

The entertainment firms are, in effect, in a monopolistically competitive market. Initially the movie firm lowers its price, even without any competition, in order to (try to) maximize its revenues. The introduction of videos does not seem to have much effect on movie prices. But by the time Nintendo appears, video prices have started to fall faster, while movie prices continue to fall.

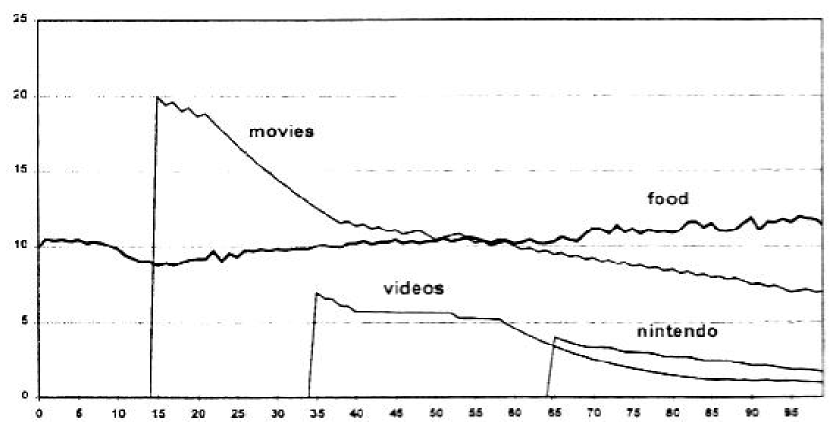

FIGURE 5a. Prices over time by commodity

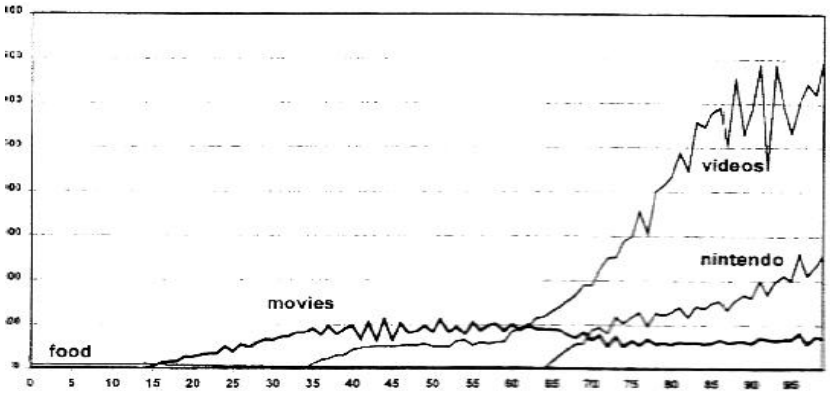

FIGURE 5b. Quantity flows over time by commodity

11. Simulation experiments - base case measures of real economic growth

We turn now to a more detailed exploration of the base case XEcon simulation scenario, focusing on two sets of measures of real economic growth. One set--the statistician's measures--are based on well known price indices. The other is based on individuals' utilities observed by XEcon's creator.

As a prefatory matter, table 1 shows results for eight replicates of the base case scenario, the only difference being the seed of the random number generator. Random numbers are used at t = 0 to give individuals and firms geographic locations, and to assign individuals such things as incomes and initial commodity stocks. Then, during the course of the simulation, random numbers are used to generate the sets of commodity bundles individuals 'imagine' consuming as part of their satisficing search process.

Table 1 first shows the means of the summary indicators over these eight replicates, then the standard deviations of the means, and then correlations. The standard deviations are not sampling errors, since each indicator is completely determined within a simulation, given the random number seed. Rather, these statistics are an indication of the economy's degree of 'path dependence'. If these are relatively small, as is the case, then path dependence in the sense of Arthur's (1989) beta versus vhs VCR multiple equilibria situation is not a significant feature of the economy. The relatively low standard deviations (about 10 percent) mean that individual simulations are likely not atypical (for the given set of initial conditions), so later results for convenience show only single simulations.

The first empirical index, shown in the first column of table 1, is the standard status quo quinquennial Laspeyres. The second column shows the results for an empirically ideal Laspeyres index where, unlike the standard quinquennial one, the index is chained using annual data, and all price and expenditure data are used; not just those for goods that exceed the 5% threshold for including a

TABLE 1
Initial results for the base case XEcon simulation: means, standard deviations and correlations for eight replicates

Statistic	Measure of Real Growth (percent per chronon, assuming constant nominal income)						
	Statistician's Measures				*Creator's Measures*		
	Standard Laspeyres	Annual Laspeyres	Annual Fisher HF = 0	Annual Fisher HF = 2	Average Utility	Plutocratic Malmquist	Democratic Malmquist
Mean	195	304	294	346	147	458	450
Standard Deviation	23	41	39	44	15	48	48
Correlations							
Standard Laspeyres	1.00	.78	.77	.78	.88	.86	.88
Annual Laspeyres		1.00	1.00	1.00	.93	.92	.86
Annual Fisher, HF = 0			1.00	1.00	.92	.91	.84
Annual Fisher, HF = 2				1.00	.93	.92	.85
Average Utility					1.00	1.00	.97
Plutocratic Malmquist						1.00	.97
Democratic Malmquist							1.00

commodity in the expenditure basket or those prices from just the 50% of (food) firms with the largest sales of each commodity.

The third empirical index in table 1 is a Fisher annual chain index. For this Fisher index, new goods have been ignored in the chronon when they first appeared on the market. This standard practice corresponds (essentially) to HF = 0. In contrast, in the fourth empirical index, HF = 2 corresponds to an assumption that new goods have reservation prices immediately before they come onto the market equal to two times their first observed market price.

In addition, the last three columns show results for indices knowable only to XEcon's creator. One is the simple average of individuals' (cardinal) utilities. The other two are annual chained 'plutocratic' and 'democratic' Malmquist quantity indices. The 'plutocratic' ('one dollar, one vote') version of the Malmquist quantity index is calculated by applying the common utility function to the average consumption bundle of a group (either the entire XEcon population, or the subset in an income tertile). On the other hand, the 'democratic' Malmquist index is based on chaining Malmquist quantity indices of consumption for each and every individual, and then averaging these over individuals (again either within an income tertile, or for the entire population).

In each case, the indicator is based on the formula $((100\ F_0/F_T) - 100)$, where F is the Fisher (or Laspeyres or Malmquist) index, or $((100\ U_T/U_0) - 100)$ for average utility, in order to show the implied real growth rates from the beginning of the simulation at time t = 0 to the end at t = T.[17] These indicators measure real growth because nominal income is constant in the simulation, by construction.

In table 1, the standard quinquennial Laspeyres index shows lower real growth than the other empirical indices. Moving from quinquennial to annual chain indices (either Laspeyres or Fisher) significantly raises measured economic growth (i.e. records larger price declines) in this hypothetical economy where the only source of growth is the introduction of new goods. Intuitively, the five year periods of fixed consumption baskets in the standard price index give 'too much' weight to the commodities whose prices are relatively stable (food, in thiscase). Whether we use Laspeyres or Fisher indices in this case seems less important.

From table 1 we also see that including some value for the unobserved reservation price of new goods, by arbitrarily setting HF = 2, further increases measured growth. Even though the initial purchase volumes of the new goods are small, the change from HF = 0 to HF = 2 has a noticeable impact.

Turning to the (unobservable) measures of XEcon's creator, both the plutocratic and democratic Malmquist indices show higher rates of growth than either the empirical indices or average utility. The intuition is that with the rather low marginal utilities posited for higher levels of consumption, the ray from the origin through a bundle of 'older' goods must be extended a great distance to intersect the same indifference curve as a bundle with a larger share of 'newer' goods that is closer to the origin. Finally, the correlations between the standard

Laspeyres and the 'best practice' empirical measures of the statistician are lower than those among the 'best practice' measures and the social welfare measures of the creator.

In table 2, we turn to differences in these indicators across income groups; specifically, tertiles or thirds of the income distribution. We also explore further the influence of the Hicks new goods factor, HF. Recall that individuals in XEcon have been endowed with heterogeneous incomes (e.g. Gini ≈ .33). In all cases in table 2, the growth rate of the economy according to the specified indicator is expressed as an index. The point of comparison is the growth in average utility for all income groups combined (i.e. the upper right cell of the table).

TABLE 2
Indicators of real economic growth by income tertile (index form, utility for all income groups = 100)

Indicator	Income Tertile			All Incomes
	Bottom	Middle	Top	
Creator's Utility-Based Measures				
Utility	44	87	144	100
Plutocratic Malmquist	132	282	494	312
Democratic Malmquist	149	315	539	302
Statistician's Empirical Fisher Indices				
HF = 0	94	161	232	192
HF = 2	127	211	259	228
HF = 5	181	292	301	284
HF = 9	259	409	360	364

The first three rows show the creator's measures of the growth in social welfare: first in terms of average (cardinal) utility, and then in terms of the two variants of the Malmquist index The last four rows show the impact of alternative assumptions for the 'Hicks new goods factor' (HF) on the statistician's Fisher annual chain index for expenditure, this time positing HF = 2, 5, or 9.

The most dramatic result is the wide variation in growth rates by income group, both for the creator's social welfare indicators, and for the 'best practice' empirical Fisher indices. The introduction of new information goods has over three times the impact for the top third of the income spectrum as compared to the bottom third. The reason, simply, is that higher income is associated with a lower marginal utility for food; hence a greater proclivity to substitute toward the new entertainment goods. This suggests a significant disequalizing impact on 'real' incomes from the introduction of the new entertainment goods.

The effect of higher HF, as in table 1, is to raise measured growth rates. However, higher HF also appears to attenuate the differential effects by income group, to the point that with HF = 9, growth in real living standards in the top tertile is lower than in the middle tertile, a misleading result if we take the creator's results as the gold standard.

The specific results in table 2 suggest a general question about the disequalizing effects of the introduction of new goods. Figure 6 extends the Hicksian analysis in figure 1 to show two individuals at the same time: individual 'a' with lower- and individual 'b' with higher -income. Both have the same utility function. The situation is some time after the introduction of movies, when the price of movies has fallen considerably, and is well below either individual's reservation price. Their consumption choices have now moved from $\{x_{0a}, x_{0b}\}$ to $\{x_{1a}, x_{1b}\}$, and, as a result out from $\{I_{0a}, I_{0b}\}$ to higher indifference curves $\{I_{1a}, I_{1b}\}$. In this case, a Malmquist quantity index, based for example on the 'Malmquist ray' shown, would indicate a higher (lower) proportionate increase in consumption for the higher (lower) income individual.[18]

In other words, the arrow along the Malmquist ray from I_{0a} to I_{1a} is a smaller proportion of the distance from the origin to I_{0a} than the corresponding arrow between I_{0b} and I_{1b}. Thus, a new good which has initially lower, but ultimately higher, marginal utility, than existing goods provides greater benefits for higher-income than for lower-income groups as prices fall from their introductory levels, and consumption of the new good diffuses.

Our results differ from those of the Boskin et al. report (1996), but are consistent with Diewert's (1996) assertion that a price index adjusted for new goods bias "would probably not be appropriate for adjusting transfer payments to the poor (since) ... an increasing selection of commodities may not be relevant to the poor who are forced to spend the bulk of their income on a few essentials."

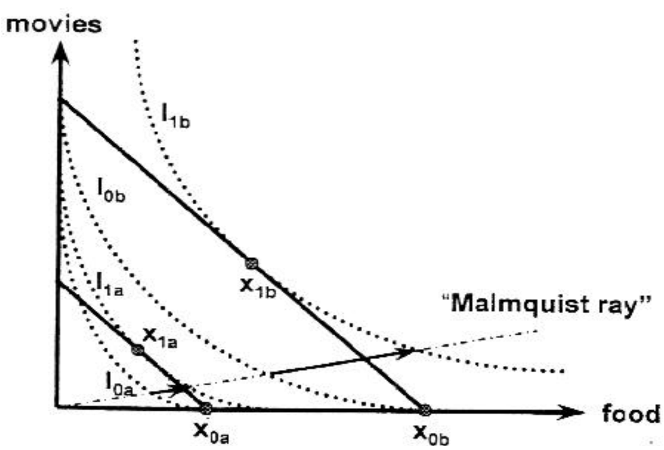

FIGURE 6. Extension of Hicksian analysis to rich and poor individuals

12. Simulation experiments - alternative scenarios for income levels and returns to scale

Finally, two further sets of scenarios have been simulated. One varies the character of the new goods. So far, we have been focusing on information goods. Their key feature is that they are (re)produced with dramatically increasing returns to scale (i.e. declining average costs), so that measured real economic growth can arise simply from the fall in their prices as their market share increases. Alternatively, we can posit new entertainment goods that are conventional services (e.g. dining out, live theatre), produced with constant average costs.

The other set of scenarios simply triples the mean income in the economy. The shape of the income distribution, and hence the degree of income inequality in this alternative scenario, is not changed.[19]

Table 3 shows the resulting indicators of real economic growth. Columns 1 and 3 show results for the base-case lower mean income scenarios, while the second and fourth show results for higher (i.e. tripled) mean income scenarios. Correspondingly, columns 1 and 2 show the results for information goods, while the third and fourth give results when the new goods are conventional services.

The most dramatic results are the differences between the statistician's view, based on the various empirical price indices shown in the top four rows, and the creator's view, indicated by the social welfare indices shown in the last three rows. It should be noted that average utility as an indicator of social welfare is really a 'rubber' number. We could just as well have used the square, or the square root, of individuals' utility functions as the basis for measuring social welfare, since there is no basis for cardinalizing utility (nor, for that matter, anchoring inter-personal comparisons of utility). Any such monotone transformation would not have changed individuals' behaviour. They would have chosen exactly the same sequence of consumption bundles in an XEcon simulation.

However, no monotone transformation of utility functions can change the sign of a growth rate or its rank order. Thus, even though average utility is a 'rubber' number, we can draw conclusions about directions of change, and about rank orderings. Moreover, the Malmquist indices are invariant with respect to monotone transformations of the underlying utility functions, depending only on their ordinal properties.

Thus, the information in table 3 does allow us to conclude for the XEcon economy that new information goods generate greater increases in social welfare when incomes are higher (i.e. growth rates are higher in the second than in the first column for the last three rows). Intuitively, the reason is that the higher purchasing power in the high income economy allows a greater proportion of overall expenditure to be reallocated away from food toward movies and such.

Even without dramatic increasing returns to scale, as when the new goods are

TABLE 3
Real economic growth rates (percent) for four empirical measures and three social welfare indicators, and for four XEcon simulation scenarios

	Scenario:				
Indicators of Real Growth	New Information Goods			New Conventional Services	
	Low Mean Income		High Mean Income	Low Mean Income	High Mean Income
Statistician’s Empirical Indices					
Standard Laspeyres	191	>	107	-21	-9
Annual Laspeyres	311	>	160	-31	-19
Annual Fisher (HF = 0)	300	>	165	-38	-21
Annual Fisher (HF = 2)	356	>	177	-20	-13
Creator’s Social Welfare Indices					
Average Utility	156	<	259	248	470
Plutocratic Malmquist	487	<	924	1499	3555
Democratic Malmquist	472	<	916	2110	4584

conventional services (the last two columns), the introduction of this other type of new entertainment good allows substitution toward more valued consumption. Thus, social welfare (measured by average utility and both Malmquist indices in the last three rows) rises (i.e. the measure is positive) with the introduction of conventional entertainment services at either income level.[20]

The statistical indicators of real economic growth in the first four rows give *opposite* results. These measures register lower growth with new information goods at higher incomes (i.e. the first four rows of the second column are lower than the corresponding figures in the first column). Moreover, they also show absolute declines in real income for new conventional services at both income levels (i.e. the first four rows in the last two columns are all negative).

The explanations are straightforward. Firms' pricing behaviour is endogenous. In the case where the new entertainment goods are information goods produced with increasing returns to scale (the first two columns of table 3), prices fall in the low income scenario. But in the high income scenario, the higher purchasing power when movies come on the market at t = 15 is sufficient that the movie firm does not have to lower prices. In fact, movie prices rise until the movie firm is faced with competition from videos at t = 35, after which they fall. The prices of videos and Nintendo, however, do fall in this high income scenario in a time profile similar to the low income scenario.

For conventional services (i.e. the scenarios in the last two columns), the option of lowering prices to expand market share is not open; the firm would go bankrupt. However, the marginal utility of food is low enough, in a relative sense, that when these new goods are introduced, the firms can raise prices and people will still shift a portion of their expenditures toward these new goods. This is why measured real economic growth is negative in the last two columns and first four rows of table 3. At the same time, welfare has improved following the introduction of these new goods; simply taking advantage of their availability, notwithstanding the rise in their prices after introduction, has improved social welfare as measured by all three of the creator's indices.

These results suggest that in the face of new goods, even best practice methods for constructing empirical deflators can induce errors in comparative assessments of real economic growth. With increasing returns to scale, we may conclude that a low income economy is growing faster because prices of new goods fall more dramatically. However, the low income economy may be generating smaller increases in social welfare because its members are less able to shift their consumption, even at the relatively lower prices, toward the new goods. When there are constant returns to scale in the production of new goods, their introduction may be associated with a rise in prices, and hence a fall in real income as far as it can be measured. However, in welfare terms, the population is better off -- not only because they face an expanded range of choice, but also because they can exercise this choice.

These conflicts between measured real economic growth and improvements in social welfare may be relevant to comparisons of empirical growth rates in developed and less developed economies, and the large literature on ‘convergence.’

13. Concluding comments

This analysis has used a computer simulation-based theoretical model, XEcon, to explore questions related to the measurement of real economic growth. The focus has been on the treatment of new goods in the construction of price deflators. Among the common features of new goods are their delayed recognition in standard price index estimation, their differential diffusion for different groups within the household sector, and declining prices. The analysis has been carried out in a dynamic disequilibrium setting, with heterogeneous agents and the possibility of ‘increasing returns to scale’ production.

One consideration is that the form of recent technical progress is new; it is ‘post-industrial’, concentrated in the information and communications area. Products based on these technologies have been experiencing very rapid technical progress by historical standards, and have been accompanied by dramatic reductions in prices.[21] Given the peculiar nature of information, there is also a question of where to locate these commodities in relation to the conventional goods versus services dichotomy. Following Hill (1997), we have treated information as a new third type of intangible good, whose dominant economic characteristic is dramatically increasing returns to scale.

Our theoretical analysis, using XEcon, has generated both expected and problematic results. It is intuitively plausible that attaching some value to novelty in and of itself, where the appearance of novel goods has not previously been valued, will result in lower measured price increases, and hence higher measured real rates of growth. Also, more rapid updating of price indices, when there are rapid price declines associated with the appearance of new goods, will also result in lower measured price increases, and hence higher measured real economic growth. This is what we find with the XEcon-based simulation analysis.

However, there are problematic results when we try to posit a ‘gold standard’ against which to assess empirical measures of real growth. There is a tradition in economics of positing individual utility functions -- not only as the basis for explaining individual behaviour, but also for judging social welfare changes. When we do this, we find divergences between this kind of gold standard and statistical measures. Most seriously, even ‘best practice’ empirical price indices may generate rankings for measured real growth that are opposite those we would get if we could directly assess social welfare.

A further result is that there are differential impacts of new goods by income group. Since lower income groups are less inclined to substitute away from necessities like food, their consumption baskets contain less of the new goods whose prices are falling dramatically. Thus, price indices by income group may show slower real economic growth for those with lower income. They also show smaller gains in average utility and in ‘true’ (Malmquist) quantity terms. This in turn suggests that in policy discussions about ‘correcting’ price indices like the CPI for new goods bias, there may be grounds for making different corrections for different income groups. More generally, our XEcon results suggest that the introduction of new goods can increase social inequality in ways that are not picked up by standard measures of income inequality.

Post Script -- The analysis reported here is a work in progress. Anyone interested in obtaining a copy of the XEcon software in order to replicate and explore the simulations presented here, please contact wolfson@statcan.ca.

Notes

I am deeply indebted to Steve Gribble for the many innovations and discussions without which this analysis would not have been possible, to Stan Kondrat and Susan Leroux for excellent systems work, and to Erwin Diewert, Zvi Griliches, Steve Keuning, Alice Nakamura, Andrew Sharpe, John Baldwin, and Stu Wells for valuable discussion. I alone am responsible for the content, including any errors or infelicities. A shorter and earlier version of this paper is Wolfson (1997).

1 More precisely, these goods have cost structures characterized by low variable costs relative to fixed costs, so average costs decline as production increases. As a shorthand, we generally refer to this as increasing returns to scale.

2 For convenience of exposition, and in line with Hill (1997), the term ‘goods’ is used in a general sense to include all valued products of economic activity. Thus, ‘goods’ will be taken to include tangible goods like foodstuffs, conventional services like live theatre, and intangible or information products like videos (the sequence of images, not the medium), unless indicated otherwise.

3 The problem of tastes that change over time is considered in Fisher and Shell (1972).

4 Trajtenberg (1990) and Hausman (1997), on the other hand, are recent examples where, building on this Hicksian analysis, estimates have been made. Hausman finds a reservation price that is about double the introductory price of Apple-Cinnamon Cheerios. Trajtenberg analyzed CT scanners, and found much more striking results -- reservation prices about 1,000 times recently observed market prices. Still, he considers radical product innovations, ‘truly new goods’ such as CT scanners, to be relatively infrequent as compared to incremental quality improvements and increased variety within ‘product classes’.

5 In a population of heterogeneous individuals indexed by i, the sets of $\{x_0^i\}$ and $\{x_1^i\}$ will generally be different, and thus so will be the $\{\ddot{e}_0^i\}$. We can construct an overall population index by mechanically averaging the $\{\ddot{e}_0^i\}$. This average is similar to the social welfare function discussed by Blackorby (1975). However, instead of using a common reference set (x^* in Blackorby’s notation), we assume that each individual’s initial reference set is their actual consumption bundle $\{x_0^i\}$, and everyone’s initial ‘welfare’ value is equal to 1.

6 At the same time, overall properties of the aggregate economy such as its stability are endogenous, if not emergent in the sense of Epstein and Axtell (1996).

7 In simulations (not reported here) where this simplifying assumption has been relaxed,

and there is explicit feedback from firms' sales to individuals' incomes, the dynamics are more complex, but the results support the general conclusions of the simpler case.

8 "There are only two industries. This has always been true,", said Madame Ping.... "There is the industry of things, and the industry of entertainment. The industry of things comes first. It keeps us alive ... But making things is easy now ... This is not a very interesting business anymore. After people have the things they need to live, everything else is entertainment. Everything." The Diamond Age (p. 372) by Neal Stephenson.

9 In terms of Hill's (1997) trio of commodity types, food corresponds to a tangible good, the first group of entertainment commodities to Hill's second category, services, and the second group of entertainment commodities to Hill's third category of intangible or information goods.

10 Pollak's (1990) 'Bergson family' of additive utility functions is a special case. XEcon also allows a piecewise linear functional form to be specified. The scenarios to be discussed have been simulated with both utility functional forms. Since the results are generally similar, only those for the smooth polynomial form have been reported.

11 This social welfare function, which gives 'one person, one vote' is similar to what Diewert (1990) refers to as the Prais-Mullbauer democratic price index. The approach of positing specific utility functions is also similar to that of Jorgenson and Slesnick (1990). This average utility measure of social welfare is equivalent to the standard style of economic analysis, since standard analysis typically assumes homogeneous representative agents, so that individual and social welfare are identical.

12 In statistical agency practice, new goods may be introduced into the price index commodity basket when their expenditure share is less than 0.1%, while the basket itself typically contains hundreds of distinct 'commodities'.

13 Note that given a fully specified utility function, it is possible for the creator to compute this 'Hicks new goods' factor, HF, exactly. However, with the utility function used, and agents' heterogeneous incomes and consumption bundles in XEcon, HF varies both with income and with levels of consumption of other goods. Thus, it is far from unique, and in any chronon will vary across individuals. In addition, individuals' consumption bundles typically will not be 'optimal' with respect to their utility functions and prevailing prices, since they are adjusting only gradually, and then toward a moving target as firms simultaneously adjust their prices. XEcon's model of the statistician is much simplified by the use of an arbitrary HF value, but realistic in that no unobservable information is used in constructing the 'empirical' price indices. Furthermore, no important results are compromised since the creator's Malmquist quantity indices provide implicit measures of the 'true' HF values.

14 Diewert (1997, 427) is explicit that "(b)efore we can discuss sources of bias in the computation of consumer price indexes ..., we (must) have in mind some specific conceptual framework .... The conceptual framework I shall adopt in order to discuss bias is the ... social COL (cost of living) index as the underlying 'correct' concept." Earlier, Allen (1975, p. 43, 47) observed that, "index numbers are attempting something more difficult than usual -- the measure of some concept rather vaguely defined and not capable of direct observation. ...(Still,) an economic-theoretic index can be sought as a *constant utility price index*" (italics in original). Our approach is similar in that it presumes knowledge of individuals' underlying utility functions. However, because individuals in XEcon are generally not in equilibrium, we do not ask the creator to compute a cost of living index based on the more usual 'equivalent variation' concept. We use the Malmquist quantity index instead.

15 This particular simulation assumes there are no conventional services like dining, theatre and exotic vacations; these are considered in the last set of simulations.

16 Due to the complexity of the underlying micro dynamics in XEcon, the fluctuations seen here are better thought of as characteristic of a chaotic system, and not the result of any simple cyclical dynamics.

17 Actually, U_0 is an average over the first five chronons, $F_0 = M_0 = 1$ by definition, and F_T, M_T and U_T are averages over the last five chronons.

18 In the XEcon simulations, this ray would initially be along the food axis. It is shown here in the interior of the orthant only to make the exposition clearer. Note that any of a range of 'Malmquist rays' could have been chosen to make the point. For example, if the ray is always along the food axis, we have the special case of a purely 'food equivalent' Malmquist index.

19 The high income scenario for information goods does show greater path dependence - half of eight replicates manifest falling prices, but the other half have rising prices for movies. We focus on the results from one of the latter simulations. Since the intent is to highlight a paradox by means of a counter-example, this arbitrary choice of a simulation scenario is entirely in keeping with the logic of the argument.

20 The values of the Malmquist indices, in particular, may seem high. However, it can be verified that a simple numerical example focusing only on food and movies, using the same utility function, and the same price changes emerging from the XEcon simulations reported here, will generate very similar results. The intuition is that even without satiation, as marginal utilities fall, especially for those with higher incomes, it is necessary to go proportionately further out along the Malmquist ray to meet the necessary indifferences curve (I_{1b} in terms of figure 6 above).

21 The next wave of technical progress may well be in the bio-technology area. Insofar as technical progress in this area generates new substances (e.g. genetically engineered drugs) whose cost of discovery is many orders of magnitude higher than their reproduction costs, they will raise essentially the same measurement problems.

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