NBER WORKING PAPER SERIES

IS GDP BECOMING OBSOLETE? THE “BEYOND GDP” DEBATE

Charles R. Hulten
Leonard I. Nakamura

Working Paper 30196
http://www.nber.org/papers/w30196

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 2022

We thank Steven Landefeld and Dylan Rassier for their helpful comments on an earlier draft of this paper, as well as the participants at the October 14, 2021, seminar at the Bureau of Economic Analysis. Remaining errors and interpretations are our own. The opinions expressed are our own and not those of the Federal Reserve Bank of Philadelphia or the Federal Reserve System, or any other organization with which we are affiliated. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

At least one co-author has disclosed additional relationships of potential relevance for this research. Further information is available online at http://www.nber.org/papers/w30196.ack

Is GDP Becoming Obsolete? The "Beyond GDP" Debate
Charles R. Hulten and Leonard I. Nakamura
NBER Working Paper No. 30196
July 2022
JEL No. C43,C51,C82,O47

ABSTRACT

GDP is a closely watched indicator of the current health of the economy and an important tool of economic policy. It has been called one of the great inventions of the 20th Century. It is not, however, a persuasive indicator of individual wellbeing or economic progress. There have been calls to refocus or replace GDP with a metric that better reflects the welfare dimension. In response, the U.S. agency responsible for the GDP accounts recently launched a "GDP and Beyond" program. This is by no means an easy undertaking, given the subjective and idiosyncratic nature of much of individual wellbeing. This paper joins the Beyond GDP effort by extending the standard utility maximization model of economic theory, using an expenditure function approach to include those non-GDP sources of wellbeing for which a monetary value can be established. We term our new measure expanded GDP (EGDP). A welfare-adjusted stock of wealth is also derived using the same general approach used to obtain EGDP. This stock is useful for issues involving the sustainability of wellbeing over time. One of the implications of this dichotomy is that conventional cost-based wealth may increase over a period of time while welfare-corrected wealth may show a decrease (due, for example, to strongly negative environmental externalities).

Charles R. Hulten
Department of Economics
University of Maryland
Room 3114, Tydings Hall
College Park, MD 20742
and NBER
chulten@umd.edu

Leonard I. Nakamura
Federal Reserve Bank of Philadelphia
10 Independence Mall
Economic Research
Philadelphia, PA 19106
USA
leonard.nakamura@phil.frb.org

I. Introduction[1]

America entered the Great Depression lacking an organized national statistical system with which to track the aggregate economy and to inform economic policy. By 1933, 25% of the work force was unemployed, up from around 3% four years earlier. There was a partial recovery, but the rate went up again to 20% in 1938 before falling to as low as 1.2 % during World War II. There were no official estimates of Gross Domestic Product at the start of the Depression with which to guide the policy response, but by the mid-1930s this began to change. However, the National Income and Product Accounts, in their more-or-less current form, were only published in the late 1940s.[2] The lack of information about the aggregate economy and its components was particularly unfortunate in light of the importance of aggregate demand in Keynesian economics.

The development of these accounts was called "One of the Great Inventions of the 20th Century," by Paul Samuelson and William Nordhaus.[3] Yet, GDP has also attracted substantial criticism in recent years. The leading example is perhaps the 2009 report by the International Commission on the Measurement of Economic Performance and Social Progress, *Mismeasuring Our Lives: Why GDP Doesn't Add Up*, co-authored by Stiglitz, Sen, and Fitoussi. As summarized by its lead author in a 2018 piece titled *Beyond GDP*,

"GDP is not a good measure of wellbeing. What we measure affects what we do, and if we measure the wrong thing, we will do the wrong thing. If we focus only on material wellbeing - on, say, the production of goods, rather than on health, education, and the environment – we become distorted in the same way that these measures are distorted; we become more materialistic".

He goes on to note that "The OECD has constructed a *Better Life Index,* containing a range of metrics that better reflect what constitutes and leads to wellbeing."

---

[1] This paper builds on our papers "*Accounting for Growth in the Age of the Internet: The Importance of Output-Saving Technical Change*" (2018); and *"Expanded GDP for Welfare Measurement in the 21st Century,"* (2021). We thank Steven Landefeld and Dylan Rassier for their helpful comments on an earlier draft of this paper, as well as the participants at the October 14, 2021, seminar at the Bureau of Economic Analysis. Remaining errors and interpretations are our own. The opinions expressed are our own and not those of the Federal Reserve Bank of Philadelphia or the Federal Reserve System, or any other organization with which we are affiliated.

[2] For an historical perspective on the early evolution of the U.S. GDP accounts, see Carson (1975).

[3] The quote by Samuelson and Nordhaus is cited in J. Steven Landefeld, "GDP: One of the Great Inventions of the 20th Century," *Survey of Current Business*, January 2000.

The importance of the wellbeing argument from a measurement perspective is that "there appears to be an increasing gap between the information contained in aggregate GDP data and what counts for common people's wellbeing (Stiglitz et al., page 12)." This argument has been taken up by the Bureau of Economic Analysis, the agency responsible for the national accounts and GDP, in a new initiative "*GDP and Beyond*". This new initiative was announced in the *Survey of Current Business (*Bohman (2020)): "Recently, BEA launched a Bureau-wide initiative to expand our official statistics beyond conventional measures of economic growth by highlighting aspects of economic well-being and sustainability." This issue also includes an important article by Landefeld et al. (2020) that provides a taxonomy of the various options for the Beyond GDP project and references to the extensive literature.[4]

A number of other economists have questioned the relevance of the GDP concept. Nordhaus and Tobin titled their 1973 paper in which they constructed a measure of economic welfare, "*Is Growth Obsolete?*". Coyle (2014) remarked that the GDP accounts were designed for an earlier economic environment, and Jones and Klenow start their 2016 paper with the statement that "As many economists have noted, GDP is a flawed measure of economic welfare." The inadequacy of GDP was also stressed by Martin Feldstein (2017), who argued that real GDP was now "not even measuring output, and certainly not wellbeing." The active debate about the role of GDP growth in promoting climate change and diminishing biodiversity (Dasgupta (2021)) is another facet of the welfare critique of measured GDP. The literature continues to grow, driven by questions about GDP as a suitable measure of aggregate economic welfare.

The Stiglitz-Sen-Fitoussi report advocates "working towards the development of a statistical system that complements the measures of economic activity by measures centered on individual well-being and by measures that capture sustainability (page 12)." This is also the goal of our paper. They also note that "Changing emphasis [from production to wellbeing] does not mean dismissing GDP and production measures". But, while GDP may not be dismissed, it would seemingly be replaced by a welfare metric as the preferred "headline" measure of

[4] The GDP and Beyond program at BEA is by no means a recent initiative, but a continuation of an ongoing effort, as witnessed by the 2010 article in the *Survey of Current Business* by Landefeld et. al. "GDP and Beyond: Measuring Economic Progress and Sustainability." Indeed, BEA has been active in recent years in improving the U.S. national accounts with such developments as the Integrated Macroeconomic Accounts and the capitalization of intangible capital.

aggregate economic activity. The authors state that "Another key message, and unifying theme of the report, is that the time is ripe for our measurement system to *shift emphasis from measuring economic production to measuring people's well-being"* (page 12, italics original). This seems to suggest that the choice of headline measures is an either-or matter.

We take a more ecumenical view in this paper, arguing that different questions about the economy require their own specific "headline" answers. On the one hand, GDP is generally regarded as the appropriate metric for questions of counter-cyclical policy and for policies that involve the allocation of resources; these provided the initial impetus for the formation of the U.S. National Income and Product Accounts. Moreover, the products within GDP are important sources of economic welfare, including, as it does, the provision of such necessities as food, shelter, clothing, transportation, and medicine. Thus, the hunt for measures centered on individual well-being must include GDP near the center.

On the other hand, there are good reasons to believe that there are products whose contribution to welfare exceeds their contribution to recorded GDP. There have been, for example, enormous gains in overall wellbeing from health care through channels not counted in GDP, as witnessed by the recent development of vaccines against the Coronavirus. Moreover, the Information Revolution has enabled consumers to make more informed choices and thus more efficient use of their income. These examples imply that wellbeing may have increased more rapidly than GDP.

However, in other areas, Beyond-GDP reforms may have the opposite impact. These include the environmental damage associated with the production and consumption of GDP goods, the sustainability of current resource use, and the effects of rising income inequality. These examples tend to imply that overall wellbeing may have increased less rapidly than GDP.

Measuring the gap (positive or negative) between a more welfare-based economic aggregate and GDP is not an easy task given that one side of the gap, GDP, is a monetary metric, while many of the metrics on the welfare side are not, making comparison difficult. Many aspects of wellbeing that might plausibly be included in an expanded measure of wellbeing lie outside (and, in some cases, well outside) the reach of monetary metrics, or what Pigou (1920) termed the "measuring rod of money." As we shall see, many of these aspects are subjective and idiosyncratic, and some involve value judgments. Part of the challenge arises from the absence of any common natural units with which to measure and compare the various types of wellbeing under consideration. However, these variables are too important to ignore when assessing the progress that has been made, so these measurement challenges must, to the extent possible, be overcome.

This is the point at which this paper joins the Beyond-GDP debate. Our approach is to build outward from the existing GDP accounts and their underlying economic theory to include sources of utility and disutility tied to GDP goods but not captured by GDP itself. Our extension of the conventional GDP model to include these "spillovers" is based on our two earlier papers, both of which start with the standard general equilibrium model of utility maximization and extend this model to incorporate Lancaster's "New Approach to Consumer Theory" (1966a).

There is a separate "consumption technology" in the Lancaster framework that transforms the goods acquired from their producers, measured at production cost, into consumption activities (or "commodities") that give utility based on their characteristics. In effect, the consumption technology introduces a gap between conventional production-oriented GDP and the associated consumer wellbeing. The gap is then measured using the compensating/equivalent variation approach. The result is a monetary metric of the value of the additional utility that can be added to resource-based GDP to arrive at a welfare-oriented measure we term Expanded GDP (EGDP). This approach connects the two measures within the same theoretical and measurement framework, which aids interpretation and comparison.

This paper also adds a multi-year dimension to our previous work on EGDP by introducing the consumption technology into the conventional cost-based measurement of capital stock and wealth. The result is an alternative metric we call "E-wealth" that is the intertemporal counterpart of EGDP. Just as GDP and EGDP provide answers to different questions, so also do wealth and E-wealth. The two wealth metrics are thus complements, not substitutes, and, as with GDP and EGDP, both reveal important aspects of the economic system and, together, both speak to the issue of sustainability: the E-wealth metric may reveal a decline in sustainability, while the corresponding conventional cost-based measure appears sustainable.

Finally, we highlight the different roles of GDP and Gross Domestic Income (GDI) in the Beyond GDP project. They are different and independently measured metrics of aggregate economic activity, the latter referring to the resource cost of inputs and the former to expenditure and output. The two are theoretically equal in the double-entry accounting practice of the national accounts, so some clarification is needed about what it means to go beyond GDP without changing the inputs or technology that define GDI. We propose, in this paper, a mechanism that allows wellbeing per unit of GDI to change over time.

II. GDP: Conceptions and Misconceptions

A. Real GDP is often treated as though it were a single homogenous entity representing the total product of an economy, something you might purchase in a store. Nominal-price GDP is, in fact, a statistic built up from the data in a large number of tables, and real GDP is the estimate obtained mostly by controlling for price-level changes using a price deflation procedure. GDP is meant to be an indicator of the volume of economic activity, but that does not mean that it necessarily refers to a specific set of goods and services. There are, in fact, four different ways that nominal "GDP" could be estimated:

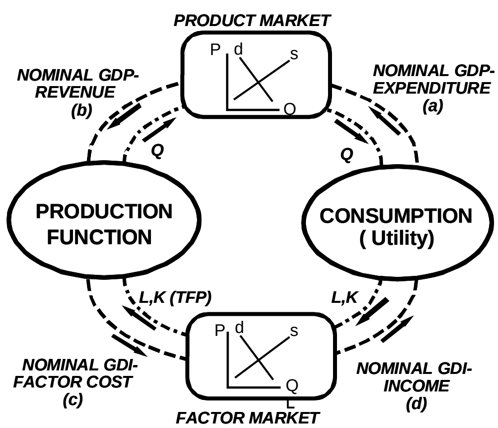

FIGURE 1

(a)   the expenditure on the goods and services acquired;

(b)   the payments received by the producers or owners of these goods and services;

(c)   the cost to the producer of acquiring the labor and capital needed to produce this output;

(d)   the income accruing to labor and capital.

These four alternatives are shown in the circular flow diagram above. Each of these flows reveals a different aspect of the economy but, while they are separate, they are interconnected. The counter-clockwise flow around the outer edge of the figure is valued in nominal prices: quadrant *(a)* is a flow of payments into the product market from consumers, while *(b)* is a flow out of that market to producers. The flows are simply transfers and are thus equal (in principle, if not in practice) and, together, they constitute nominal-price GDP. The cost of production *(c)* is a flow into the factor market, and *(d)* is a flow out of that market to the owners of labor and capital; since the flows are ultimately (after some intermediation) transfers occurring within the factor and financial markets, they are also equal. Together, they constitute nominal GDI.

Two transformations also take place in the circular flows. First, the inputs of labor and capital acquired by producers are transformed into output, and the revenue from the sale of output *(b)* pays for the cost *(c)*, and they are thus equal. Secondly, income from *(d)* is used to purchase goods in the product market (via *(a)*) which are transformed into welfare according to the choices and expenditures made in light of the utility function. Income thus equals expenditures (including saving). Thus, the four elements *(a)* through *(d)* that constitute GDP and GDI are, in principle, equal. The overall result is the Frank Knight circular flow model of national income accounting (Patinkin (1973)).

The clockwise inner flows in quadrants *(c)* and *(b)* of the circular flow diagram refer to the real (constant price) quantity of inputs (L and K, in the diagram) and real aggregate output (shown as Q). The quantities of labor and capital are linked to real output via the prevailing technology and its level of productivity. Similarly, the income obtained from L and K in quadrant *(d)* is transformed into the welfare obtained from the purchase and consumption of real output Q *(a)*.

B. From Accounting to Analysis. The nominal-price flows in the four quadrants of Figure 1 can be formalized in an algebraic form by the following equation, shown here for the aggregate economy:

$$(1a) \quad GDP_t = P^Q_t Q_t = (P^L_t L_t + P^K_t K_t) = GDI.$$

The quantity of output is the Q_t of Figure 1, whose price is P^Q_t; the two input quantities are, as before, L and K, with prices P^L_t (the wage rate) and P^K_t (the gross return to capital, or the Jorgensonian user cost of capital). GDP is the value of the product $P^Q_t Q_t$ and GDI is the gross income accruing to the two inputs $(P^L_t L_t + P^K_t K_t)$, all in year t.

The equality of nominal price GDP and GDI in equation *(1a)* holds when they are valued in the current product and factor prices prevailing in each year. During periods of rising product prices, the welfare content of the expenditure for good Q_t is eroded as the purchasing power of money declines, and each dollar of GDP buys fewer goods. Thus, it is usual in accounting practice to present an alternative measure of "real" GDP that corrects for inflation by expressing the nominal amount in the constant prices of a base-year (e.g., of $t=0$). The price deflation procedure results (in theory) in $GDP_{t,0} = P^Q{}_0 Q_t$. In other words, nominal GDP = $P^Q{}_t Q_t$ is multiplied by the price deflator $P^Q{}_0/P^Q{}_t$.

The concept of "real" GDI is more complicated. In common usage, real *income* is commonly taken to mean income corrected for its purchasing power. This is essentially the wellbeing associated with the income emerging from the factor markets that flows to the consumer in quadrant *(d)*. It is also the meaning used by BEA for its "Inflation-adjusted measure of disposable personal income" account, where deflation is done using the personal consumption expenditure price index. There are a lot more complexities, but in our simplified version of the gross income framework, this amounts to $GDI_{t,0} = (P^Q{}_0/P^Q{}_t)(P^L{}_t L_t + P^K{}_t K_t)$; since nominal GDP in each year equals nominal GDI in that year, a general GDP price deflator can be applied to GDI to control for the purchasing power of income.

However, there is also a second concept of inflation-corrected GDI in the flows in quadrant *(c)*: real factor cost. Recalling equation *(1a)*, GDI itself is defined in nominal prices as the current cost to producers of acquiring the inputs of labor and capital, or $(P^L{}_t L_t+P^K{}_t K_t)$. Inflation affects both wages and capital prices (actual or implicit) and thus increases the cost of production. Using an input price index to correct for factor price inflation results in $(P^L{}_0 L_t+P^K{}_0 K_t)$. The key result, here, is that real GDP in this sense is not equal to real GDI in its form of factor cost:

$$(1b) \quad GDP_{0,t} = (P^X{}_0 X_t + P^Y{}_0 Y_t) \neq (P^L{}_0 L_t + P^K{}_0 K_t) = RFC_{0,t} .$$

This has an important implication: the wedge between $GDP_{0,t}$ and $RFC_{0,t}$ is known as the Solow Residual (1957) measure of total factor productivity (TFP). TFP is a measure of the increase in output per unit total input which, in the Solow-Jorgenson-Griliches framework, is based on the shift in the aggregate production function relating labor and capital to output ($Q = e^{\lambda} F(L,K)$), where λ is the rate of TFP growth.[5] However, TFP can be approached from the price side of the economy as well as the output side via the parallel aggregate factor price frontier. A factor price frontier is an equation linking output price to input price in a way derived from a constant-returns-to scale production function when product and factor markets are competitive (both conditions for the equalities in equation *(1a)*), and is the source of the difference between the two concepts of real GDI. [6]

Another implication of the two concepts for the structure of the national accounting system is that the appropriate form of inflation-adjusted nominal GDI may take different forms depending on what questions are asked of it. When generalized, this is one of the main themes developed in this paper. Yet another is the importance of the link between theory and measurement, to which we return in section III below.

C. The circular flow formulation and the associated equations also have important implications for the Beyond-GDP project. First, the implied measure of aggregate economic activity in the circular flow diagram is seen to be *both* a measure of wellbeing and of the cost of production. Resource cost versus wellbeing is therefore not an "either-or" matter. Indeed, as we have previously noted, the goods of quadrant *(a)* include expenditures for many of the basic necessities of life. The issue for the Beyond GDP movement is therefore *not* whether wellbeing should be introduced into the national accounts, but how much additional wellbeing is missed by the current GDP metric, and how it might be measured.

Second, the connectivity of the four quadrants of the diagram means that any change made in one quadrant must be accommodated by a change in the others if current national accounting practice is to be preserved. Thus, any change contemplated in a reform of GDP must also find its way into nominal GDI (and *vice versa*). What does moving beyond GDP mean for

---

[5] TFP is, in effect, the residual output not attributable to the use of the inputs and thus has no resource cost. Many factors are involved in this result, like the diffusion of knowledge and imitation, inspiration, and learning.

[6] The factor price frontier relates product price to the price of the factor inputs multiplied by the inverse of the TFP rate ($P_Q = e^{-\lambda}\varphi(P_L,P_K)$). In other words, a positive rate of TFP growth increases output per unit of labor and capital (real factor cost) but lowers the price of output relative to the prices of the inputs because of the efficiency gain. Thus, λ drives a wedge between real factor cost and the cost of output, as in the discussion of the two concepts of real GDI.

GDI? This is a question that needs to be considered when proposing additions or subtractions to the various flows during the process of going beyond GDP.[7]

Third, the equality of the monetary flows in the four quadrants of Figure 1 do not make provision for beyond-GDP sources of utility or wellbeing add-ons of the sort envisioned by the Beyond GDP movement. Where in the circular flow of payments do these additions fit? Indeed, many of the non-GDP sources of wellbeing are not even susceptible to the Pigovian measuring rod of money. The question then is how the different non-monetary and monetary measuring rods are to be fitted together into a new “architecture” that better portrays the true extent of aggregate wellbeing. This is where our paper makes its conceptual contribution by offering a way of augmenting the circular-flow accounting model to allow for additional sources of wellbeing.

III. The Neoclassical Model of GDP

A. The data flows recorded in Figure 1 are more than just a large accounting exercise that reflects the aggregate structure of an economy. They can also be derived from a simple theoretical model of the aggregate economy under the assumption of general equilibrium. This approach recognizes that the data flows in Figure 1 are generated by the production and consumption of goods and services, so it is therefore not surprising that they can be linked to formal models of that structure. Indeed, the accounting equation *(1a)* can be derived from the conventional theory of utility maximization subject to a constraint. The link between theory and national income accounting practice was elaborated in the important contributions of Christensen and Jorgenson (1969, 1970) and, more recently, it is the conceptual basis for the “New Architecture” of the accounts put forward by Jorgenson and Landefeld (2006). This body of work establishes a linkage that provides conceptual consistency between theory and observation (following the Koopmans (1947) injunction against measurement without theory). Theory also provides a framework that guides and constrains what is to be included in the corresponding

[7] The problem in moving beyond current GDP is complicated by the presence of intermediate inputs and outputs. Intermediate products are those goods that are produced for delivery to other industries as inputs into their production. Steel production delivered to the auto industry is an example. Because they are both inputs and outputs, the volume of their net production is zero. As a result, the GDP goods entering the product market from quadrant *(b)* are deliveries to final demand and not total output. A similar netting-out process occurs on the input side of the circular flow diagram, leaving the primary factor inputs of labor and capital in the factor markets (as, for example, in Hulten (1978)).

GDP accounts, a role that becomes even more important when considering how to revise the existing accounts to better represent economic wellbeing.

The goal of our paper is to augment standard economic theory in a way that accommodates the further expansion of the GDP accounts to better capture true wellbeing. In order to facilitate graphical intuition, we focus on the case of two goods, *X* and *Y*, and two inputs, *L* and *K*, and two consumers with identical utility functions, *U(X,Y)*.[8] The common utility function is maximized subject to a constraint on how much can be produced in any year, represented by the production possibility frontier *F((X,Y;L, K, t)*. This production frontier transforms the given amount of labor and capital available in each year via the prevailing technology into the products available for consumption or use (recall the transition from quadrants *(c)* to *(b)* in the circular flow account model of the preceding section). The *t* term in the production function is a time-shift variable allowing for autonomous changes in the production possibility frontier in each year due to changes in the total factor productivity with which the inputs are used.

This production possibility frontier is shown in Figure 2 as the curve PPF_0. It indicates the maximal combinations of *X* and *Y* that can be attained from the optimal allocation of the inputs in any given year and is, in effect, the physical "budget" constraint of a two-sector macro

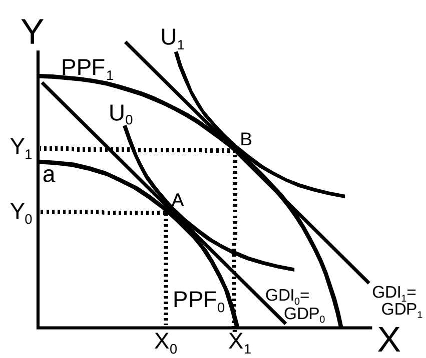

FIGURE 2

economy. The point *A* is the point of tangency between PPF_0 and the highest indifference curve, U_0, of the utility function *U(X,Y)*. U_0 thus represents the highest level of utility that can be

---

[8] This is the well-known 2x2x2 model of basic microeconomic theory. The 1957 article by Francis Bator, "The simple analytics of welfare maximization," has what is probably the classic exposition of this model. Many of the diagrams of this paper, and of our earlier work, are inspired by those in Bator's exposition.

achieved consistent with remaining on the constraint imposed by the PPF_0. It is also the market equilibrium of this two-good economy, where supply equals demand for both goods. In this textbook case, the slope of PPF_0 at *A*, the marginal rate of transformation (MRT) between *X* and *Y*, equals the slope of U_0, the marginal rate of substitution (MRS). The MRT is also the ratio of the marginal costs of *X* and *Y*, and the slope of the MRS is the ratio of the marginal utilities. The ratios are equal, bringing marginal cost into balance with the marginal utilities.

Since *A* is a competitive equilibrium where the MRT and MRS are equal, the equality defines the price ratio P_X/P_Y, which is also the slope of the mutual tangent line at *A*. The tangent line has the form $P_X X + P_Y Y$, which, in view of the accounting equation *(1a)*, equals GDP. Again, the connection between the equilibrium price and marginal utility emphasizes the welfare dimension of GDP. Similarly, the connection between price and the marginal cost of producing the quantities of *X* and *Y* at *A* indicates the cost dimension. Moreover, this cost is related to factor income under constant returns to scale in production when labor and capital are paid the value of their marginal products, in which case cost equals $P_L L+P_K K$. Constant returns also imply that $P_Q Q = P_L L+P_K K$, confirming that GDI equals GDP. The fact that the tangent line in Figure 1 is also equation *(1a)* of the preceding section establishes a link between theory and accounting.

B. Figure 2 also illustrates the possibility that a shift in the production possibility frontier can occur over time. This is shown in Figure 2 as the shift from PPF_0 to PPF_1. The shift can arise from three sources: growth in the labor force or in the stock of capital, or an increase in TFP.

This outward shift in the production function causes the equilibrium to shift from *A* to *B*, and the utility function to increase from U_0 to U_1. In the process, the tangent line increases from ($GDI_0 = GDP_0$) to ($GDI_1=GDP_1$). The part associated with costless TFP efficiency change is important for the current debate because a shift in TFP allows for welfare improvements that leverage available inputs.

IV. Lancaster's "New Approach to Consumer Theory"

A. The issue raised by the Beyond GDP movement is whether there is significantly more to wellbeing than the utility embodied in GDP. As it stands, there is no provision for an additional source of utility or wellbeing in the circular flow diagram of Figure 1 of the national accounts or in the theory of Figure 2. Where, for example, would the additional utility be located in these figures? We address this issue in this section by showing how the theory and accounting framework of the preceding sections can be built out to include additional sources of utility.

Our proposed solution to the additional utility problem is to invoke the model developed by Kelvin Lancaster in his 1966 papers on the "New Approach to Consumer Theory" and integrate it into the structure of Figure 2. This is the main point of departure of this paper that differentiates it from other critiques of GDP. The idea underlying Lancaster's "New Approach" is that utility depends on the characteristics of goods consumed and not on the goods themselves as acquired from producers. This led him to introduce the concept of a consumption technology that transforms these goods into a form that conveys an additional actual benefit. Lancaster uses the example of a meal, which is more than just the sum of the individual items of food consumed, but a complex interaction of various factors.[9] One of the key features of the consumption technology for the meal is the technique and the recipe used to select and combine a variety of the ingredients, as well as creating an ambience. These are not priced into the products that comprise GDP, and both are regarded by Lancaster as part of the consumption technology.

In its fullest form, the structure of the Lancaster model is quite complex. However, the model he actually works with is a simplified form in which he assumes that the results of consumption technology's output, Ω, are linearly connected to outputs (the X and Y) in our two-good example, but, in the general, a vector of goods Q). In this case, $\Omega = BQ$, where B is a set of parameters that define the consumer's technology. The associated utility function is then $U(\Omega_t) = U(BQ_t) = U(g(Q_t))$. In the conventional formulation of utility theory, goods and commodities are identical and $B = 1$. In the more general case, the consumption technology indicates that different levels of utility can be obtained from a given Q, depending on the efficiency with which the transformation occurs.

[9] "A meal (treated as a single good) possesses nutritional characteristics but it also possesses aesthetic and social characteristics, and different meals will possess these characteristics in different relative proportions. Furthermore, a dinner party, a combination of two goods, a meal and a social setting, may possess nutritional, aesthetic, and perhaps intellectual characteristics different from the combination obtainable from a meal and a social gathering consumed separately" (Lancaster (1966a), page 133). Subjective factors like ambience, mood, and novelty matter, as well as knowing which foods, sauces, spices and beverages go well together.

B. Adding the Lancaster consumption technology to the conventional analysis of aggregate economic activity as shown in Figure 2 is the main technical contribution of our line of analysis. The addition provides a pathway for utility to increase (or decrease) beyond that already embodied in GDP and allows for the possibility that the standard of living may grow at a different rate than real GDP.

Incorporating the Lancaster consumption function into Figure 2 is analytically straight-forward, at least in the reductionist macro framework of this figure.[10] Figure 2 portrays the equilibrium solution to the conventional problem of maximizing utility $U(X_t,Y_t)$ subject to the technology constraint $F(X_t,Y_t,t)$ implied by the production possibility frontier.[11] The simplified version of the Lancaster consumption technology can be brought into play by expanding the utility function so that it allows for a time shift of its own, $U(X_t\,,Y_t\,,t)$. This addition changes the dynamics of the problem in an important way by allowing a second effect to influence the outcome of the optimization problem, often by making more effective use of the income available, or, in other words, to get more "utility bang for the GDP buck." Thus, where maximal utility is constrained by the production frontier in Figure 2, this need not be the case when the utility function is also allowed to shift costlessly. This is the situation portrayed in Figure 3,

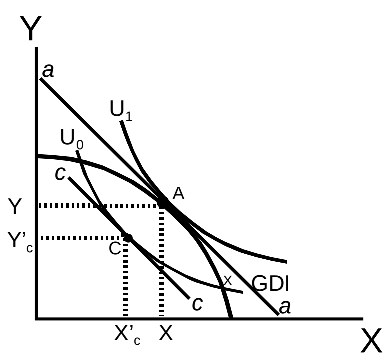

FIGURE 3

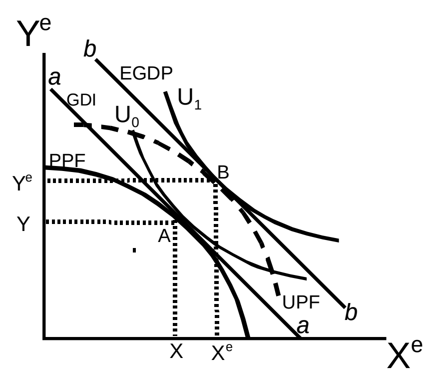

FIGURE 4

[10] The Figures 1, 2, and 3 used in this paper are modifications of similar figures in our 2018 paper.

[11] Since the objective of this paper is to introduce the idea of a consumption technology into the conventional utility maximization framework and study the implications for the Beyond GDP project, we do not go into the many important modeling issues raised by Deaton and Muellbauer (1980) and Redding and Weinstein (2017). For example, we do not attempt to model and parameterize how additional information affects consumer choice.

which illustrates what happens when a shift in the consumption technology causes the utility function $U(X_t,Y_t,t)$ to shift outward by the factor $1+\theta$, and the indifference curves to shift inward.[12] The shift is shown here to apply equally to both X and Y (commodity neutral) for simplicity of exposition. The technology defining the production frontier, $F(X_t,Y_t,t)$, is held constant in the figure in order to isolate the utility effect. In other words, GDI is unchanged (the price line *aa* is here designated only by *GDI* for clarity of exposition, instead of *GDI = GDP* as in the preceding figure). The same amount of real GDP, X and Y, thus supports a higher amount of wellbeing. This "bang for the buck" might also be called "utility-augmenting innovation" or, equally, "output-saving technical change".

How large a "bang" does the shift in the consumption technology produce? The expenditure needed to support the old U_0 is represented by the line *cc* in the figure, which is assumed to be parallel to *aa* for illustrative purposes. Thus, at the point of tangency C, the required expenditure needed to attain the previous indifference curve is now only $P^X X_c + P^Y Y_c$, a saving of V' due to the shift in utility:

$$(2) \quad V' = (P^X X + P^Y Y) - (P^X X'_c + P^Y Y'_c)$$

The saving V' provides a monetary value metric for measuring utility-augmenting innovation. In so doing, it provides a theoretical solution to the problem of incorporating additional sources of wellbeing into the conventional monetary framework of Figure 2.

C. Figure 4 is a variant of Figure 3 that clarifies the relation between GDI and post-Lancaster welfare-adjusted GDP and leads to conventional compensating and equivalent variations that value the shift in utility. In Figure 4, an upward translation of the indifference curves now places U_0 tangent to the equilibrium point A, i.e., (X,Y), the point where it was prior to the shift in the consumption technology. In other words, the original competitive equilibrium prices and quantities (and GDI) are unchanged by the shift in utility to the indifference curve, U_1, which now lies beyond the production frontier, which is to say, beyond GDI. A new tangency point B is established on a notional price line *bb*.

---

[12] This function $U(X_t,Y_t,t)$ is defined in a three-dimensional space whose axes are X, Y, and U. The indifference curves are projections of the three-dimensional utility function onto the two-dimensional product space, XY. An upward shift in the function thus leads to a inward shift in the latter.

This upward translation of the utility function also translates the units of measurement. Since the actual physical quantities of goods are unchanged, the values at *B* can be expressed in equivalent utility-loaded "efficiency" units, $X^e = (1+\theta)X$ and $Y^e = (1+\theta)Y$, where the θ (as before) is a parameter determining the shift in the consumption technology. The utility-loaded "quantities", X^e and Y^e, are located on a quasi-utility-possibility frontier *UFP* shown in the figure. The corresponding notional prices, P^{Xe} and P^{Ye}, have the property that $P^{Xe} = P^X(1+\theta)$ and $P^{Ye} = P^Y(1+\theta)$. These equalities indicate that if output doubles in consumption efficiency units, the efficiency price must fall by half. Note that the nominal value of the good does not change when reported in efficiency units, leading to the equality $P^X X = P^{Xe}X^e$, and, similarly, $P^Y Y = P^{Ye}Y^e$. These equalities show that nominal GDP is left unchanged by the improvement in efficiency, implying that $P^{Xe}X^e + P^{Ye}Y^e = P^X X + P^Y Y$.

What has changed is the difference between $[P^X(1+\theta)X + P^Y(1+\theta)Y]$ and $(P^X X+P^Y Y)$, the equilibrium valuations at the points *A* and *B*, on the price lines *aa* and *bb*. This difference is the compensating variation, *V*, which defines the willingness to pay for the additional utility $(1+\theta)$. In other words, the *V'* in Figure 3, is now repositioned relative to GDP to yield:

$$(3) \quad V = [P^X(1+\theta)X + P^Y(1+\theta)Y] - (P^X X + P^Y Y) = \theta(P^X X + P^Y Y)$$
$$= \theta\, GDP = \theta\, GDI.$$

The *V* in *(3)* captures the monetary effect of a θ-shift in the consumption technology relative to GDI and is thus a potentially measurable metric for the unobserved θ.

What does equation *(3)* mean for the measurement of GDP and GDI? *V* is a monetary measure of the change in welfare not associated with a change in GDI, and it can be added to GDP to arrive at an alternative expanded measure of GDP. We term this notional amount *expanded GDP (EGDP)*, and use *(3)* to derive the following link between *EGDP* and conventional GDI:

$$(4) \quad EGDP = [P^X(1+\theta)X + P^Y(1+\theta)Y] = V + (P^X X + P^Y Y)$$
$$= V + GDP = (1+\theta)GDP = (1+\theta)GDI .$$

This formulation expresses in technical terms our contribution to the Beyond GDP project. The *EGDP* defined in *(4)* clearly goes beyond *GDP* by the addition of the wellbeing metric *V*. It establishes that there are two valid concepts of aggregate economic performance, one anchored in the productivity of the resources on the PPF and the other in the realm of wellbeing. In addressing the question of whether aggregate economic activity should measure productivity or welfare, the EGDP framework of *(4)* allows both to be measured in an internally consistent way.

D. The compensating and equivalent variations associated with Figure 4 indicate the amount that consumers would be willing to pay for the additional wellbeing. In theory, they provide a solution to the problem of estimating of the monetary value of θ and V in a way symmetric with market GDP, which is itself an indicator of the willingness to pay for the goods that currently comprise GDP. Adding an estimate of V to market GDP is thus a natural extension of the GDP accounting framework.

This "solution" is not so easy in practice. A difficulty arises from the fact that the willingness-to-pay metric for any one good in isolation (say, for example, X in Figure 4) is usually derived using a partial equilibrium approach. This approach holds constant the price and quantity Y and thus ignores the possible substitution effect associated with a change in price of X. Unfortunately, it is very difficult for empirical studies to capture the full general equilibrium nature of the willingness-to-pay problem required by the *CV/EV* in Figure 4. This is unfortunate for the purpose at hand, because even if accurate partial equilibrium estimates of X and Y were available, the sum of the two partial equilibrium estimates does not result in the correct general equilibrium answer (except under exceptional assumptions). Thus, adding them to GDP, even when they can be estimated accurately, does not yield the true EGDP. Moreover, many of the partial equilibrium estimates are based on hypothetical experiments that value specific goods without having to confront the tradeoffs implicit in a true budget constraint.

An even greater difficulty arises from the occasional nature of the partial equilibrium studies. The price and quantity transactions that flow around the circle in Figure 1 can be tapped to produce consistent estimates of GDP on the regular and timely schedule needed for national accounting. The same cannot be said of the willingness-to-pay estimates of θ, which are not based on regular market flows, but instead must depend for the most part on non-market estimates from periodic studies and surveys.[13]

---

[13] These "administrative" points may seem somewhat pedestrian, but regularity and consistency over time are two of the most important features of the GDP accounts. They are needed in order to track the growth and fluctuations of

However, this does not mean that partial equilibrium estimates of willingness-to-pay θ's are without value. While they are unlikely to be as accurate and timely as the more standard, transaction-based, GDP estimates, they have already shed valuable, if only periodic, light on areas in which the GDP accounts have problems (e.g., the potential magnitude of the willingness to pay for Internet applications that are offered without a direct charge).[14] This approach is also helpful in improving many other problem areas in real GDP, like those goods for which no reliable output price deflators are available and real output is valued at production cost (thus missing productivity change).

The θ approach can also help in the process of incorporating some of the more difficult measurement areas of wellbeing into a larger framework that includes GDP. This process is what Stiglitz et al. presumably mean by "working towards the development of a statistical system that complements the measures of economic activity by measures centered on individual well-being and by measures that capture sustainability (op. cit)." The development of such a system, like the implementation of the θ approach itself, is also not an easy task. Many of the requisite welfare metrics are non-monetary and subjective, as well as involving value judgments.

While problems with the implementation of the consumption technology approach should not be minimized, the way forward to a broader wellbeing account is sufficiently difficult that the estimation of θ offers an option that should not be ignored. Indeed, the development and incorporation of this approach into the larger accounting framework is, for now, best regarded as a work in progress, with subsequent developments appearing in an experimental satellite account. There is a well-established precedent in the SNA tradition for using the satellite approach for incorporating diversely-sourced data into the accounting system.

V. Some Historical Perspectives on the Consumption Technology and θ

A. The consumption technology described in this paper has been introduced in general theoretical terms and the shift in that technology treated as a black box. But, what exactly are the

---

real GDP and its components over time, which, in turn, are needed to assess the evolution of the economy. This point also applies to the assessment of the growth in wellbeing.

[14] The valuable study by Brynjolfsson et al. (2019) of the partial equilibrium value of new goods in the Digital Economy is an exception. It does provide a time dimension, but it also illustrates the important point that, while the annual values may be quite large, their contribution to the growth of GDP may be small. Both matter for understanding the evolution of GDP and aggregate wellbeing.

factors that cause the technology to shift outward? How important are they as additions to the level and growth of EGDP? The historical record since the start of the Industrial Revolution suggests that the extra-GDP effects of the consumption technology have been very large in the areas of health care and information development and transmission. The associated contributions to wellbeing may thus go well beyond the benefits attributed to them by the GDP metric alone.

B. The world of 1820 lacked effective medical treatments for many, if not most, serious afflictions. As Gawande (2012) put it: "over the past two centuries, surgery has become radically more effective ... [with] changes that have proved central to the development of mankind's abilities to heal the sick." Effective anesthesia was a game changer in the practice of surgery, allowing surgeries that involved more lengthy procedures to be performed. It was also a game-changer for patient comfort and wellbeing.

The realization in the 19th Century that infections were caused by germs also led to a major advance in medical practice. The simple expedient of having the attending surgeons wash their hands and clean their instruments prior to a surgical intervention was an important, and virtually costless, innovation over the prevailing practice. Gawande points to Semmelweiss, who "had found that hand washing by birth attendants eliminated puerperal sepsis, the leading cause of maternal death".

The development of antiseptics and antibiotics was another medical game-changer for both clinical and patient outcomes. The importance of the antibiotics revolution is highlighted by David Landes (1998), who starts his book *"The Wealth and Poverty of Nations"* with an account of how Nathan Rothschild, "probably the richest man in the world, at least in liquid assets," died from an infection that might easily have been treated with modern antibiotics. Not even the richest of people could buy an outcome readily available today despite what was clearly an enormous willingness to pay.

The development of antibiotics clearly provided utility benefits beyond the pure clinical outcomes embodied in GDP, since, for example, it reduced the need for amputation and the pain and life-change that it implies, and the painful practice of cauterizing a wound. Antibiotics have also largely freed communities from some of the fearsome epidemic diseases of history.

The prevention of disease through vaccination is another area where the welfare gains are huge and ultimately achievable at a minimal resource cost. The development of vaccines brought once fearsome diseases like smallpox, diphtheria, tetanus, yellow fever, and polio more or less under control, with enormous increases in human wellbeing. They also have important spillover effects that benefit entire populations. The spillover effects of a successful vaccine against the COVID-19 virus are considerably greater than its consequences for GDP alone, as important as that is. The lock-down and self-imposed isolation are very disruptive of normal lifestyles and daily routines, and the anxiety and sorrows and other psychological costs imposed on individuals are very large.

The computer revolution has enhanced the revolution in medicine in another way, with important breakthroughs in minimally-invasive and arthroscopic surgery. Minimally invasive surgical techniques have, for example, led to significant decreases in recovery times and increases in patient comfort. These benefits accrue to the consumer-patient and occur over and beyond the amount spent on the procedures themselves. And, anyone who has experienced older forms of cardiovascular surgery will appreciate the comfort factor.

Finally, mention should be made of the substitution of drug therapies for surgical intervention or hospitalization. Low-dose aspirin is s good example. It lowers the risk of heart disease and stroke at very little cost compared to the clinical problems it deters. Moreover, the statin anti-cholesterol drugs, which also treat cardiovascular problems, have outsized benefits. In addition to the clinical benefits, they have positive effects on the quality of life (e.g., diet) beyond the reduced probability of serious afflictions.

C. We have gone into great detail about the advances in medical technology because they speak to the question posed at the start of this section: is the consumption technology a real phenomenon or simply a theoretical construct? The examples cited above show that it is very real indeed as it pertains to medical care. The Information Revolution presents another set of examples of the importance of the consumption technology. In their book *How Google Works,* Schmidt and Rosenberg (2014) argue that the world has entered an era in which "the internet has made information free, copious, and ubiquitous" to the consumer. The onset of the "Internet Age," was remarkably rapid. A survey by the U.S. Census Bureau (2014) found that the fraction of U.S. households with a computer at home rose from about one-quarter in 1993 to more than three-quarters in 2012. Other studies cited in Hulten and Nakamura (2021) also found that the share of adults who use at least one social media site increased from less than one-tenth in 2005 to two-thirds in 2015, and market penetration of smart phones more than doubled from 35 percent to 77 between 2011 and 2016.

The impact of the Internet Age on peoples' lives has been enormous. Nowhere is this better illustrated than in the institution of marriage. A study by Cacioppo et al. (2013) reported that more than a third of new marriages originated from an on-line meeting, while a 2019 study by Rosenfeld et al. reported 39% of heterosexual couples met their partner online, up from 22% in 2009. These impacts have affected peoples' lives in ways that are not counted in GDP.

While on-line dating and friendships are important benefits of the new Internet Age, they are only part of the full "free, copious, and ubiquitous" available information as a result of the information revolution. There is a phenomenal amount of information literally at one's fingertips and available as the need arises. The information ranges over many areas, and is accessed through search engines, on-line encyclopedias and dictionaries, and GPS maps indicating traffic, best routes, nearest hospitals, gas stations, and places to eat (to name a few of the major areas). And it is available on a portable device that fits in a pocket. The cell phone itself is a masterpiece of technical innovation: it is a telephone, camera, music player, video player, personal organizer, and Internet access point.

The value of this readily available information and communication accrues directly to the consumer in various ways, but in general it allows them to make more informed decisions about how to spend their income. It also allows people to communicate with their friends. This is the "bang for the buck" described in the main text as a shift in the consumption technology. There is, of course, a resource cost – the cost of the cell phones and other equipment, the cost of subscriptions and access fees, and direct fees for some content. However, the cost that finds its way into GDP is relatively small: according to BEA estimates for 2019, the "Data processing, internet publishing, and other information services" share of GDP is 1.2%, or around $270 billion; the share of the "Broadcasting and Telecommunications" (excluding broadcasting less Internet) is 1.6%, and the "Computer and electronic products" is 1.4%. This is not a large footprint for a revolution in consumer benefits, which Hulten and Nakamura (2021) put at $100 billion to more than $1 trillion in their review of the existing studies. But, while the benefits do not appear large when compared to a total GDP of around $21 trillion in 2020, they do appear large when compared to the total input cost of the "free" Internet apps, which Nakamura et al. (2018) estimate to have been $103 billion in 2015. This evidence suggests that significant gains have accrued to consumers beyond what appears in GDP. The UN's Intersecretariat Working Group on the National Accounts has authored a note (2022) suggesting that these consumer benefits could be included in a satellite national income account.[15]

This brief review of the potential size of θ has focused on the positive side of this parameter. However, not all the impacts of the Information Revolution are positive. The negatives include harassment or unwanted messages. Moreover, Twenge et al. (2019) found that people who spend more time on social media and less direct time with others are more likely to be depressed. There are also the much noted problems of disinformation and privacy.

There are, moreover, other powerful forces on the negative side of the ledger. The footprint of humanity has weighed heavily on the environment and left a large mark, creating negative externalities associated with damage to the environment. However, so much has been written recently (e.g., Dasgupta (2021) and the various U.N. IPCC reports), and so much attention has been given to it that we will not go into detail here. What we will do is show, in the following section, that the many negative environmental externalities can be modeled within the θ-EGDP framework and, moreover, that environmental damage can cause EGDP growth to fall well below that of measured GDP.

VI. Extensions of the θ Framework

A. EGDP and Externalities. The analysis of the consumption technology in the preceding sections and the resulting θ and V in Figure 4 are based on the utility of a representative (or single) agent. They determine the willingness to pay for the additional non-GDP benefits of acquiring X and *Y as perceived by the consumer*, not an assessment of the benefits as perceived by others. There may thus be a divergence between the private and social estimates of these key parameters.

[15] We thank Dylan Rassier for pointing this out to us. This note also discusses some of the issues associated with household inputs to the production of social media and data (see also Coyle and Nakamura, forthcoming).

This divergence can be important for the movement to reform GDP. In the representative agent interpretation of Figure 4, there are multiple (albeit identical) agents, and the direct benefit or harm experienced by any one of them individually may spill over to others. The sum of the individual willingness to pay may thus differ from the overall social outcome once the spillovers are taken into account.[16]

Environmental damage is a much discussed example of the externality problem. Even if the own-θ is positive for each individual, the collective social damage imposed by the spillovers is a debit to wellbeing that may be large enough to offset the positive private benefits. The damage to the environment may even be large enough to cause the overall group θ, inclusive of the externality, to be negative (perhaps very negative). In this case, the aggregate consumption technology shifts *inward* rather than outward, as in Figure 4. The θ-EGDP model thus offers one way of incorporating negative environmental (and other) spillovers into a framework that includes GDP but also goes beyond it. But, while it offers one way to proceed, it must be emphasized that the negative environmental critique is broader than the θ–externality approach.

Moreover, not all welfare spillovers are negative. There are also beneficial multi-agent spillovers, like those associated with education (Lucas (1988)). And, there are other ways that goods can yield additional utility per unit of GDP besides the Lancaster rationale. Vaccination against a disease not only benefits the recipient, but also prevents or inhibits its transmission to others.

B. Market Distortions. We have thus far focused on increases in utility resulting from shifts in the production possibility frontier or the consumption technology. However, there can also be changes in utility from other sources even when the production technology or the consumption technology is unchanged. They can arise from the fact that the point of equilibrium in Figures 2 and 4 are determined under the assumption that resources and technology are used efficiently. Unfortunately, this is not always the case. Regulatory and tax systems, and the oligopolistic market power of suppliers (including that generated by intellectual property), can cause significant distortions in the efficiency of both production and consumption. When this occurs,

---

[16] This spillover situation also applies to the case of non-identical agents. In this more general situation, however, there are additional issues associated with the equitable distribution of benefits and costs. There may also be different *θ's* when agents are not assumed to be identical and thus a potential aggregation problem.

as it does rather frequently in the real world, there is another way that wellbeing can be improved or reduced: an increase or decrease in the efficient use of existing resources.[17]

Figure 2 embodies the basic assumption of perfect competition, which also connects the circular flow model of Figure 1 to the economic theory of Figure 2. When this assumption is violated, the effect of the market distortion may cause the economy to locate at a suboptimal point on or inside the production possibility frontier. The indifference curve associated with this point then lies below the maximal utility of point *A* in the preceding figures, and removing or reducing the distortion will cause utility to increase. This change in utility occurs with the same total resources and technology and may be confused in empirical studies with the shifts in the technology, when, in effect, it reflects the prevailing policy and competitive environment. This is the essence of the contributions by Basu and Fernald (2002) and, later, by Baqaee and Farhi (2019).

What does this mean for the θ framework? The effect of market distortions on the Figure 2 solution at point *A* is illustrated in Figure 5. The distortion in the product market due to monopoly or non-neutral product taxes changes the relative cost-benefit tradeoff between *X* and *Y*, and introduces a distortionary wedge between the producer's marginal rate of transformation

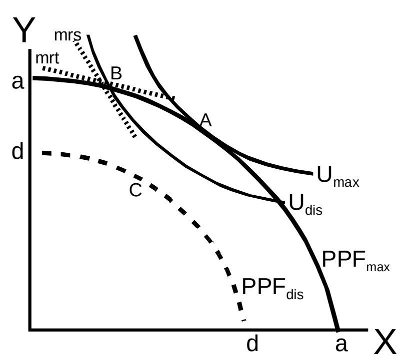

FIGURE 5

and the consumer's marginal rate of substitution. This is shown as point *B* in Figure 5, where the former is represented by the price-line labeled *mrt* (the equilibrium producer price ratio) and

[17] The real world often intrudes on macroeconomic theory. Samuelson (1962) has called the simple aggregate neoclassical theory model a parable that "has considerable heuristic value in giving insights into the fundamentals" of complex issues and theory (page 124). This applies both to macroeconomic analysis and to national accounting frameworks.

the latter by *mrs* (the equilibrium consumer price ratio). The difference between the two is the price distortion. Removing the distortion moves the economy along the production frontier back to point *A*, and in the process, increases the level of consumer utility from U_{dis} to U_{max}. As a result, compensating and equivalent variations can in principle be defined, and thus an estimate of an implied θ. When a price distortion occurs in the factor markets, the production possibility curve shifts inward from PPF_{max} to PPF_{dis}, and the economy relocates to a point like *C*. A recession in economic activity also causes an inward shift. Both result in a lower indifference curve. The lesson for the Beyond GDP project is that the policy environment is another factor that plays a role in promoting aggregate wellbeing.

C. The New Goods Problem. A truly new good is one that has characteristics that have no close substitutes among existing goods, similar or otherwise.[18] Smart cell phones have many characteristics and capabilities that make them quite different from older land-line telephones. The Internet is another example. The question is then how the gain in wellbeing is to be defined and measured.

This is not a straightforward matter. When a new good arrives in the marketplace, it appears on a new dimensional axis in the framework set out in Figure 4. The history of this kind of product innovation is thus one of shifting dimensions of production and choice, and not primarily an innovation-induced shift in the existing production or consumption technologies for the goods *X* and *Y*. Moreover, there is no prior price or quantity history on which to base comparisons and measure the extent of the new good's value. There is thus no factual way of knowing the true value of the good in the periods before its introduction – or certainly before its conception. What is the willingness to pay for a good that no one has ever seen or even thought of?

This is the new goods problem. But, while there is no "right" answer, there are ways of getting defensible estimates. Following Hicks (1940) and Rothbarth (1941), one solution is to adopt the pretence that the good *Z* did in fact exist before its entry into the market but was not in demand because its price was too high. The good *Z* was finally able to enter the market when its

18. A good summary of the new goods problem can be found in the introduction to the 1997 CRIW conference volume *The Economics of New Goods*, edited by Timothy Bresnahan and Robert Gordon. This volume also contains many important contributions to the new goods literature, including the well-known paper by William Nordhaus on tectonic innovation.

price fell below the $Z = 0$ "reservation" price level, the price above which there was no demand for it. After it does enter the market, the Hicks-Rothbarth solution can be used to estimate the one-time gain in consumer welfare its arrival created. After that, *Z* joins *X* and *Y* as another (largely) priced component of GDP, but the initial one-time increase is missed. This increase can be quite large: estimates by Hausman (1996), for example, suggest that the introduction of a new brand of cereals created a 20 percent upward bias in that component of the CPI.

The logic of the Hicks-Rothbarth model can be combined with the analysis of market distortions in Figure 5 to derive a general equilibrium version of the model that fits into the EGDP framework of the preceding sections. Figure 5 illustrates the case where various types of market constraint act as bounds on attaining the optimum point *A*. In the new goods case, we can think of *Z*'s non-appearance in the market place prior to its introduction as being due to the constraint $Z = 0$, which bounds the economy away from its optimal *A*. In other words, we continue the Hicks-Rothbarth pretence (or, rather, extend it) that there was always a three dimensional production space *XYZ* prior to the arrival in the market of *Z*, but the constraint $Z = 0$ prevented the *Z* dimension from being available. Once the new good does becomes available and consumers are free to move to the optimal point analogous to *A* in Figure 5, the level of GDP rises, and a higher level of utility is attained. As in that figure, a compensating variation can be defined that implies at willingness to pay for the arrival of the new good and used to define a general equilibrium form of θ that measures the resulting the one-time jump in benefits. But, again, in this generalized Hicks-Rothbarth interpretation of the new goods problem, this form of θ is not due to a shift in the consumption technology, as in Figure 4, even though it does result in an increase in the attainable level of utility. Nor is it due to a shift in technology as in Figure 2. It is the result of becoming able to move *along* the whole *XYZ* frontier and thus being able to use the available labor, capital, and technology more efficiently (as with the removal of a distortion).

However, it is also important to note that the arrival of the new good may have an additional effect on the consumption technology, and perhaps a large one. It may bring additional non-GDP benefits to the consumer in the same way as *X* and *Y*, and these benefits may continue in the years after the introduction of *Z*. Some of the new items may be rather ordinary from a technological standpoint, like Frisbees. Others may be at the cutting edge of innovation and an important source of the growth in wellbeing (recall Section V).[19]

VII. Further Extension of the Consumption Technology Model to Include Wealth Accounting and the Question of Sustainability

A. The GDP model thus far presented treats each year as a separate accounting event, with each year having its own circular flow account. Successive years are, however, connected by capital stock formation. This connection involves additions to capital stock through investment and subtractions via depreciation and, when tracked and recorded over time, the result is the conventional wealth account of an economy.

Wealth accounting is an important part of an integrated set of national accounts, tracking, as it does, the future consumption potential of an economy. The standard theoretical model underlying these accounts involves maximizing an intertemporal utility function whose arguments are the annual flows of consumption over time, $U(C_1, C_2, C_3, \ldots)$, which can be simplified to an analytically more useful additive form as the discounted present value $\Sigma_t[U(C_t)/(1+i)^t]$, where i is a constant rate of discount. This form of the intertemporal utility function is maximized subject to the constraints imposed by the technology available in each year, $Q_t = C_t + I_t = (1+\lambda)^t F(L_t, K_t)$, where L_t, is the amount of labor input, λ is the rate of TFP growth, $K_t = I_t + (1-\delta)\, K_{t-1}$ is the capital accumulation process, and K_0 is the initial endowment of capital. The solution of this constrained optimization program is the optimal consumption path $(C^*_1, C^*_2, C^*_3, \ldots)$. In order to attain this path, current output is divided between current consumption and investment, which increases the future production of output (and thus future consumption).

---

19. The focus of this paper has been on the GDP and EGDP associated with individual goods. The focus of Nordhaus (1997) is on "tectonic" innovation: an innovation or series of linked innovations so sweeping in their effects that they lead to major structural changes in an economy and have important way-of-life and societal ramifications. Nordhaus argues that the advent of electric lighting was one such tectonic event in its impact. The broader Industrial Revolution is another example. We certainly agree that tectonic innovation is an important concept to keep in mind when thinking of technical revolutions, and probably applies to the Digital and Genomic Revolutions. However, while conventional economic theory and the associated measurement framework based on the Pigovian measuring rod of money can, in principle, address the extra-GDP effects of innovations in individual goods (as with our EGDP), it is not well suited to dealing with the sweeping changes of a technological revolution with all its important structural and societal elements. Indeed, it is the latter that seem relevant to the Stiglitz et al. conception of a Beyond GDP framework that includes elements that are subjective and idiosyncratic and involve value judgments.

.

B. Wealth and the Role of the Consumption Technology. In order to explore the role of the consumption technology (and its θ) in the context of wealth maximization, it is first necessary to recast the intertemporal optimization problem in a way that links it to the *XY* framework of Figure 2. Figures 2 and 4 portray the optimal allocation of two goods, *X* and *Y*, at a single point in time, but this can be transformed, as per Hulten (1979), into the optimal allocation problem of an economy with single good at two points in time. In this formulation, consumption in the current period, C_0, replaces *X*, and consumption in the following period, C_1, replaces *Y*. Instead of the production possibility frontier, $F(X,Y)$, there is now the intertemporal utility possibility frontier (IUPF), $\Phi(C_0,C_1)$, the maximum achievable combination of consumption now and consumption later, given technology, inputs, capital accumulation, and the initial endowment of capital. The highest attainable level of utility is the indifference curve of the intertemporal utility function $U(C_0,C_1)$, that is tangent to the IUPF (equivalent to the point *A* in Figure 2).

The tangency between the IUPF and the intertemporal utility function now defines the maximum attainable value of wealth associated with the optimal consumption path. Where before we had $P^X X + P^Y Y$, the intertemporal analogue is now $P^C{}_0 C^*{}_0 + P^C{}_1 C^*{}_1$. This is shown in the first equality of the following equation

$$(5) \qquad W_0 = \Sigma_t P^C{}_t C^*{}_t = \Sigma_t C^*{}_t /(1+i)^t = P^I{}_0 K_0 + H_0,$$

The second equality follows because the price of C_0, $P^C{}_0$, can be normalized to a value of one since it can be taken as the numeraire in this one good world ($P^C{}_0 = 1$), while the price of the good in a later period, $P^C{}_1$, is $1/(1+i)$, where i is the rate of interest. Thus, where GDP is the sum of the price times quantity of *X* and *Y*, the analogous wealth is the sum of the normalized price times quantity of $C^*{}_0$ and $C^*{}_1$, or $C^*{}_0 + C^*{}_1/(1+i)$, in the two-period version of *(5)*.

The third equality in *(5)*, $P^I{}_0 K_0 + H_0$, is analogous to the GDI term in *(1)*, $P^L L + P^K K$. The H_0 here is the discounted present value of the stream of future wages, and K_0 is again the endowment of capital at the start of the period. Where $P^L L + P^K K$ allocates GDP between labor and capital in any year, $P^I{}_0 K_0 + H_0$ allocates wealth between the present value of annual payments to labor and the initial endowment of capital. The reason for this asymmetry is that capital is an intertemporal intermediate input, which is to say, the investment made in one year enables future consumption which cancels, in present value terms, that investment (analogous to the intermediate goods delivered from one industry to another that are used up by the latter in production). Thus, all investment made after the starting year of the analysis cancels, leaving the value of the initial endowment.[20]

Given the attention paid to the link between GDP and EGDP in this paper, it is worth noting that equation *(5)* can be easily modified to include a consumption technology. This is accomplished, as before, by adding a time shift variable to the utility function. Assuming, for simplicity of exposition, a constant rate of change of θ, this leads to $(1+\theta)^t C_t$ in place of C_t in the intertemporal utility function and in *(5)*. The latter results in a version of consumer wealth that parallels the transition from GDP to EGDP:

$$(6) \quad EW_0 = \Sigma_t [(1+\theta)^t C^*_t]/(1+i)^t \quad ,$$

(a more general version would make the individual θ a function of time). This Expanded Wealth adjusts for changes in the efficiency of consumption over time and allows for improvement in future living standards from this source of innovation.

The wealth analogy of the difference between GDP and EGDP can be taken further. Where before we had $EGDP = (1+\theta)GDP = (1+\theta)GDI$, the parallel "Beyond Wealth" relation is

$$(7) \quad EW_0 = \{\Sigma_t [(1+\theta)/(1+i)]^t\} W_0$$

The annual $(1+\theta)$ is here replaced by its accumulated present value, $\Sigma_t [(1+\theta)/(1+i)]^t$. This formulation allows for innovations that expand the intertemporal utility possibility frontier and thus have far-reaching effects.

However, while *(7)* indicates that E-wealth expands the conventional cost-based wealth to arrive at a welfare measure, it is not intended as a replacement for conventional wealth but, instead, as a complement that addresses different questions (as with GDP and EGDP). Conventional wealth is useful for issues involving the utilization and allocation of existing capacity, for problems involving the intertemporal allocation of resources (e.g., investment in future productive capacity), and for estimating the sources of growth of the economy. It is also

---

[20] The study by Abraham (2010) provides a good review of the issues surrounding the human capital term, H_0, and shows that different approaches give very different estimates. It might also be noted that H_0 grows over time not only because of labor force growth, but also because of increased investments in health and education. We also note that the capital term in principle includes intangible capital and tangible public capital.

an indicator of the concentration of the ownership and control of an economy's productive capacity. The welfare-based measure is an indicator of the true extent of accumulated wellbeing when the adjustment is made for the utility not included in GDP (health, information, environment, etc.).

C. Wealth, Capital, and the Sustainability of Wellbeing. There is a large literature on the question of whether prevailing economic trends are sustainable into the future, dating back to at least Malthus. The issue has been actively discussed in recent years, particularly with respect to climate change and environmental pollution, but also with a stress on natural resource and ecological sustainability (see, for example, the report by Dasgupta (2021) on biodiversity). Stiglitz et al. stress the need to bring the issue of economic sustainability into the Beyond GDP sphere of issues, and Recommendation 3 of their Report starts with "Measures of wealth are central to measuring sustainability" (page 13). A reasonable working definition of sustainability might well be a time-path of annual wealth stocks (or wealth per capita), and the associated consumption paths, which do not trend downward over time or collapse.

There are many approaches to the sustainability problem, and the E-wealth model of the preceding section contributes yet another. That model identifies two concepts of wealth that are relevant to the problem: cost-based wealth stock W_t and welfare-expanded wealth, EW_t. They reveal different ways that the path of future wellbeing can he unsustainable, even though they are connected by the time path of the θ as per equation *(7)* , where : $EW = \{\Sigma_t [(1+\theta)/(1+ i)]^t\} W$.

First, the time path of cost-based *W* may not be sustainable due to factors not necessarily related to damage to the environment. How might this happen? A heedless disregard for the consumption of future generations, who are not present to protect their interests, may lead to inadequate current investment. On the other hand, this seemingly heedless behavior may reflect the belief that productivity (the λ implicit in *(5)*) may make future generations so much richer that current consumption may be increased.

Second, sustainability may fail because of environmental factors, even if the time path of cost-based wealth can be sustained. The problem, occurs when the degradation of the environment causes the path of θ in *(7)* to be sufficiently negative that the time path of E-wealth, *EW*, trends downward, despite an upward trend in the optimal path associated with *W*. Thus, what appears to be sustainability under the conventional definition of wealth is now seen to be unsustainable when, in effect, $(1-\theta)^t$ drags the economy down. The situation in which the θ declines over time may accelerate this process. The bottom line is that the conventional definition of wealth is not a sufficient statistic for determining the sustainability of wellbeing (one of the points of the Dasgupta (2021) report).

VIII. How Far "Beyond GDP"?

A. Many things contribute to overall human wellbeing, some positive and others negative. The list of possibilities set out in Stiglitz et al. and Landefeld et al. is quite broad, ranging from those near the boundary established by the current GDP framework to ambitious non-monetary metrics and indicators for which units of measurement are hard to define, much less measure, and which require increasingly subjective valuations or value judgments. This leads to the following question: how far beyond current GDP should the Beyond GDP project be extended?

The Pigou (1920) answer to this question is that "National accounts should include elements that reflect economic welfare that can be brought directly or indirectly into relation with the measuring rod of money." It is this common measuring rod that allows different components of GDP to be valued using a common metric and combined into a system like that of the circular flow framework. The importance of comparability across the items included within the reach of the Pigou measuring rod cannot be overstated. These items often come in quantities whose amounts are not directly comparable (e.g., ounces of liquid, pounds of flour, yards of cloth, etc.) and are rendered comparable by valuing these using a common monetary metric.

The monetary reach extends beyond GDP to include other sources of wellbeing for which a non-market monetary metric can be established (for example, via a compensating or equivalent variation). However, this monetary reach excludes many sources of wellbeing of a more subjective nature. For example, Stiglitz et al. in Recommendation 6 (page 15) call for "robust and reliable measures of social connections, political voice, and insecurity." They go on to say "The choice of relevant functionings and capabilities for any quality of life measure is a value judgment, rather than a technical exercise." Many of these quality-of-life indicators go well beyond the monetary measuring rod used in the construction of the GDP accounts and into the spheres of psychology, sociology, philosophy, and political science. This does not diminish their individual importance, but it does raise the question of what kind of "exercise" is appropriate for their measurement and how much each new metric contributes to an overall index of wellbeing, as well as how it is related to GDP (which, again, is itself an important source of wellbeing). Is there a common measuring rod of wellbeing that can put individual values and sources of welfare on a comparable scale that indicates their total combined amount? Are value judgments even quantifiable? Can one person's value judgments be compared with another's? This last question leads to the further question of the comparability of subjective values across different cultural traditions, religions, ideologies, and periods of time. There are a lot of issues to sort out.

B. The taxonomy presented in Landefeld et al. (2020) in their Table 2 is of great value in the sorting out process, given the great diversity of sources of wellbeing. They organize the possibilities into five categories that include:

1. Improved or repackaged GDP statistics;

2. Satellite accounts that contain supplemental datasets that extend the scope of the national accounts without changing the official statistics;

3. Aggregate welfare measures that combine components of the national accounts with other variables to derive summary statistics for a country's overall wellbeing, following the principles of good economic measurement;

4. Subjective wellbeing measures based on assessments of welfare that rely on self-reported evaluations of happiness or satisfaction;

5. Indexes of wellbeing indicators, including indexes of economic and noneconomic variables that are judgmentally weighted as well as "dashboards" that do not attempt to weight the various dimensions or that leave the weighting to the users of the data.

The taxonomy establishes a boundary between what has been called the "positive" and "normative" sides of economics. The first three categories are conceptually amenable to a monetary measuring rod because they include sources of wellbeing that either extend or are linked to current GDP. Categories 4 and 5 are mostly subjective or value-laden and generally are located beyond the measuring rod of money. It is in these categories that the greatest challenges to the Beyond GDP project occur. Income inequality is an important example -- so important, indeed, that it merits its own section.

IX. Income Inequality

A. Income inequality is one of the greatest sources of discontent with GDP and GDI as measures of wellbeing. How the GDI "pie" is sliced matters, not just its size. A lot of wellbeing may be lost through an unequal distribution of the total, particularly if the prevailing social ethic is highly egalitarian. However, much less may be lost if the existing tax and transfer system already embodies a significant redistributive ethic, or the Gini Index is relatively low. In any case, what constitutes distributional equity and how it might be achieved is part of a larger historical debate over social justice that considerably predates the national accounting movement and concerns about the relevance of GDP.

One consequence of the ongoing debate is that there is currently no lack of available estimates of the extent of income and wealth inequality. Contributions to the measurement literature include, prominently, Piketty's 2014 *Capital in the Twenty-First Century* and the Atkinson-Piketty-Saez Top Incomes Project, and there are many others. Likewise, a number of distributional metrics are also available. One is the Gini Index, which summarizes the degree of egalitarianism with a single number. Another is the ratio of the income of those in the top income percentiles to those in the bottom. The BEA deals with the distribution of income issue in a satellite account to the main national accounts, where they report the distribution of GDP and its components by level of income. But, while the BEA's distributional satellite provides estimates of the distribution of GDP by income percentile, the satellite account stops short of indicating how much *aggregate* wellbeing is implied by that distribution, leaving that to the "users of the data."

Moreover, while there is no lack of data on income (and wealth) inequality, there is a question about how the degree of *income* inequality present in the data translates into a measure of the inequality in *wellbeing*, and how the result can be fitted into a comprehensive wellbeing metric of the kind envisioned by the Beyond GDP project. To do this, a link between income and welfare would have to be made explicit, and this raises the question of the Easterlin Paradox and the associated question whether the marginal utility of income necessarily diminishes as income increases. Diminishing marginal utility is the case typically assumed in U.S. tax and transfer policy, and it implies that a one percent growth rate of real GDP does not lead to a corresponding increase in utility or wellbeing. On the other hand, if the marginal utility of income is assumed to equal one, as is implicit in much neoclassical growth analysis, the increase in the one implies a proportionate increase in the other. The implication for the Beyond GDP project is that distribution of income may not be a good guide to the true distribution of wellbeing. But, if an income-based metric of overall wellbeing is deemed unsuitable, is there a better alternative?

One option would be to use an index of overall happiness as a non-monetary measure of self-perceived wellbeing, and the *World Happiness Report* is one possibility in this regard. It makes use of procedures based on subjective surveys of elements of individual happiness as self-reported on a scale of 0 to 10. The individual elements are quite diverse, including social and personal factors as well as an income variable.[21] However, the happiness metric does not have a monetary dimension, and it is thus not apparent how it might replace, or be aggregated with, conventional monetary GDP to form a new headline alternative to GDP.[22] The importance of the aggregation problem is underscored by the observation that existing aggregate happiness indexes are typically "egalitarian" in that the happiness of each individual is counted equally, whereas GDP is a market-oriented aggregate based on the prevailing distribution of income. Still, this line of research has yielded valuable insights and might be treated as a complement to GDP and some version located in a satellite account to the core national accounts.

The comparison of real GDP per capita and an index of long-term happiness shown in Landefeld et al. is instructive. The happiness index in their Chart 5 reveals essentially no increase over the period 1965 to 2011, while real GDP per capita increased two and a half fold over the same period. As Landefeld et al. note, other studies have found a higher correlation between happiness and GDP, and the work of Stevenson-Wolfers is an important case in point.

---

21 In Chapter 2 of the 2017 World Happiness Reports, "The Social Foundations of World Happiness" by John F. Helliwell, Haifang, Huang, and Shun Wang, the authors note that many diverse not-economic factors contribute to happiness, including healthy years of life expectancy, social support (as measured by having someone to count on in times of trouble), trust (as measured by a perceived absence of corruption in government and business), perceived freedom to make life decisions, and generosity (as measured by recent donations) in addition to GDP per capita.

22 Happiness and satisfaction have long had a connection to economics in the form of cardinal utility. Cardinal utility is based on the assumed existence of "utils," units of measurement that permit interpersonal and intertemporal comparisons of wellbeing and happiness. The total quantity of utils in a society was seen as a natural indicator of national wellbeing, and economic progress as the growth of the total. The well-known difficulty is that utils are an abstract construct that is not observable and has little or no basis in psychology. The ordinal concept that displaced the cardinal dispensed with utils in favor of revealed preference and the associated willingness-to-pay metric (which, of course, is the basis for the utility represented in this paper by Figures 2 through 5).

The difference in the trends of the competing metrics suggests that care must be taken when comparing wellbeing to GDP or when using the one to replace the other. A satellite account showing the alternate metrics of wellbeing/happiness might, however, be instructive for insight building if offered as a complement to current GDP.

The data dashboard approach provides another avenue for introducing wellbeing into the Beyond GDP metric that avoids the income problem, and well as the problem of finding metrics for the diversity of non-GDP sources of wellbeing. Dashboards can track separate unweighted indicators of wellbeing that are important by themselves (or in combination with others) for insight-building into areas where progress has (or has not) been made. The OECD's *Households' Economic Well-Being: the OECD Dashboard* is an important example. The United Nations Human Development Index is another. However, there is still a "bottom-line" problem.

B. The role of the social welfare function. The constrained utility maximization model of standard neoclassical economics, as extended in this paper, must also contend with the value judgment/interpersonal comparison problem. Although the EGDP model thus far developed takes a much less comprehensive approach to wellbeing, it must give an account of how total GDP at the optimal point *A* in Figure 4 is distributed across individuals. This was not an issue when consumers are assumed to be identical in their income and preferences, but does become one when preference and income are heterogeneous.[23] This is the point at which the social welfare function comes into play.

A social welfare function embodies the prevailing societal ethic about the fairness of the income distribution. It makes interpersonal judgments based on the utility experienced by different individuals. In its usual formulation, it maps the individual utilities into an aggregate index of overall societal welfare via a function of the general form $W(U^1, \ldots, U^N)$, where, in the two good economy of Figure 2, etc., the individual utility functions are represented by $U^i(X^i,Y^i)$; these are, in turn, a function of the amounts of X^i and Y^i consumed. The level of social welfare

[23] In the identical agent case portrayed in the figures of Sections III and IV, the indifference curves of the representative agent can then be entered directly on the figures and an equilibrium point *A* determined. This situation changes when there are two (or more) agents with different utility functions. If their indifference curves were both plotted on Figure 4, there would be two points of tangency like *A* on the same production possibility frontier. Therefore, neither could serve as a unique equilibrium point because each would support a different relative price system and GDP.

thus depends both on the total amount of X and Y produced and how the totals, $X=\Sigma X^i$ and $Y=\Sigma Y^i$, are distributed among individuals. This is determined by the maximization of $W(U^1, \ldots ,U^N)$ subject to a utility possibility frontier $\Omega(U^1, \ldots ,U^N)$ that indicates the maximal combinations of utility $(U^1, \ldots ,U^N)$ that are possible given the limits imposed by the available inputs and technology on production side of the economy in Figure 2 (specifically, by the production possibility frontier).

The relation between the production and utility possibility frontiers is somewhat complicated -- the former is defined in a space with XY dimensions and the later in utility space. However, the diagrammatic exposition offered by Bator (1957) shows how the dimensionality problem can be resolved. By way of a brief sketch, a separate Edgeworth Box and its contract curve are inscribed inside the production possibility frontier at each point (X,Y). The contract curve for each box, which registers the Pareto Optimal combination of utilities for that box, is transcribed to utility space to form, *inter alia*, the utility possibility frontier. The social welfare maximizing point on that frontier is then determined by the tangency with the welfare function $W^*(U^1, \ldots ,U^N)$. This tangency determines the socially optimal distribution of utilities, which then determines output in the XY space by working backward through the Edgeworth Box to an equilibrium point (like A in Figure 2) on the production possibility frontier to determine the optimal X^* and Y^*. The associated socially optimal GDP is defined by this point, *along with its optimal allocation across individuals*.

This solution allows us to address the question: how much social welfare is gained in GDP terms for moving to the socially optimal point from the prevailing income redistribution, assuming that the prevailing distribution is suboptimal? Once it is determined that A^* is the socially optimal point on (or near) the production frontier, the GDP measured in socially optimal prices for all other points on the frontier can also be determined. Suppose, for example, the market equilibrium point A in Figure 2 is priced at the socially optimal prices defined by A^*. A comparison of the implied GDP at the two points – a sort of compensating variation -- can be calculated (in theory) and used to measure in terms of the yardstick of money the increase in social welfare involved. The monetary change in the distribution of X and Y among agents at two points can be calculated along with the implied redistribution of income.

A form of social θ^* can then be defined by the compensating variation. As with Figure 5, the once-over gain is the result of moving from an inferior point to the optimum solution. However, this θ^* is qualitatively different from the original consumption technology θ's of Figure 4. Those are still in play and operate through ongoing shifts in the consumption technology that translate into shifts in the utility possibility frontier in welfare space, shifts that can be positive or negative. Thus, it is possible that an increase or decrease in the utility possibility frontier can change social welfare to an even greater extent than it affects GDP or EGDP (e.g., a degradation caused by environmental factors).

C. At first glance, the utilitarian social welfare framework would seem ideally suited for the objective of bringing the income distribution within the GDP/EGDP framework. There are, however, some complications. There is, first, the well-known problem of Okun's equality versus efficiency tradeoff (Okun (1975)). The act of redistributing income may alter the structure of incentives in a way that leads to less total income. This leads to the situation portrayed in Figure 5 where the economy is relocated at an interior point inside the production possibility frontier, or at an inefficient point along the frontier. One can debate the size of the disincentive effect or decide that the increase in social equity (of, say, moving to an equal distribution of income) is worth the efficiency penalty; what should not be overlooked is its possible presence in the theoretical framework above, and the tradeoff that must then be faced.

Second, the utility functions on which the welfare function $W^*(U^1, \ldots, U^N)$ is based are a function of the individual shares of the economic goods X and Y, i.e., $U^i(X_i,Y_i)$. However, as we have seen in Section VII and in the first part of Section VIII, the general concept of wellbeing transcends the contribution of its economic elements, important as they are. The non-economic elements (e.g., those mentioned by Stiglitz et al. and in the table by Landefeld et al.) are sources of wellbeing that might plausibly be located in a generalized utility function, even though they may be considered as background variables for the purposes of maximizing $W(U^1, \ldots, U^N)$. This leaves a lot of sources of welfare unaccounted for in the background. Still, this approach seems like the most plausible point of contact between the EGDP of formal economic optimization theory developed herein and the broader world of wellbeing beyond EGDP.

One further point about the social welfare function is worth noting because it touches on the general problem that many aggregate wellbeing metrics face: by what process is it obtained?

How are subjective value judgments to be quantified into a specific metric? These are important questions if the metrics are to be of operational use to the Beyond GDP project. And, in the case of the social welfare function, this is a historically vexed issue ("the greatest for the great number," Rawlsian original position, the Arrow Impossibility Theorem, etc.). The choice of welfare function matters because it is, in effect, a choice about how the aggregate welfare generated by economic activity should be divided among the population and, by extension, how income should be distributed equitably. For each form of welfare function there is a socially optimal point A^* on the utility possibility frontier. And, for each A^* there is a corresponding pair of goods X and Y on or near the production possibility frontier, as well as their distribution among individuals and the associated distribution of income. This correspondence thus establishes a link between the form of the welfare function and its implied income distribution. It is the income distribution associated with a particular form that is usually the actual focus of choice in matters of distributional equity.

The salience of this point is driven home by a comparison of the different income distributions associated with different types of social welfare function. With a pure laissez-faire welfare function, the original market point A on the production possibility frontier and the social welfare solution A^* on the utility possibility frontier are identical, implying that the market distribution of income at A is also socially optimal and that no redistribution is warranted. A strictly egalitarian function, on the other hand, implies a policy of income leveling and thus complete income equality (although any highly redistributive tax and transfer system that lowers the Gini Index significantly might also be considered egalitarian). A political economy system that relies on voting or some other democratic public choice mechanism might result in either a highly egalitarian or a laissez-faire outcome, but it is more likely to produce a tax and transfer system that modifies the original pre-transfer market distribution of income to an intermediate result. The resulting post-transfer market income distribution (and the implicit social welfare function) might be considered socially optimal because of the public choice process by which it is determined.

A key point for the Beyond GDP project is that each alternative type of social welfare function (and associated socially optimal distribution of income) implies a different point on or inside the same production possibility frontier, implying, in turn, that the *same* total amount of labor, capital, and the prevailing level TFP can lead to very different amounts of imputed social wellbeing. In the strictly egalitarian case, the implied growth rate of social welfare may be considerably less than that of real GDP. In this case, the assessed wellbeing attributed to the Digital Revolution, with its Silicon Billionaires and its rising Gini Index, looks very different from that associated with a laissez-faire welfare function. Thus, a comparison of these cases suggests that to assume *a priori* a particular form for a social welfare function is more or less to assume the conclusion about the growth and distribution of wellbeing and the importance, if not the size, of the social θ^* parameter.

D. Wealth and Distributional Equity. As economies evolve over time and grow, so do individual incomes. In addition, individual incomes and consumption also tend to exhibit a life-cycle pattern, and both are subject to idiosyncratic and systemic shocks as well. A good case can be made for using some measure of lifetime income in discussions of distributional equity as (at least) a supplement to the cross-sectional distribution of income in any single year. Some of the people in the top few percent of the income distribution in one year may not be there in the following year or a decade later.

The sharing of gains from economic growth is challenging for distributional analysis. It may be the case that the gains may be shared unequally, raising the Gini Index, but the incomes of the lowest percentiles of the population may still be considerably higher compared to the pre-growth era. China, with its era of double-digit growth and soaring Gini Index, provides a good example. Having both high growth and egalitarian distribution would be the best outcome under a highly egalitarian social welfare function, but may not be attainable if the process of income redistribution conflicts with the conditions and incentives necessary for that growth.

X. Fixing Existing Gaps in Current Real GDP

A. The current GDP accounts offer many opportunities for improvement. A great deal has been written on this issue, much of it before the current Beyond GDP movement, and many problems and gaps have been identified and many suggestions for improvement have been made. This is, to some extent, inevitable given the market orientation of GDP and the changes in the structure of an economy over time. As the economy evolves, so must the corresponding statistical accounts that describe the evolving economy, and the national accounts are a perpetual work in progress. Statistical agencies must work hard to keep abreast of the changes, and the ambitious new proposals of the Beyond GDP project should not distract from addressing these problems as they evolve.

One notable set of unresolved problems lies in the accuracy of the price deflators used to obtain the real output of the service-providing industries. When commenting on this issue, Griliches (1992) observed that the "problem arises because in many services sectors it is not exactly clear what is being transacted, what is the output, and what services correspond to the payments made to their providers (page 7)." He also observed that nominal expenditures in a "number of service industries series … [are] deflated by makeshift deflators.

The use of price deflators based, for example, on the cost of provision can lead to understated estimates of the real output originating in the affected sectors, hardly a desirable feature for the purpose of estimating productivity or wellbeing. This understatement is one explanation of the peculiar pattern observed in estimates of TFP growth in the BLS Multifactor Productivity program. The level of TFP in any year is essentially the ratio of real output to real input, so the failure to capture increases in the output price level biases the estimated growth of TFP downward. This may help explain the approximately zero rate of growth of TFP in the BLS estimates for the service sector industries of the U.S. over the period 1987 to 2015. A zero (or even a very low) rate of TFP growth sustained over the three decades that span the Digital Revolution is implausible, particularly when it is estimated to have occurred at negative rates in many of the information-intensive subsectors. The bias issue is all the more serious since the output of the service sector has accounted for a growing share of GDP over the last 50 years.

Because the goods and services that comprise real GDP embody a major source of personal wellbeing, an accurate assessment of its growth over time is important for the issues of this paper. The growth of TFP is particularly important given that it is an autonomous and costless source of real GDP growth and thus of wellbeing. The bias problem thus suggests that the area Beyond GDP is not the only place to look for unmeasured wellbeing. Indeed, the importance of getting the prices right (or at least better) cannot be overstated.

B. How big the bias problem actually is and how much uncounted wellbeing is missed by current measurement practice is hard to determine, but the evidence about the price deflator bias presented in the studies by Groshen et al. (2017) and Moulton (2018) suggests that it is potentially large. The former found that the then current price-deflation procedures resulted in a downward bias in the annual growth of real GDP of -0.41 percentage points per year in 2015, while the latter puts the bias at -0.65 percentage points (there are, it should be noted, differences in sectoral coverage). Others have put the bias higher. A back-of the-envelope calculation made in our earlier work for the period from the late-1980s to the beginning of the financial crisis suggests that the current omissions and biases may amount to as much as a -1.0 percentage point correction, adding roughly a 0.5 percentage point increase in the growth rate of real output and a proportionate decrease in its corresponding prices. A bias of this magnitude suggests that quite a lot of the wellbeing that would be implied by a more accurately measured real GDP may be missed by current practice.

These problems are not easy to fix. Shapiro and Wilcox (1996) called it "the house-to-house combat of price measurement," and argued that: "There is no simple formula that one can apply to deduce [the] magnitude of the problem, nor any simple solution. Unfortunately, there is no substitute for the equivalent of a ground war: an eclectic case-by-case assessment of individual products" (p. 124). This combat has become even harder with the advent of the Internet, with its various products and applications distributed below cost, or at a zero price. The absence of a price is obviously a problem for the price-quantity separation needed for real output, as is the absence of clearly defined units of output. The labor and capital involved in the production of these Internet products are counted in GDI, but this cost is financed indirectly, often by advertising and marketing revenues (Nakamura et al. (2018)). Advertising and marketing are intermediate inputs to the sale of the final product that is advertised, and the cost of the intermediate advertising inputs is embodied in the price of the final good. It is the latter that enters GDP, and there is thus a disconnect between the GDI generated by, say the Internet, and the value to the consumer that appears in GDP as a higher price for other goods. This is an increasingly pressing problem for the measurement of GDP, given the explosive growth of the Internet.

C. The comments of this section have thus far been focused on problems with accurately measuring real GDP, but there are also problems with the measurement of GDI. There have, for example, been changes in the structure of the labor market (e.g., the emergence of the gig economy). Moreover, the service-sector problem described by Griliches is due, in part, to the intangible nature of many of the services "provided." A similar problem also arises with intangible knowledge and organizational capital of a firm. Driven by the Digital Revolution, intangible investment, in its broadest forms, now exceeds that of more traditional tangible capital (Corrado, Hulten, and Sichel (2009)). But, unlike the traditional form, this type of capital is typically produced within the firm as own account investment, and thus generates no direct market valuation. The valuation is typically measured at production cost. In line with the United Nation System of National Accounts (SNA), BEA currently counts only part of these intangibles.

Proposed improvements or additions to GDP should be consistent with the framework of the SNA in those countries that adopt its standards. The SNA plays a valuable role in maintaining measurement consistency, and thus comparability, across the national accounts of different countries. This comparability does, however, imply constraints on the extent and design of the additional wellbeing measures incorporated in a country's accounts, and on how various "fixes" to existing GDP are carried out. There is, in addition, an even greater problem associated with the internationalization of national accounting: the global reach of the modern national economy leads to a greater degree of economic interdependence. What does national economic activity and citizen welfare mean in an increasingly open-economy world? How does the decline of wellbeing from jobs lost in one country balance against the gain in welfare from those jobs transferred to another? How does the SNA deal with a world in which economic activity is transnational and capital and product markets are global? In particular, can it accommodate the national location of intangible assets developed elsewhere and the global value of what they generate?

XI. Conclusion

This paper began with a short account of how GDP developed as a response to the needs of counter-cyclical policy, influenced by the dictates of Keynesian economics. GDP continues to evolve and has become a policy tool for addressing questions of unemployment and capacity utilization, as well as resource allocation. Its main focus has therefore been on the market sector of the economy and not on the long-term growth of wellbeing. As a result, the growth rate of real GDP has come to be regarded as virtually synonymous with economic progress. The Beyond GDP movement seeks to correct this perception.

Our extension of the conventional theory of national accounting to include a Lancaster consumption technology, and the resulting welfare-oriented Expanded GDP metric, is offered as our conceptual contribution to the growing Beyond GDP literature. This extension is, in effect, a monetary bridge between the core GDP accounts and a system of one or more satellite accounts containing non-GDP elements of wellbeing that are currently not included in the GDP (as with our proposed EGDP). This bridge allows the wellbeing indicators in those accounts to be expressed in the same units as GDP, thus permitting direct comparability. Comparability is needed in order to address the question whether wellbeing is growing more or less rapidly than resource-based GDP. This is the bottom-line question of the Beyond-GDP project, and a rationale for including monetary wellbeing measures within the framework of the national GDP accounts

The main focus of this paper is theoretical, and its goal is to develop a technical infrastructure to serve as a unifying framework for the Beyond GDP project. The paper offers no new empirical results and, indeed, it points to some of the theoretical difficulties faced by an attempt to implement the θ-EGDP framework (although many problems are not unique to that framework and are, instead, inherent in the subjectivity of the many types of wellbeing under consideration). The theory also points to the use of empirical techniques, like willingness to pay, that have proved useful for valuation in situations where market data are unavailable or inaccurate (e.g., the new goods problem).

Finally, we reiterate that GDP and welfare metrics provide insights and answers to different questions about the economic system and its growth, and both have important roles to play in the architecture of a unified statistical system. Thus, the currently perceived imbalance in favor of GDP should not be corrected by creating an imbalance in favor of the well being aspects.

REFERENCES

Abraham, Katherine G., “Accounting for Investments in Formal Education,” *Survey of Current Business*, June 2010 Volume 90, Number 6, 42-53.

Arrow, Kenneth J., Partha Dasgupta, Laurence H. Goulder, Kevin J. Mumford, and Kirsten Oleson. “Sustainability and the Measurement of Wealth,” *Environment and Development Economics* 17: 317–353, 2012. doi:10.1017/S1355770X12000137

Baqaee, David R., and Emmanuel Farhi, “The Macroeconomic Impact of Microeconomic Shocks: Beyond Hulten’s Theorem,” *Econometrica*, 87 (4), 2019, 1155-1203.

Basu, Susanto, and John G. Fernald, “Aggregate productivity and aggregate technology,” *European Economic Review*, 46, 6, June 2002, 963-991.

Bator, Francis M. "The simple analytics of welfare maximization," *The American Economic Review* 47, 1, 1957, 22-59.

Bohman, Mary, “GDP and Beyond: an Introduction,” *Survey of Current Business*, June 2020 Volume 100, Number 6.

Bresnahan, Timothy, and Robert J. Gordon, “Introduction,” in Timothy Bresnahan and Robert J. Gordon, eds., *The Economics of New Goods*, University of Chicago Press: Chicago, Vol. 78, The University of Chicago Press for the NBER, Chicago, 1997, 1-26.

Brynjolfsson, Erik, Avinash Collis, W. Erwin Diewert, Felix Eggers, and Kevin J. Fox, Felix Eggers, *GDP-B: Accounting for the Value of New and Free Goods in the Digital Economy The Digital Economy, GDP and Consumer Welfare: Theory and Evidence*, March 2019.

Cacioppo, John T., Stephanie Cacioppo, Gian C. Gonzaga, Elizabeth Ogborn, and Tyler J. VanderWeele, “Marital Satisfaction and Break-ups Differ Across On-line and Off-line meeting Venues,” *Proceedings of the National Academy of Science*, June 18, 2013, 10135-10140.

Carol S., “The History of the United States National Income and Product Accounts: The Development of an Analytical Tool,” *The Review of Income and Wealth*, 21. 7, June 1975, 153-181.

Case, Anne, and Angus Deaton, *Deaths of Despair and the Future of Capitalism*, Princeton University Press March 2020.

Christensen, Laurits R., and Dale W. Jorgenson, “The measurement of U.S. real capital input, 1929–1967,” *Review of Income and Wealth*, 15, December 1969, 293–320.

Christensen, Laurits R., and Dale W. Jorgenson, “U.S. real product and real factor input, 1929–1969,” *Review of Income and Wealth*,” 16, March 1970, 19–50.

Corrado, Carol A., Charles R. Hulten, and Daniel E. Sichel, “Intangible Capital and U.S. Economic Growth,” *Review of Income and Wealth*, 55, 3, September, 2009, 661-685.

Coyle, Diane, *GDP: A Brief But Affectionate History*, Princeton: Princeton University Press, 2014.

Coyle, Diane and Leonard Nakamura, "Time Use, Productivity, and Household-Centric Measurement of Welfare in the Digital Economy" *International Productivity Monitor*, forthcoming.

Dasgupta, Partha, *The Economics of Biodiversity: The Dasgupta Review*. https://www.gov.uk/government/collections /the-economics-of-biodiversity-the-dasgupta-review, February 2021.

Deaton, Angus, and John Muellbauer, *Economics and Consumer Behavior*, Cambridge University Press, 1980.

Deaton, Angus, and Paul Schreyer, *GDP, wellbeing, and health: thoughts on the 201`7 round of the International Comparison Program*, November, 2020.

Feldstein, Martin, "Underestimating the Real Growth of GDP, Personal Income, and Productivity," *Journal of Economic Perspectives*, 31, 2, Spring 2017, 145–164.

Gawande, Atul, "Two Hundred Years of Surgery," *N Engl J Med*, 2012; 366: pp 1716-1723

Griliches, Zvi, "Introduction," in Griliches, Zvi, ed., *Output Measurement in the Services Sectors*, Chicago: University of Chicago Press, 1992, 1-22.

Groshen, Erica L., Brian C. Moyer, Ana M. Aizcorbe, Ralph Bradley, and David M. Friedman, "How Government Statistics Adjust for Potential Biases from Quality Change and New Goods in an Age of Digital Technologies: A View from the Trenches," *Journal of Economic Perspectives*, 31, 2, Spring 2017, 187-210.

Hausman, Jerry, "Valuation of New Goods under Perfect and Imperfect Competition," T. Bresnahan and R. J. Gordon, eds., *The Economics of New Goods*, Chicago, Illinois: University of Chicago Press, 1996, 209–37.

Hausman, Jerry, "Cellular Telephone, New Products, and the CPI," *Journal of Business and Economic Statistics*, 17 (2), 1999, 188–194.

Hausman, Jerry, "Sources of Bias and Solutions to Bias in the Consumer Price Index," *The Journal of Economic Perspectives*, 17, 1, Winter 2003, 23-44.

Helliwell, J., Layard, R., & Sachs, J. (2017). World Happiness Report 2017, New York: Sustainable Development Solutions Network.

Hicks, John R., "The Valuation of Social Income," *Economica*, 7:2, 1940, 105-24.

Hulten, Charles R., "On the 'Importance' of Productivity Change," *American Economic Review*, 69, 1, March 1979, 126-135.

Hulten, Charles R., "Total Factor Productivity: A Short Biography," in *New Developments in Productivity Analysis*, Charles R. Hulten, Edwin R. Dean, and Michael J. Harper, eds., Studies in Income and Wealth, vol. 63, University of Chicago Press for the NBER, Chicago, 2001, 1-47.

Hulten, Charles R., and Leonard I. Nakamura, "Accounting for Growth in the Age of the Internet: The Importance of Output-Saving Technical Change," NBER Working Paper 23315, July 30, 2018 (revised).

Hulten, Charles R., and Leonard I. Nakamura, "Expanded GDP for Welfare Measurement in the 21st Century," in *Measuring and Accounting for Innovation in the 21st Century*, Carol Corrado, Jonathan Haskel, Javier Miranda, and Daniel Sichel, editors, vol. 78, The University of Chicago Press for the NBER, Chicago, 2021, 19-59.

Intersecretariat Working Group on the National Accounts, United Nations, *"Guidance Note on Recording and Valuing "free" Digital Products in an SNA Satellite Account," I* https://unstats.un.org/unsd/nationalaccount/RAdocs/DZ4_GN_Free_Digital_Products_Satellite.pdf7A

Jones, Charles I., and Peter J. Klenow, "Beyond GDP? Welfare Across Countries and Time," *American Economic Review*, 106, 9, September, 2016, 2426-2057.

Jorgenson, Dale W., "Production and Welfare: Progress in Economic Measurement," *Journal of Economic Literature*, 56, September 2018, 867-919.

Jorgenson, Dale W., "Capital Theory and Investment Behavior," *American Economic Review*, 53, 2, May 1963, 247-259.

Jorgenson, Dale W., and Zvi Griliches, "The Explanation of Productivity Change," *Review of Economic Studies*, 34, July 1967, 249–83.

Jorgenson, Dale W., and J. Steven Landefeld, "Blueprint for Expanded and Integrated U.S. Accounts; Review, Assessment, and Next Steps", in *A New Architecture for the U.S. National Accounts*, Jorgenson, Dale W., J., Steven Landefeld, and William D. Nordhaus, editors, vol. 66, The University of Chicago Press for the NBER, Chicago, 2006, 13-112.

Jorgenson, Dale W., and Paul Schreyer, "Measuring Individual Economic Well-being and Social Welfare within the Framework of the System of National Accounts," *Review of Income and Wealth*, 63, November 2017, S460-S477.

Koopmans, Tjalling C., "Measurement Without Theory," *The Review of Economics and Statistics*, 29, 3, August 1947, 161-172,

Lancaster, Kelvin J., "Change and Innovation in the Technology of Consumption," American Economic Review, 56, 1/2, March 1966a, 14-23.

Lancaster, Kelvin J., "A New Approach to Consumer Theory," *The Journal of Political Economy*, 74, 2, April 1966b, 132-157.

Landefeld, J. Steven, "GDP: One of the Great Inventions of the 20th Century," *Survey of Current Business*, January 2000. 6-9.

Landefeld, J. Steven, Brent R. Moulton, Joel D. Platt, and Shaunda M. Villones, "GDP and Beyond: Measuring Economic Progress and Sustainability", *Survey of Current Business*, April 2010 Volume 90, Number 4, 12-29.

Landefeld, J. Steven, Shaunda M. Villones, and Alyssa Holdren, "GDP and Beyond: Priorities and Plans," *Survey of Current Business*, June 2020 Volume 100, Number 6.

Landes, David S., *The Wealth and Poverty of Nations: Why Some Are So Rich and Some So Poor*," W.W. Norton & Co Inc., 1998.

Lucas, Robert E. Jr., "On the Mechanics of Economic Development," *Journal of Monetary Economics*, 22, 1988, 3-42.

Moulton, Brent R., *The Measurement of Output, Prices, and Productivity: What's New Since the Boskin Commission*, The Hutchins Center on Fiscal and Monetary Policy, The Brookings Institution, July 25, 2018

Nakamura, Leonard, Jon Samuels and Rachel Soloveichik," 'Free' Internet Content: Web 1.0, Web 2.0, and the Sources of Economic Growth," *Federal Reserve Bank of Philadelphia Working Paper 2018-17*, May, 2018.

Nordhaus, William D., 1996, "Do Real-Output and Real-Wage Measures Capture Reality? The History of Lighting Suggests Not." in Timothy Bresnahan and Robert J. Gordon, eds., *The Economics of New Goods*, University of Chicago Press: Chicago, 27-70.

Nordhaus, William D., and James Tobin, "Is Growth Obsolete?" in: *The Measurement of Economic and Social Performance*, Studies in Income and Wealth, National Bureau of Economic Research, vol. 38, 1973, 1-80.

Okun, Arthur M., *Equality and Efficiency: The Big Tradeoff*, The Brookings Institution; 1st Edition, January 1, 1975.

Organisation for Economic Co-operation and Development (OECD), *How's Life? 2020: Measuring Well-being*, Paris: OECD Publishing., 2020.

Organisation for Economic Co-operation and Development (OECD*), Households' Economic Well-Being: the OECD Dashboard*, www.oecd.org/std/na/household-dashboard.htm.

Patinkin, Don, "In Search of the 'Wheel of Wealth': On the Origins of Frank Knight's Circular Flow Diagram," *American Economic review*, vol. 63 (5), 1037-1046.

Pigou, Alfred C., *The Economics of Welfare*, London: Macmillan and Company, 1920.

Redding, Stephen J., and David E. Weinstein, "A Unified Approach to Estimating Price and Welfare Measurement," Working Paper, March 2017.

Romer, Paul, "New goods, old theory, and the welfare costs of trade restrictions," *Journal of Development Economics*, 43, 1994, 5-38.

Rosenfeld, Michel J., Reuben J. Thomas, and Sonia Hausen, “Disintermediating Your Friends: How Online Dating in the United States Displaces Other Ways of Meeting,” *Proceedings of the National Academy of Sciences*, September 3, 2019, 17753-17758.

Rothbarth, E., “The Measurement of Changes in Real Income under Conditions of Rationing,” *Review of Economic Studies*, 8, 1941, 100-107.

Samuelson, Paul A., “Parable and Realism in the Theory of Capital: The Surrogate Production Function,” *The Review of Economic Studies*, 29 (3), 1962, 193-206.

Schmidt, Eric, and Jonathan Rosenberg (with Alan Eagle), *How Google Works*, Grand Central Publishing, September 2014.

Shapiro, Matthew D., and David W. Wilcox, “Mismeasurement in the Consumer Price Index: An Evaluation,” *NBER Macroeconomics Annual 1996*, Volume 11, Ben S. Bernanke and Julio J. Rotemberg, Editors, MIT Press, 1996, 93 -154).

Smith, Aaron, and Monica Anderson, *Social Media Use in 2018*, Pew research Center, March 1, 2018. http://www.pewinternet.org/2018/03/01/social-media-use-in-2018/rc

Solow, Robert M., “Technical change and the aggregate production function,” *Review of Economics and Statistics*, 39, August 1957, 312–320.

Stevenson, Betsey, and Justin Wolfers. 2013. "Subjective Well-Being and Income: Is There Any Evidence of Satiation?" *American Economic Review*, 103 (3): 598-604.

Stiglitz, Joseph E., “Beyond GDP,” Dec 3, 2018, https://www.project-syndicate.org/commentary/new-metrics-of-wellbeing-not-just-gdp-by-joseph-e-stiglitz-2018-12.

Stiglitz, Joseph E., Amartya Sen, and Paul, Jean-Paul Fitoussi, *Report of the Commission on the Measurement of Economic Performance and Progress*, 2009.

Twenge, J. M., Cooper, A. B., Joiner, T. E., Duffy, M. E., & Binau, S. G. “Age, Period, and Cohort Trends in Mood Disorder Indicators and Suicide-Related Outcomes in a Nationally Representative Dataset, 2005–2017,” *Journal of Abnormal Psychology*, April, 2019, 185-199.

U.S. Department of Commerce, Bureau of the Census, “Computer and Internet Access in the United States: 2012,” February 2014.

University of Michigan. Index of Consumer Sentiment. 2020; ww.sca.isr.umich.edu/tables.html.

Veenhoven, Ruut, “Overview of Happiness Surveys Using Measure Type: 111B/3-step Verbal Happiness.” World Database of Happiness, Collection: Happiness in Nations; www.worlddatabaseofhappiness.eur.nl/hap_nat/worlddatabaseofhappiness.eur.nl (April 7, 2020).