Aggregate Productivity and the Level of Living, and Estimates for 1948-2016

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Abstract

The purpose of GDP is to measure production, though it is often used as a broader indicator of economic well-being. The purpose of aggregate productivity (TFP) is to measure the change in aggregate output per unit of input and is often used to assess innovation, but it too is also used to proxy welfare change. GDP and TFP measures sit within the production account, but (Basu & Fernald, 2002) argues that changes in aggregate TFP are, in fact, directly proportional to changes in aggregate welfare (in their stylized closed economy representative agent model). Thus, they provide a clear conceptual link between the production account and welfare measurement. (Basu, Pascali, & Schiantarelli, 2012) demonstrates that the same basic approach shows that (modified) TFP growth measures aggregate welfare change in a more general economy, with international trade, taxation, and government spending.

This paper argues that once the stylized economy includes these features, changes in aggregate welfare (still within a stylized macro model) can be derived from the Income and Expenditure account (in constant prices). The production account yields measures of TFP, while in the Income and Expenditure account yields measures of the level of living (Jorgenson, 2010). This paper shows how the Income and Expenditure Account fits within the basic framework of the national accounts, but is currently not implemented as a part of the official statistics in the U.S. We assemble such an account for the U.S. by building off the official national income and product accounts and BEA-BLS integrated production account.

The empirical contribution of this paper is to present estimates of the level of living in comparison to aggregate TFP in the U.S. between 1947 and 2016. Estimates indicate that between 1948 and 2016, aggregate total factor productivity grew by 0.75% per year, while the level of living grew by 0.86% per year. Focusing on the more recent period that includes the productivity growth slowdown in the U.S., between 2007 and 2016 productivity grew at 0.15% per year, while the level of living grew by about 0.33%

[1] The views expressed in this paper are solely those of the authors and not necessarily those of the U.S. Bureau of Economic Analysis, or the U.S. Department of Commerce.

per year, though this does not take into account the various cyclical factors that affect measurement over the business cycle. Given the conceptual link between the level of living and welfare change, one way to increase the SNA's congruence with economic theory is to include the Income and Expenditure Account in current and constant prices, along with the level of living.

1. Introduction

Since its inception, the GDP accounts have been narrowly defined and codified to measure economic production. While the use of GDP more broadly, for example to assess aggregate welfare or well-being, usually comes with appropriate technical caveats, (Jorgenson, Forthcoming) cuts to one of the core issues by writing that "While the GDP was intended by its originators as a measure of production, the absence of a measure of welfare in the national accounts has led to widespread misuse of the GDP to proxy welfare."

This paper addresses this (implicit) criticism by using the national accounts as a lens to review conceptual and empirical issues around welfare measurement within the national accounts. At the outset, it is worth noting that this paper is fairly narrow in scope in that it doesn't go "Beyond GDP" in the sense of (Jones & Klenow, 2016) by adding leisure, mortality, and inequality to measure welfare. The paper has three basic goals. The first is complementary to existing conceptual work that relates GDP, productivity, and welfare measurement via an economic model. Recent work here by (Basu, Pascali, & Schiantarelli, 2012) and (Hulten & Schreyer, 2010) covers many of conceptual issues involved in relating the national accounts to aggregate welfare, and the work in this paper is similar in nature. To summarize (Basu, Pascali, & Schiantarelli, 2012) argues that a modified TFP residual along with measures of capital stock per capita, can be used to proxy for aggregate welfare change, while (Hulten & Schreyer, 2010) concludes that real saving (net of depreciation) and the terms of trade are needed in addition to TFP measures to proxy for welfare change. Both of these papers focus on a steady state growth model, and thus develop measurement concepts that are consistent with this modeling framework.

This paper uses a simple economic model to demonstrate that once the modeler moves from a closed economy representative agent macro model to an economy with international trade, this one change has important implications for the relationship between national accounting concepts and aggregate welfare measurement. Unlike the two previously mentioned papers that derive model consistent measures, the model presented in this paper is for motivational purposes only. We then transition to implementation of the production and income and expenditures account and its relation to concepts currently included in the U.S. national income and product account (NIPA), and no longer are tied to all of the implications of the steady state model. An advantage of this approach is a clear link to the historical official GDP and productivity estimates produced for the U.S. Future work remains to compare the sources of differences

between (Basu, Pascali, & Schiantarelli, 2012) and this paper, which in principal agree on many of the underlying conceptual issues.[2]

The second goal is to demonstrate that while the production account no longer includes sufficient information to assess aggregate welfare change, the income and expenditure account does provide the necessary information in the context of the simple macro model. This is captured as changes to the level of living (Jorgenson & Landefeld, 2006), which is defined as the level of the quantity of expenditure to the quantity of income. The third part of the paper uses the constructed production and income and expenditure to measure changes in TFP and the level of living. We find that between 1948 and 2016, aggregate total factor productivity grew by 0.75% per year, while the level of living grew by 0.86% per year. Focusing on the more recent period that includes the productivity growth slowdown in the U.S., between 2007 and 2016 productivity grew at 0.15% per year, while the level of living grew by about 0.33% per year. Obviously these measure abstract from many important components of measuring true consumer welfare, like the "consumption technology" of (Hulten & Nakamura, 2017), but are nevertheless of interest because 1) they are based on information currently in the national accounts, and 2) yield straight-forward empirical comparisons that are linkable to concepts already included in the system of national accounts.

The remainder of the paper proceeds as follows. Section 2 presents the argument that expenditure and income are the relevant concepts for measuring aggregate welfare in the context of a simple macro model. Section 3 demonstrates how to implement the account and how it relates to the current U.S. national income and production accounts, while section 4 presents the growth accounting estimates. Because implementing the accounts involves some choices about data construction, some of the practical issues are discussed in section 5. Section 6 concludes.

2. Welfare Change in the Context of a Simple Macro Model

This section provides a simple macro to describe how productivity is related to "welfare", and how this relationship changes with new features. It starts with the (Basu & Fernald, 2002) specification to show that in this stylized economy, aggregate welfare change is proportional to the change in aggregate productivity, or output per unit of input. When international trade is introduced, the expanded model demonstrates that welfare change is related to expenditure per unit of income. This motivates moving from the production account to the income and expenditure account, and details in implementing this account are presented in the remainder of the paper.

We start with a closed economy 2-period representative agent macro model, with no uncertainty. It should go without saying that this model is not intended to capture many important elements that are

[2] (Hulten & Schreyer, 2010) does not contain empirical estimates. The empirical estimates of (Basu, Pascali, & Schiantarelli, 2012) are based on some official data, but also build in adjustments for the present discounted value of TFP change, so it is difficult to compare these with official GDP and TFP estimates.

related to true economic welfare and its sole purpose is to provide the simplest possible framework to highlight the relevant issues.

In the model, the representative agent maximizes the presented discounted value of utility, with choices over labor and consumption:

$$\max_{C_1,C_2,L_1,L_2} V(K_1) = U(C_1, 1-L_1) + \beta U(C_2, 1-L_2) \tag{1}$$

subject to the standard budget constraints, production function, and perpetual inventory accounting relationship between investment and capital. Capital in period 1 is predetermined. For clarity of later discussion, we write the relevant equations:

$$I_1 = Z_1 F(K_1, L_1) - C_1 \tag{2}$$

$$K_2 = I_1 + (1-\delta)K_1 \tag{3}$$

$$C_2 = Z_2 F(K_2, L_2) + (1-\delta)K_2 \tag{4}$$

Equation (2) specifies that period 1 investment is what is left over after production (at productivity level Z_1) and consumption in period 1, given the labor choice in period 1. Equation (3) is the evolution of capital given the capital stock in period 1. Equation (4) states that everything is consumed at the end of period 2, including the leftover capital stock.[3]

Abstracting from the choice of labor, equations (2)-(4) are three equations in 4 unknowns I_1, C_1, K_2, C_2. Thus determining K_2 determines I_1, C_1, C_2. With this, the maximization can be rewritten without the constraints as:

$$\max_{K_2,L_1,L_2} V(K_1) = U(Z_1 F(K_1, L_1) + (1-\delta)K_1 - K_2, 1-L_1) + \beta U(Z_2 F(K_2, L_2) + (1-\delta)K_2, 1-L_2) \tag{5}$$

Let K_2^* solve this maximization problem and V^* be the presented discounted value of utility at the optimal choices. The Basu-Fernald argument applies the envelope theorem to show that:

$$\frac{dV^*}{dZ_1} = \frac{\partial V^*}{\partial Z_1} = \frac{\partial U}{\partial C_1} F(K_1, L_1^*) \tag{6}$$

So that

$$dV^* = \frac{dZ_1}{Z_1} Y_1 \psi \tag{7}$$

[3] This is consistent with the underlying assumption that investment and consumption are tradeable 1:1.

where ψ is the marginal utility of consumption at the optimum. Since $\frac{dZ_1}{Z_1}$ is the change in TFP, equation (7) shows that changes in welfare (which appear in the model as the present discounted value of utility) are proportional to changes in TFP. (Basu & Fernald, 2002) provide intuition for this result by noting that "…the welfare benefit is proportional to productivity growth, not to output growth, since the consumer subtracts the welfare cost of supplying any extra capital and labor" and that "Since economic profits appear small…it [the TFP residual] remains an excellent index of welfare change."[4] Measuring $\frac{dZ_1}{Z_1}$ is common in academic, research, and statistical communities. The current formulation originated with the Solow residual (Solow, 1957), but in practice now includes adjustments to account for improvements in the quality of outputs and inputs (Jorgenson & Griliches, 1967).

The purpose of this next section is to show how when we expand the model on one dimension, in particular, allowing for international trade, this takes us from the production account (the account from which the TFP residual is measured) to an income and expenditure account. This leads to the concept of the level of living (Jorgenson, 2010). While international trade is one relevant example, in practice any differences that lead to deviations between the production account and expenditure account would yield a similar argument. One of the purposes of this paper is to enumerate these differences, and this is done in the subsequent section.

With international trade, at an exogenous interest rate r, the relevant accounting equations (constraints) become:

$$\begin{aligned} Y_1 &= Z_1 F(K_1, L_1) \\ Y_2 &= Z_2 F(K_2, L_2) \\ CA_1 &= Y_1 - C_1 - I_1 \\ S_1 &= Y_1 - C_1 \\ K_2 &= I_1 + (1-\delta)K_1 \\ C_2 &= Y_2 + (1-\delta)K_2 + (1+r)(Y_1 - C_1 - I_1) \end{aligned} \tag{8}$$

The equation for CA_1 is simply the definition of the current account, and S_1 the definition of saving. C_2 is the intertemporal budget constraint that imposes that net lending or borrowing on international markets (via international trade) must be paid back in period 2 (in the case of borrowing, a negative current account), or yields additional consumption in period two in the case of lending.

In this setting, the representative agent's value function at the optimum can be rewritten as:

[4] As mentioned earlier, (Hulten & Schreyer, 2010) present an alternative model that does not support the exposition that subtracting off capital and labor services is the appropriate intution.

$$V^*(K_1) = U(Z_1F(K_1, L_1^*) - (K_2^* - (1-\delta)K_1 - CA^*, 1 - L_1^*) + \beta U(Z_2F(K_2^*, L_2^*) + (1-\delta)K_2^* + (1+r)CA_1^*, 1 - L_2^*) \quad (9)$$

Since the productivity level Z and the interest rate r are treated as exogenous[5], the envelope theorem can be applied like before and yields:

$$\frac{\partial V^*}{\partial Z_1} = \frac{\partial U}{\partial C_1} F(K_1, L_1^*)$$
$$\frac{\partial V^*}{\partial r} = \beta \frac{\partial U}{\partial C_2} CA_1^* \quad (10)$$

The major take away is that with the only two exogenous variables being the level of productivity, and the interest rate, changes in the present discounted value of utility are now related to changes in the level of productivity and the current account balance that prevails at interest rate r.

The next objective is to relate this to the level of income and expenditure in the economy. To do this, we define an expenditure function $X = E(C, S)$, that is quantity of total expenditure, at time t, and is a function current consumption and saving, and the quantity of all income $A = G(K, L)$, that is a function of capital and labor services. In current dollars, $p_X X = p_A A$ as an accounting identity. In real terms, the we relate the two by a function λ, such that $E(C, S) = \lambda G(K, L)$. That is, some function λ converts current labor and capital services into current consumption and saving. Obviously saving yields future consumption, and utility from this consumption.

Based on equation(10), we posit that λ is a function of Z, and r.[6] That is, aggregate welfare change depends on the level of productivity and the world interest rate, which affects future consumption possibilities. This yields the relationship between expenditure and resources used as:

$$E(C, S) = \lambda(Z, r) G(K, L) \quad (11)$$

Taking the derivative of (11) with respect to time yields the growth accounting relationship[7]:

[5] The determination of the world interest rate in this context is beyond the scope of the current paper. Obviously, z and r are related in general world equilibrium. But, treating r as exogenous makes the point that with international trade, the current account balance and saving is an important part of expenditure.

[6] Note that in the case without international trade, this would reduce to λ being a function only of Z and would yield the original (Basu & Fernald, 2002) argument.

[7] This imposes the normalization that $\lambda(Z, r)$ and $G(K, L)$ equals one in the base year. Since the empirical implementation below is done base on index numbers, with a base year of 2009, this should not be bothersome.

$$\frac{\partial \lambda}{\partial Z}\frac{\partial Z}{\partial t}+\frac{\partial \lambda}{\partial r}\frac{\partial r}{\partial t}=\frac{\partial X}{\partial t}-\frac{\partial A}{\partial t} \tag{12}$$

The preceding discussion can be summarized as: 1. welfare change is related to changes in TFP and the interest rate in this stylized model, 2. the impact of exogenous change TFP and the interest rate can be summarized in the function λ, and 3. this can be measured as the growth rate in expenditure less the quantity of income from capital and labor services. That is, the growth accounting expression relates changes in lamba, Z, and r, to changes in expenditure and income, and equation (10) relates changes in Z and r to changes in aggregate welfare. The function λ is termed the "level of living" in (Jorgenson & Landefeld, 2006), although no attempt is made in that paper to show analytically how λ, or Z, is relative to welfare. This argument above is the first that we are aware of make this link explicit. Also note that with no international trade, the above discussion reverts to the (Basu & Fernald, 2002) economy where changes in welfare are proportional to changes in TFP.

This completes the conceptual discussion on how in a simple macro model with a closed economy, changes in aggregate welfare are proportional to changes in TFP. With international trade, we argue that changes in TFP and the determinants of international trade (the interest rate) can be summarized in the measure λ, the level of living. This basic conclusion is similar in nature to the (Basu, Pascali, & Schiantarelli, 2012) findings. They conclude that a modified TFP residual and capital stock per capita can be used to proxy for welfare change. The modifications that they consider are similar in nature to those described in the next section, though there are some technical differences. For example, one of their modifications to the TFP residual is that it is based on domestic absorption. This differs from the measure of expenditure presented below, both in nominal and real terms.[8] The remainder of the paper demonstrates in practice the difference between the production account, which can be used to measure the change in TFP, and the income and expenditure account which can be used to measure changes in the level of living, and applies these accounts to measure changes in both between 1948 and 2016.

3. Implementing the Production, and Income and Expenditure Accounts

3.1. Accounting Tables in Nominal Dollars

The conceptual framework above highlights the differences between production and income-expenditure accounting by focusing on how the model changes in the presence of international trade. The national accounts, however, are significantly more complicated than the simple stylized model presented above. This section discusses how to implement the production and income and expenditure account within the current framework of the U.S. national accounts. The accounts presented here closely follow (Jorgenson

[8] See Table 3. In the implementation below, domestic absorption is defined as consumption plus investment. The account presented below is based on gross investment and its price index, which includes net lending and borrowing and net capital accounts transactions.

& Landefeld, 2006), but are updated to reflect the latest U.S. national income and product accounts (NIPAs).[9] The conceptual framework requires measures in quantity indexes, in particular constant quality prices and quantities. The easiest way to describe the accounts is to compare how they relate to concepts in the official accounts.

Table 1 presents the Domestic Production in nominal dollars for the year 2016. As an accounting identity, domestic production balances income. The production side of the account starts with the official GDP. One key aspect of the account is the symmetric treatment of durables held by business, household and the government. Thus, the product side includes imputations for services of consumer durable goods, services of household and institutional real estate (including owner occupied homes) and services of durables, structures, land, and inventories held by government. The imputation method is discussed in detail in (Jorgenson & Landefeld, 2006) and amounts to building a stock of these assets, assuming a rate of return, and implementing the standard capital service price formula. Because owner occupied housing is already included in the GDP account, the official amount is netted off from the imputation for household and institutional real estate. For analogous reasons, general government and government enterprise consumption of fixed capital is netted out, as is the surplus of government enterprises.

The other major difference between the production account used here and the official GDP measure is the treatment of taxation. Because the production account is conceptually related to the value actually received by the producer (i.e. the prices faced when making optimizing decisions about profits), taxes do not accrue to the producer and are subtracted off from the value of GDP. This subtraction appears in the production account table as federal taxes on production and imports, current transfer receipts from business, and motor vehicles taxes. Because property taxes paid are a component of the cost of capital these are added back in, as are subsidies because these are an explicit payment for production.

The income side of the account is the measure the value of capital and labor services used in production. This starts with the official definition of national income and subtracts off rest of world (ROW) income. It also includes the consumption of fixed capital, and the statistical discrepancy is allocated to capital income. As balancing items, the imputed service flows included on the product side are included on the income side as well; these represent the implicit barter transaction between the owner and the user of the household and government assets and ensure a consistency in the GDP accounting between rented and owned assets. Net taxes are subtracted as well as these are not income received by the producing units. Overall, in in 2016, production account GDP was about 2% higher than official GDP.

The Income and Expenditure Account for 2016 in nominal dollars is given in Table 2. The expenditure side includes personal consumption expenditures (PCE), government expenditures, and gross national saving at market prices. The intuition for including these items at market prices is that market prices reflect purchaser valuations. PCE includes estimates of spending on nondurables from the NIPAs. Added to this are services of consumer durables, services of structures and land (owner occupied housing), and services

[9] A minor difference is that (Jorgenson & Landefeld, 2006) uses (mostly) Fisher aggregation while that presented here uses tornqvist aggregation.

of durables held by institutions. Finally, NIPAs estimates of PCE services are included, but net of the NIPA estimate of owner occupied housing services to avoid double counting.

Government consumption expenditures includes government spending on nondurable and durable goods, imputed services of durable goods and land held by the government, and government employee compensation. Note that general government consumption of fixed capital need not be subtracted (to avoid double counting) from the expenditures account because it is not included in the detailed components of government consumption expenditures that are included in this table, whereas the government enterprise surplus and consumption of fixed capital must be netted out because it is already included in the imputed services of durables, structures, land, and inventories held by government in the government expenditures.[10]

The final component of gross domestic expenditures is gross national saving and the statistical discrepancy. The statistical discrepancy is allocated to gross saving to balance the account. Gross saving is derived from the capital account.

The Domestic Capital Account is presented in Table 3. The accounting identity is that investment equals saving. Gross private domestic investment incudes private fixed investment, change in private inventories, investment in residential and purchases of consumer durables. Gross investment includes government investment in intangible and tangible assets and balance on the current account.

As in the simplified model above, the balance of the current account is defined as the value of output less current consumption and investment and measures changes in future claims on foreign countries. In the case of a positive current account, foreign countries borrow to finance current consumption and must repay this financing by producing more output than consumed in future periods. This output, in essence, is repaid to the financing country as extra consumption in the future. Thus, a positive current account balance, ceteris paribus, reflects additions to future consumption just as investment in physical capital adds to future production (and consumption) possibilities. In the U.S. national accounts, the current account reflects net lending and borrowing and net capital account transactions. Net capital account transactions capture flows of value from traded non-produced assets.[11] The bottom panel of Table 3 shows the sources of gross saving. This includes NIPA estimates of net saving that captures personal saving, undistributed corporate profits, and net government saving. Purchases of consumer durables are added to this for the reasons discussed above, as is consumption of fixed capital to arrive at the measure of gross saving. As noted, the statistical discrepancy is included here to balance the account. That completes the description of the expenditure side of the income and expenditures account.

The income side of the income and expenditures account includes gross income from the production account. But it also adds back in production taxes and subtracts subsidies. This yields gross domestic

[10] Put another way, because government consumption expenditures are built from the detailed components, government consumption of fixed capital isn't included in the first place, so there is no need to net it out.

[11] Examples include mineral rights, electromagnetic spectrum, and offshore drilling rights and purchases and sales of intangible assets, such as copyrights and trademarks.

income at market prices and reflects the actual income generated to purchase goods and services at market prices. Finally, gross income includes income receipts from the rest of the world less income payments and current (net) taxes and transfers to the rest of the world as domestic persons use this income to purchase current consumption and investment goods.[12]

3.2. Price and Quantity Indexes

The productivity and level of living measures described above require quantity indexes of output and input and income and expenditure. This section provides a brief overview of the prices used to construct the quantity indexes based on the latest version of the U.S. NIPA accounts; more information is presented in (Jorgenson & Landefeld, 2006).

Deflators for the production account are constructed following broadly accepted practices in the productivity accounting literature, but differ in scope by including the imputations for durables held by the household and government sectors.[13] In practice, the output price is constructed as a tornqvist index over private output (consumption and investment goods produced by the private sector) and output of the general government and government enterprise sectors, which includes the labor and capital services employed in those sectors.[14] As noted above the prices of private output are adjusted for net taxes to represent prices received by the producer.

The deflator for inputs in the production account is constructed as the tornqvist aggregate of the prices of capital and labor inputs, including the imputations for capital services of consumer and government durables. Construction of these prices follows the methods detailed in (Jorgenson, Ho, & Stiroh, 2005). The labor input price is constructed as a tornqvist index of labor compensation per hour over workers cross classified by sex, age, and education to control for changes in the composition of the workforce over time. Historical price data is taken from (Jorgenson, Ho, & Samuels, 2016), while the more recent data is taken from (Garner, Harper, Howells, Russell, & Samuels, 2018). Capital service prices are constructed as an aggregate over capital services prices at the asset level. Asset-level user costs are formulated using methods described in (Jorgenson, Ho, & Stiroh, 2005) and account for the opportunity costs of capital investment, depreciation, taxation, and the revaluation of capital assets.

The deflators for expenditures and income are based on deflators for the components of expenditure and income. Gross expenditures are constructed as a tornqvist index of personal and government consumption expenditures at market prices and include the consumption of consumer durable and government capital services, and gross saving.

[12] Note that imports, obviously, are a subtraction from estimates of production based on expenditure side estimates of GDP, but income receipts from the ROW are used for domestic consumption expenditures even though these consumption expenditures are not domestic production. Thus, this income appears in the income and expenditures account, but not the production account.
[13] See OECD manuals on measuring productivity and capital.
[14] This implicitly defines TFP growth in the general government and consumer durables sectors to be zero.

The deflator for gross saving requires some elaboration. There is no direct information on prices for gross saving. The assumption employed here, and in (Jorgenson & Landefeld, 2006) is that the price of gross saving equals the price of gross investment. While this is not explicitly derived here, or in other work that we are aware of, an appeal to arbitrage opportunities between investment opportunities may be a sufficient justification for this choice. Subsequent research should address this issue more systematically. In practice, the deflator for gross investment is constructed as a tornqvist index over private investment (including consumer durables), government investment, and net lending and borrowing and net capital accounts transactions (see table 3). The price for net lending and borrowing and net capital accounts transactions is constructed as a reverse tornqvist to construct a price for net exports. Due to switches from positive to negative in the trade balance this price is constructed as a first order approximation to the true tornqvist price. Subsequent research should address this as well. In practice, using the actual tornqvist index does not change the long-term trends in the growth accounts presented below, but it does introduce a couple of significant spikes to the time series when the trade balance switched signs.

The deflator for income is constructed as a tornvist index of prices of labor and property income that underlie the nominal account in Table 2. Labor income includes labor income employed in domestic production and compensation of employees in the rest of the world. Since no price of compensation of employees in the rest of the world is available, the quantity index of net exports to labor services is used to define an implicit price of compensation of employees in the ROW. The quantity index is defined as the hours worked in the rest of the world, adjusted by the private sector index of labor quality. Property income is the aggregate of ROW property income and domestic property income. The deflator for domestic property income corresponds to the deflator for capital services in the production account, as described above. For ROW property income, the deflator is constructed as an implicit deflator using information on nominal net foreign income (Income receipts from the ROW less Income payments to the ROW from NIPA table 1.7.5), while the quantity indexes come from NIPA table 1.7.6.

The last component of the accounts that requires discussion is the role of depreciation. (Weitzman, 1976) provided a conceptual argument that Net National Product (GNP less depreciation), not GDP, is related to consumption based estimates of welfare. The basic intuition for this is that replacements of the productive capital stock, which appear in depreciation and are counted in gross investment, do not yield an increase in future consumption because this spending is necessary simply to bring the productive capital stock back to its previous level before the capital assets were depreciated. (Hulten & Schreyer, 2010) provides a similar argument. Thus, even though this has not been explicitly accounted for in the economic model presented above, the income and expenditure accounts are modified to include net income and net expenditure. On the other hand, since the production account is built to measure total production, it is conceptually appropriate to include gross output and gross inputs, as these capture the total resources produced and used in production in any given period.

Measures of net expenditures and net income are constructed using a reverse tornqvist procedure that backs out the price growth net income, for example, by satisfying the accounting identity that the gross income price is a tornqvist aggregate of the gross expenditure price, the net expenditure price, and the price index for depreciation. The price index for aggregate depreciation is described in (Jorgenson & Landefeld, 2006).

This completes the formulation of the production account and income and expenditure account in current and constant dollars. One key point worth emphasizing is that the account is constructed so that the price and quantity information is internally consistent; furthermore, aggregate prices and quantities are built from the disaggregated level up to the aggregate whenever possible. A large majority of the information used to construct the account is already included in the official NIPA accounts. With the introduction of the official BEA-BLS integrated industry-level production account (Garner, Harper, Howells, Russell, & Samuels, 2018), deflators for capital and labor services (the income side of the account) are available as well. The significant remaining piece not covered by the official BEA accounts is the imputation for consumer durables.

4. Growth Accounting Results

Based on the discussion above, the two relevant growth account equations are the standard growth accounting for TFP, using the underlying concepts of capital and labor services adjusted to hold quality constant, and a new growth accounting equation for changes in the level of living. In discrete time, these are approximated with Tornqvist indexes as:

$$\begin{aligned} \Delta \ln Z_t &= \Delta \ln Y_t - \Delta \ln F_t \\ \Delta \ln \lambda_t &= \Delta \ln X_t - \Delta \ln A_t \end{aligned} \tag{13}$$

In words: TPF growth is measured as the growth of output less total factor input. The level of living is measured as the growth of expenditures less the growth in all income. As noted above, for measuring the level of living, it is useful to measure income and expenditure net of depreciation.

The main empirical contribution of this paper is to assemble time series estimates to measure equation (13) and show how these are related to current estimates within the NIPA accounts. Table 4 provides the growth accounting for TFP growth, and Table 5 contains the growth account for the level of living.

Over the period as a whole, the level of living has grown faster than total factor productivity; TFP grew by about 0.75% per year, while the level of living grew 0.86% per year, on average. The table divides the growth accounting into the Post-war boom (1948-1973), the slow growth period after the oil shock (1973-1995), the IT Investment Boom (1995-2000), the Jobless Growth period (2000-2007), and the Great Recession and Recovery (2007-2016), and in all periods, the level of living grew faster than TFP. Between 1973 and 1995, and 2000 to 2007, TFP and the level of living grew at similar rates, but for the 1948-1973, 1995-2000, and 2007-2016 there were substantial differences in the growth rates between the two measures. Comparing the 2007-2016 period with the 2000-2007 period is instructive given the focus on the slowdown in measured TFP, and its implications for well-being (Byrne, Fernald, & Reinsdorf, 2016). Comparing those periods, both the growth in TFP and the level of living slowed, but the slowdown in

growth in the level of living was slightly less than that for TFP: a slowdown of 0.58% per year for TFP growth and 0.42% per year for the level of living. Comparing 2007-2016 with the 1995-2007, the slowdowns were similar: 0.72% per year for the level of living, and 0.75% per year for TFP growth.

5. Practical Issues

Implementing the production and income and expenditure account described involves implementation issues that deserve mention. Nevertheless, the issues confronted are similar in nature to other issues that arise in assembling the national accounts. Therefore, these implementation issues, while important, should not be seen as a permanent roadblock to implementing accounts of this nature more broadly. The first issue worth noting is the well-known issue of negative capital user costs, which are required to construct measure of capital input and real income. Negative user costs arise when there are low rates of return and high asset inflation rates. (Jorgenson, Ho, & Stiroh, 2005) describes various methods for overcoming this issue, but a more systematic approach is probably warranted. Another issue worth noting is the deflator for saving. As discussed above, this is currently assumed to be equal to the deflator for investment. Since this plays a key role in the empirical estimates, this deserves more attention as well. The deflator for net trade is an important is well, as this factors into the price index for gross saving. Lastly is the issue of the statistical discrepancy. In this paper, this was allocated to capital income, but it would obviously be an improvement to have a better idea of how to allocate this across labor and capital income.[15]

6. Conclusions

The appeal of being able to relate standard measures that are typically included in the national accounts and constructed to be consistent with international guidelines to changes in aggregate welfare is considerable. Significant progress has been made in the research community showing how to do this conceptually and empirically, but no consensus has emerged, and no measures of welfare change are currently produced officially by the statistical agencies in the U.S.

The conclusion of this paper is that it would be useful to move the debate about the relationship between the GDP accounts and welfare from a discussion of TFP and the production account to the income and expenditure account, and the level of living. The income and expenditure account contains the conceptually relevant information to produce measure of income and expenditure for aggregate welfare analysis. In the U.S., between 1948 and 2016, aggregate total factor productivity grew by 0.75% per year,

[15] (Hulten & Schreyer, 2010) demonstrate that assumption of geometric depreciation has important implications for the definition of net saving and net product. Deviating from geometric depreciation is not addressed in this paper.

while the level of living grew by 0.86% per year. Focusing on the more recent period that includes the productivity growth slowdown in the U.S., between 2007 and 2016 productivity grew at 0.15% per year, while the level of living grew by about 0.33% per year. Over the long term in the U.S., the measures are highly correlated, but for other economies with different structures for trade, taxation, and government spending, this need not be the case. Given the conceptual link between the level of living and welfare change, one way to increase the SNA's congruence with economic theory is to include the Income and Expenditure Account in current and constant prices, along with the level of living.

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Table 1: Domestic Income and Product Account, 2016

Line		Product	Source	Total
1		GDP (NIPA)	NIPA 1.1.5 line 1	18,624.5
2	+	Services of consumers' durables	our imputation	1,549.3
3	+	Services of household and institutional real estate (net of BEA estimate	our imputation	-711.9
4	+	Services of durables held by institutions	our imputation	0.4
5	+	Services of durables, structures, land, and inventories held by governmen	our imputation	817.2
6	+	Private land investment	our imputation	0.0
7	+	Government land and inventory investmen	our imputation	0.0
8	-	General government consumption of fixed capita	NIPA 3.10.5 line 5	459.8
9	-	Government enterprise consumption of fixed capital	NIPA 3.1 line 42- 3.10.5 line 5	66.4
10	-	Federal taxes on production and imports	NIPA 3.2 line 4	137.0
11	-	Federal current transfer receipts from business	NIPA 3.2 line 19	47.4
12	-	S&L taxes on production and imports	NIPA 3.3 line 6	1,151.0
13	-	S&L current transfer receipts fom business	NIPA 3.3 line 18	58.5
14	+	Capital stock tax	-	0.0
15	+	MV tax	NIPA 3.5 line 31	11.1
16	+	Property taxes	NIPA 3.3 line 8	499.8
17	+	Severance, special assessments, and other taxes	NIPA 3.5 line 32-34	83.3
18	+	Subsidies	NIPA 3.1 line 30	61.8
19	-	Current surplus of government enterprises	NIPA 3.1 line 19	-10.1
20	=	Gross domestic product		19,025.6

Line		Income	Source	Total
1	+	Consumption of fixed capital	NIPA 5.1 line 13	2,916.7
2	+	Statistical discrepancy	NIPA 5.1 line 42	-147.2
3	+	Services of consumers' durables	our imputation	1,549.3
4	+	Services of household and institutional real estate (net of BEA estimate	our imputation	-711.9
5	+	Services of durables held by institutions	our imputation	0.4
6	+	Services of durables, structures, land, and inventories held by governmen	our imputation	817.2
7	+	National Income Adjustment for Land Investment	our imputation	0.0
8	-	General government consumption of fixed capita	NIPA 3.10.5 line 5	459.8
9	-	Government enterprise consumption of fixed capital	NIPA 3.1 line 42- 3.10.5 line 5	66.4
10	+	National income	NIPA 1.7.5 line 16	16,052.0
11	-	ROW income	NIPA 1.7.5 line 2-3	197.1
12	-	Sales tax	Product Account	799.7
13	+	Subsidies	NIPA 3.1 line 30	61.8
14	-	Current surplus of government enterprises	NIPA 3.1 line 19	-10.1
15	=	Gross domestic income		19,025.5

Table 2: Income and Expenditures Account, 2016

Line	Income	Source	Total
1	+ Gross income	Product Account	19,025.5
2	+ Production taxes	Product Account	799.7
3	- Subsidies	NIPA 3.1 line 30	61.8
4	= Gross domestic income at market prices		19,763.4
5	+ Income receipts from the rest of the world	NIPA 1.7.5 line 2	844.3
6	- Income payments to the rest of the world	NIPA 1.7.5 line 3	647.2
7	- Current taxes and transfers to the rest of the world (net)	Foreign Transactions Current Account	136.8
8	= Gross income		19,823.7
9	- Depreciation	our imputation	3,909.7
10	= Net income		15,914.0

Line	Expenditures	Source	Total
1	+ Personal consumption expenditures		12,247.5
2	PCE nondurable goods (NIPA)	NIPA 2.3.5 line 8	2,710.4
3	PCE services (NIPA)	NIPA 2.3.5 line 13	8,699.3
4	PCE services less space rental value of inst building and nonfarm dwellings	our imputation	7,246.9
5	Services of consumers' durables	our imputation	1,549.3
6	Services of structures and land	our imputation	740.5
7	Services of durables held by institutions	our imputation	0.4
8	+ Government consumption expenditures		2,959.2
9	Government consumption nondurable goods	NIPA 3.10.5 line 8	277.6
10	Government intermediate purchases, durable goods	NIPA 3.10.5 line 7	65.5
11	Government consumption services total		192.5
12	Government consumption services	NIPA 3.10.5 line 9	672.5
13	Less sales to other sectors	NIPA 3.10.5 line 11	480.0
14	Services of durables, structures, land, and inventories held by government	our imputation	817.2
15	Less government enterprise consumption of fixed capital	NIPA 3.1 line 42- 3.10.5 line 5	66.4
16	Less current surplus of government enterprises	NIPA 3.1 line 19	-10.1
17	Government compensation of employees exluding force account labor	NIPA 3.10.5 line 4-10	1,662.7
18	+ Gross national saving and statistical discrepancy	Capital Account	4,617.0
	- Depreciation	our imputation	3,909.7
19	= Net domestic expenditures		15,914.1

Table 3: Domestic Capital Account, 2016

Line	Investment	Source	Total
1	+ Private fixed investment, nonresidential structures	NIPA 5.4.5 line 2	516.2
2	+ Private fixed investment, equipment	NIPA 5.5.5 line 1	1,054.0
3	+ Private fixed investment, IPP	NIPA 5.6.5 line 1	756.2
3	+ Change in private inventories, nonfarm	NIPA 5.7.5 line 19	35.7
4	+ Change in private inventories, farm	NIPA 5.7.5 line 2	-0.6
5	+ Private fixed investment, residential structures	NIPA 5.4.5 line 35	695.7
6	+ Personal consumption expenditures, durable goods	NIPA 1.1.5 line 4	1,411.0
7	+ Private land investment	our imputation	0.0
8	= Gross private domestic investment		4,468.2
9	+ Government investment, structures	NIPA 5.9.5 line 6	280.9
10	+ Government investment, equipment	NIPA 5.9.5 line 46	133.3
	Government investment, IPP	NIPA 5.9.5 line 57	195.5
11	+ Government investment, land and inventories	our imputation	0.0
12	= Gross domestic investment		5,077.9
13	+ Net lending or borrowing on rest of world account	NIPA 4.1 line 34	-461.4
14	+ Capital accounts transaction (net)	NIPA 4.1 line 36	0.4
15	= Gross investment		4,616.9

Line	Saving	Source	Total
1	+ Net saving (NIPA)	NIPA 5.1 line 2	436.5
2	Personal saving	NIPA 5.1 line 9	680.6
3	Undistributed corporate profits with IVA and capital consumption adjustments	NIPA 5.1 line 4	620.6
4	Wage accruals less disbursements (private)	NIPA 5.1 line 9	-
5	Net government saving	NIPA 5.1 line 10	-864.7
6	+ Consumption of fixed capital	NIPA 1.7.5 line 5	2,916.7
7	= Gross saving (NIPA)	NIPA 5.1 line 1	3,353.2
8	+ Personal consumption expenditures, durable goods	NIPA 1.1.5 line 4	1,411.0
9	+ Private land investment	our imputation	0.0
10	+ Government investment, land and inventories	our imputation	0.0
11	= Gross saving		4,764.2
12	+ Statistical discrepancy	NIPA 5.1 line 42	-147.2
13	= Gross saving and statistical discrepancy		4,617.0

Table 4: Output, Input, and TFP Growth, 1948-2016

Quantities	1948-2016	1948-1973	1973-1995	1995-2000	2000-2007	2007-2016
Output	3.19	3.95	2.82	4.44	2.86	1.51
Input	2.44	2.69	2.50	3.31	2.12	1.36

Prices	1948-2016	1948-1973	1973-1995	1995-2000	2000-2007	2007-2016
Output	2.90	2.46	4.78	1.12	2.36	0.95
Input	3.65	3.72	5.11	2.25	3.09	1.10

	1948-2016	1948-1973	1973-1995	1995-2000	2000-2007	2007-2016
TFP	0.75	1.26	0.32	1.13	0.73	0.15

Table 5: Net Expenditure, Income, and Level of Living Growth, 1948-2016

Quantities	1948-2016	1948-1973	1973-1995	1995-2000	2000-2007	2007-2016
Net Expenditure	3.31	4.17	2.80	5.03	2.76	1.68
Net Income	2.46	2.73	2.49	3.57	2.01	1.36

Prices	1948-2016	1948-1973	1973-1995	1995-2000	2000-2007	2007-2016
Net Expenditure	2.71	2.20	4.66	0.56	2.40	0.78
Net Income	3.56	3.63	4.97	2.03	3.15	1.10

	1948-2016	1948-1973	1973-1995	1995-2000	2000-2007	2007-2016
Level of Living	0.86	1.44	0.31	1.47	0.75	0.33