Tracking Cultivated Assets in Measures of Capital

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Abstract Americans invested $72 billion in cultivated assets in 2019. By category, investment was: $7 billion in long-lived food animals, $2 billion in horses, $10 billion in farm plants, and $53 billion in landscaping plants. System of National Accounts 2008, the internationally agreed guidelines for national accounts, explicitly recommends that cultivated assets should be tracked in measures of capital (United Nations Statistics Division 2008, sec. 10.88–10.96). This recommendation has been widely accepted and most European Union countries currently track some cultivated assets in their measures of capital (Jager 2017). In addition, the U.S. agricultural productivity accounts have considered tracking cows in their measures of capital (Ball and Harper 1990). However, this recommendation is not currently implemented in either the U.S. National Economic Accounts (Bureau of Economic Analysis 2019) or the U.S. agricultural productivity accounts (Shumway et al. 2015).

This paper explores how capitalizing those cultivated assets changes the U.S. National Economic Accounts from 1929 to 2019 and the industry-level production account from 1948 to 2019. First, real gross domestic product (GDP) growth before 1990 decreases slightly when cultivated farm assets are capitalized. Second, the 2000s housing bubble and bust appears more dramatic when cultivated landscaping is capitalized along with other real estate investment. Third, measured real estate sector productivity growth falls noticeably when cultivated landscaping is tracked as a capital input.

Keywords Dairy, Beef, Cow, Sheep, Livestock, Horse, Tree, Pasture, Lawn, Cultivated Asset, Capital, National Accounts, Productivity, Agriculture, Real Estate

JEL codes E01, O17, and Q1

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Introduction

Cultivated assets are defined as animals and plants that are managed by humans and that provide repeat products to their owners. System of National Accounts 2008, the internationally agreed guidelines for national accounts, explicitly recommends that cultivated assets should be tracked in measures of capital (United Nations Statistics Division 2008, sec. 10.88–10.96). Neither the U.S. Bureau of Economic Analysis (BEA), the U.S. Department of Agriculture's (USDA) Economic Research Service, nor the U.S. Bureau of Labor Statistics (BLS) currently track cultivated assets consistently with nonbiological capital. This paper explores how tracking cultivated assets in measures of capital would change BEA's National Income and Product Accounts (NIPAs) from 1929 to 2019 and the integrated BEA/BLS industry-level production account from 1948 to 2019.

This paper is divided into seven sections. Section 1 describes the current and exploratory treatment of cultivated assets in the United States. Section 2 presents data on gross nominal investment from each cultivated asset category and data on negative nominal investment from slaughtered food animals. Section 3 presents data on prices for each category and then uses those prices to recalculate overall gross domestic product (GDP) prices and GDP quantities when cultivated assets are capitalized. Section 4 estimates depreciation rates for each category and then calculates capital stock, consumption of fixed capital (CFC), and net savings when cultivated assets are capitalized. Section 5 combines the data in Sections 2, 3, and 4 with the integrated BEA/BLS industry-level production account to recalculate total factor productivity when cultivated assets are capitalized. Appendix A calculates alternative measures of nominal investment and prices when slaughtered food animals are not treated as negative investment. Finally, Appendix B gives detailed information on each cultivated asset subcategory in an Excel spreadsheet.

1. Current and Exploratory Treatment of Cultivated Assets

Description of cultivated asset categories studied

This paper studies four separate categories of cultivated assets: long-lived food animals, horses, farm plants, and landscaping plants. The next four paragraphs describe each category of cultivated asset.

Long-lived food animals are defined as animals that yield repeat food products over a long working life (United Nations Statistics Division 2008, sec. 10.92). This definition excludes animals raised for meat because they provide a product only when they are slaughtered. It also excludes breeding hogs and egg-laying chickens because those animals rarely have a long working life on modern American farms. However, it does include cows and bulls that are slaughtered for meat after a long working life producing milk and calves. Readers should note that sheep or goats that produce wool and honeybees that produce pollination services are included in this category because those animal species can produce food products in addition to their non-food products.

Horses are included in capital when they are used in business production by racetracks. Modern farm horses are assumed to be mostly pets[2] that are not used in business production[3] and, therefore, this paper mostly excludes those animals from measures of capital. However, farm horses and farm mules were an important source of power and transportation when the NIPAs started in 1929 (Olmstead and Rhode). So, farm horses and farm mules are included in the historic measures of capital.

Long-lived farm plants are defined as cultivated plants that yield repeat farm products over a long working life. This definition excludes trees raised for wood because they provide a product only when they are cut. The European Union's official guidelines for national accounts focus on vineyards and orchards (Eurostat 2010, 183). However, farm pastures meet the definition of a cultivated asset (United Nations Statistics Division 2008, sec. 10.95) because they are cultivated plants whose underground root system lives for years and supports new growth of the visible stems throughout its life. In addition, individual fruit or nut trees can provide repeat farm products even if they are not part of a larger orchard. Therefore, this paper includes pastures and individual fruit or nut trees together with vineyards and orchards in the cultivated farm plant category.

Landscaping plants are included in capital because landscaping trees and lawns are managed by humans and yield environmental services like soil stabilization over a very long period of time. Some people might argue that only landscaping owned by golf courses should be tracked because that industry has the only business model that absolutely requires landscaping plants. However, the NIPAs have a long tradition of tracking somewhat discretionary business inputs together with absolutely required business

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[2] Pets like dogs or cats are always assumed to be companion animals and therefore are not tracked in this paper.

[3] If farm horses are companion animals, then their food and stable space should be tracked as a component of farm output and personal consumption expenditures. Such tracking would increase measured farm output by more than $20 billion in 2017. This paper will not explore this topic further because it is not related to capital measurement.

inputs in measures of capital. Furthermore, the NIPAs also have a long tradition of including owner-occupied housing structures together with for-profit business structures in measures of private sector capital. In order to be consistent with those traditions, this paper capitalizes somewhat discretionary business landscaping and residential landscaping together with golf course landscaping. Appendix B gives investment by industry so that interested readers can focus on the amusement, gambling, and recreation sector (which contains golf courses) if they desire.

Current treatment of cultivated assets in the NIPAs

BEA currently tracks dairy cows, beef cows, bulls, sheep, and goats in livestock inventories. Under that treatment, births of those animals add to GDP by increasing "changes in private inventories" (line 11 of NIPA table 1.1.5). Conversely, deaths of those animals (slaughter and nonslaughter) subtract from GDP by decreasing "changes in private inventories." BEA's inventory statistics also reflect value changes associated with animal age, weight, and dairy status.

Private business expenditures on honeybees, horses, farm plants, and landscaping plants do not impact measured GDP. If those items are purchased, then they are tracked as output of the producing company and intermediate input for the purchasing company. Those two impacts precisely cancel out so that purchases have no net impact on GDP. Own-account cultivated asset production by businesses is not tracked as either output or intermediate input, but time devoted to cultivated asset production are tracked in the labor force statistics. Finally, own-account landscaping production by unpaid homeowners is not tracked as either output or intermediate input and time devoted to it is considered household production and therefore not tracked in the labor force statistics (Kanal and Kornegay 2019).

Government and nonprofit expenditures on landscaping plants do impact measured GDP. For those sectors, BEA measures output based on costs rather than market revenue. Expenditures on landscaping plants are implicitly included in total costs and therefore implicitly included in measured output. Based on the 2012 Economic Census and two surveys of the lawn industry (Barnes et al. 2006 and Bennet and McCarthy-Kersey 2006), this paper estimates that approximately one-quarter of landscaping is owned by the government and a small additional share by the nonprofit sector. Government and nonprofit ownership of other cultivated assets is very small and is assumed to be zero for simplicity.

Finally, the integrated BEA/BLS industry-level production account track the stock of cultivated plants to a limited degree. Even though land is not considered a produced asset, it is still tracked as a natural resource input for the purpose of calculating total factor productivity (Garner et al. 2020). The currently measured value of farmland includes farm plants that are bundled together with land and the currently measured value of developed land includes landscaping plants that are bundled together with land.

Proposed treatment of cultivated assets in the national accounts

This paper tracks both purchases and own-account production of cultivated assets as capital investment. Owner-occupied housing is treated as a business in the NIPAs, and therefore own-account landscaping production by homeowners is treated as capital investment (United Nations Statistics Division 2008, sec. 6.37). The paper follows the official guidelines and treats slaughtered food animals as negative investment (United Nations Statistics Division 2008, sec. 10.94), but appendix A gives results with slaughtered food animals treated as consumption of fixed capital (CFC). For the private business sector, measured value added increases by the net value of the newly tracked investment. For the government and nonprofit sector, measured value added increases by the value of the newly tracked CFC.

The real stock of cultivated assets is calculated by starting with the previous year's capital stock, adding real net investment, and then subtracting real CFC. This method is known as the perpetual inventory method and is a standard NIPA technique. Nominal capital stock is then calculated by multiplying real capital stock for each category with the price index for that category. Note that researchers could calculate the stock of plants by comparing market prices for similar properties with and without plants. As a robustness check, this paper experimented with the comparison method and found a qualitatively similar value of landscaping plants (Anderson and Cortell 1988), (Sander et al. 2010), (Dimke et al. 2013), and (Han et al. 2021). However, the comparison method is difficult to implement because market prices for individual properties are dependent on difficult to observe factors like school quality.

Livestock inventories are adjusted to avoid double-counting long-lived food animals. BEA's current measures of livestock inventory rely on statistics from USDA's National Agricultural Statistics Service (NASS) that track long-lived cattle, sheep, and goats together with short-lived food animals. Statistics from NASS that only track short-lived food animals could not be located. Instead, this paper first calculates nominal and real inventory changes[4] for long-lived cattle, sheep, and goats only and then subtracts those calculated changes from the inventory changes published by NASS. The residual represents a measure of nominal and real livestock inventory changes for short-lived food animals only.

[4] Inventories are calculated using data collected in this paper, and do not always match NASS's published statistics.

Land values are adjusted to avoid double-counting long-lived plants. The calculated farm plant stock, which was $0.1 trillion in 2019, is subtracted from the currently measured value of farmland to get an estimate of the natural resource value of farmland. Similarly, the calculated landscaping plant stock, which was $1.8 trillion in 2019 is subtracted from the currently measured value of developed land to get an estimate of the natural resource value of developed land.

Table 1. Revision to GDP from Capitalizing Long-Lived Food Animals

Current treatment in GDP	Adjusted GDP	Change to GDP
1. New food animals are tracked as additions to inventory.[5] 2. Slaughter revenue is tracked as a subtraction from inventory. 3. Nonslaughter deaths are tracked as a subtraction from inventory.	1a. New long-lived food animals are tracked as investment. 1b. New short-lived food animals are still tracked as additions to inventory. 2a. Slaughter revenue from long-lived food animals is tracked as negative investment. 2b. Slaughter revenue from short-lived food animals is tracked as a subtraction from inventory. 3a. Nonslaughter deaths of long-lived food animals are treated as CFC. 3b. Nonslaughter deaths of short-lived food animals are still tracked as a subtraction from inventory.	Increases by newly tracked gross investment in long-lived food animals **minus** slaughter revenue from long-lived food animals and **minus** any changes in food animal inventory already tracked.

Table 2. Revision to GDP from Capitalizing Horses Used for Business

Current treatment in GDP	Adjusted GDP	Change to GDP
1. Purchases of horses are tracked as intermediate inputs. 2. Own-account produced horses are not tracked.	1. Purchases of horses are tracked as investment. 2. Own-account produced horses are tracked as investment.	Increases by newly tracked value of investment in horses.

[5] Even though honeybees are a long-lived food animal, they are not currently tracked in livestock inventories. As a result, tracking that animal category has the same impact on GDP as tracking horses and farm plants.

Table 3. Revision to GDP from Capitalizing Farm Plants

Current treatment in GDP	Adjusted GDP	Change to GDP
1. Purchases of farm plants are tracked as intermediate inputs. 2. Own-account produced farm plants are not tracked.	1. Purchases of farm plants are tracked as investment. 2. Own-account produced farm plants are tracked as investment.	Increases by newly tracked value of investment in farm plants.

Table 4. Revisions to GDP from Capitalizing Landscaping

Current treatment in GDP	Adjusted GDP	Change to GDP
1. Purchases of landscaping plants by for-profit business and owner-occupied housing are tracked as intermediate inputs. 2. Own-account landscaping plants produced by for-profit business and owner-occupied housing are not tracked. 3. Purchases of landscaping plants by government and nonprofits are implicitly included in current output. 4. Own-account landscaping plants produced by governments and nonprofits are implicitly included in current output. 5. CFC of landscaping plants owned by governments and nonprofits is not tracked.	1. Purchases of landscaping plants by for-profit business and owner-occupied housing are tracked as investment. 2. Own-account landscaping plants produced by for-profit businesses and owner-occupied housing are tracked as investment. 3. Purchases of landscaping plants by governments and nonprofits are tracked as investment. 4. Own-account landscaping plants produced by governments and nonprofits are tracked as investment. 5. CFC of landscaping plants owned by governments and nonprofits is tracked as part of current output.	Increases by value of private investment in landscaping **plus** CFC of government and nonprofit landscaping.

2. Nominal Statistics on Cultivated Assets

Investment in cultivated assets: data sources and estimates

Gross investment in long-lived food animals includes both animals that replace herd deaths and animals that increase the size of the herd. Reports published by the USDA provide the primary data sources. USDA's livestock inventory reports give annual counts for the following categories: dairy cows, dairy heifers set aside for breeding, beef cows, beef heifers set aside for breeding, bulls, sheep, goats, and honeybee hives. USDA's slaughter statistics give counts of federally inspected slaughters of dairy cows, beef cows, bulls, and sheep. This paper uses trade data from the International Trade Commission (ITC), USDA estimates of nonfederally inspected slaughters, and expert judgment to estimate annual slaughter of domestic dairy cows, domestic beef cows, domestic bulls, and sheep. In addition, USDA's death loss reports estimate nonslaughter deaths for cattle, sheep, and honeybee hives. The paper splits cattle deaths between dairy cows, beef cows, bulls, and other cattle in proportion to their population share. Mortality statistics for goats could not be located, so their slaughter and nonslaughter deaths are assumed to track sheep slaughter and nonslaughter deaths. This paper then calculates the number of new food animals with the formula:

$$\text{New Animals}_t = \text{Inventory}_{t+1} - \text{Inventory}_t + \text{Slaughter Deaths}_t + \text{Nonslaughter Deaths}_t$$

This simple count of animals is then multiplied by an estimated cost per animal to get gross investment in long-lived food animals. The data used to calculate cost per animal will be described in section 3.

Net investment in long-lived food animals is calculated by subtracting slaughter revenue from gross investment. Slaughter revenue is estimated by combining USDA estimates of total cattle slaughtered each year, counts of federally inspected slaughter cattle by category, price per pound for cows on a live basis, and average dressed weight[6] to estimate total slaughter revenue for all cows and bulls. Industry research suggests that slaughtered dairy cows and slaughtered beef cows sell for similar market prices (Brazle et al. 1988), so slaughter revenue for each cow category is assumed to be proportional to the number of cows slaughtered in each category. Data on slaughter revenue for mature sheep and goats was not available. For simplicity, this paper assumes that the ratio of slaughter revenue to replacement

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[6] Dressed weights refers to carcass weight after inedible parts are removed. USDA does not report average live weight for either cows or bulls specifically, so the overall ratio of live cattle weight to dressed cattle weight is used to adjust the dressed weight for cows and the dressed weight for bulls.

cost for sheep and goats is the same as the ratio of slaughter revenue to replacement cost for beef cows and bulls. Across all animal categories, the cost of a new food animal is much higher than the slaughter revenue from an old animal. Hence, net investment in long-lived food animals is almost always positive.

Investment in horses is calculated from an annual count of racehorse births provided by the Jockey Club's online factbook.[7] This paper multiplies the count of births with a cost per racehorse estimate that will be described in the next section to get domestic production of racehorses. The paper then subtracts exports of racehorses and adds imports of racehorses, which are reported by the ITC, to calculate domestic investment in thoroughbred racehorses. Historical farm horse and farm mule investment is estimated using Census of Agriculture statistics from 1925 to 1940, USDA estimates of annual horse and mule births from 1929 to 1940, and USDA estimates of the nominal value per animal. Recent farm horse and farm mule investment is estimated using a snapshot of the working horse population in 2017 (Ellie et al. 2019), a model of the equine population, and expert judgment.

Investment in fruit, nut, and landscaping trees[8] is calculated from Census of Agriculture data giving domestic sales of young trees and ITC data giving imports and exports of young trees. To be clear, young trees typically require careful planting, tending, and protection before they are old enough to provide fruit, shade, or other useful services. One recent industry study estimated that the total value of a working almond orchard in California is approximately seven times the cost of purchasing young trees (Duncan et al. 2019). This paper assumes that this ratio of total cost to the cost of purchasing young trees is fixed over time, across states, and across tree species. Hence, the paper calculates that total investment in fruit, nut, and landscaping trees is approximately seven times domestic purchases of young trees. Finally, this paper uses detailed species data from the USDA's Census of Horticultural Specialties and the ITC to split tree investment between fruit, nut and landscaping trees.

Investment in pastures is calculated from USDA acreage reports. For alfalfa pastures, annual statistics on new alfalfa acreage are multiplied by the cost per acre data from section 3 to get nominal investment. For grass pastures,[9] annual statistics on new grass acreage are estimated indirectly. First, this paper uses periodic Census of Agriculture land-use data and annual USDA data on hay acreage to estimate total grass pasture acreage each year. The paper then uses a population model to infer new

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[7] http://www.jockeyclub.com/Default.asp?section=Resources&area=11. The Jockey Club only tracks thoroughbred racehorses. For simplicity, the paper ignores the small categories of standardbred racehorses and show horses.

[8] This category includes vineyards, bushes, and other long-lived woody plants.

[9] Clover seeds are often planted together with grass seeds, and the resulting pasture starts as a mixture of the two species. Early version of the paper tracked grass and clover separately, but this paper combines them for simplicity.

grass acreage based on annual changes in the total grass pasture acreage. This population model cannot be validated directly, but it produces historical estimates of planted grass acreage, which match reasonably well with pre-1968 data on seed disappearance.[10] Just like alfalfa, this new acreage estimate is then multiplied by the cost per acre to get nominal investment in grass pastures.

Investment in lawns is first calculated for the benchmark year of 2004. For that year, the paper calculates nominal investment based on the reported cost to establish a new lawn (Barnes et al. 2006), snapshot data on aggregate lawn acreage (Milesi et al. 2005), and historical data on developed land growth (Bigelow and Borcher 2017). The paper then uses sod sales from the Census of Agriculture to extrapolate lawn investment for years where sod sales are reported.[11] For years without Census of Agriculture data on sod sales, the paper uses weighted investment in structures, lawnmower sales, and sod price data as proxies to calculate annual investment in lawns from 1929 to 2019.

Figure 1. Revision to Measured Investment as a Share of Nominal GDP

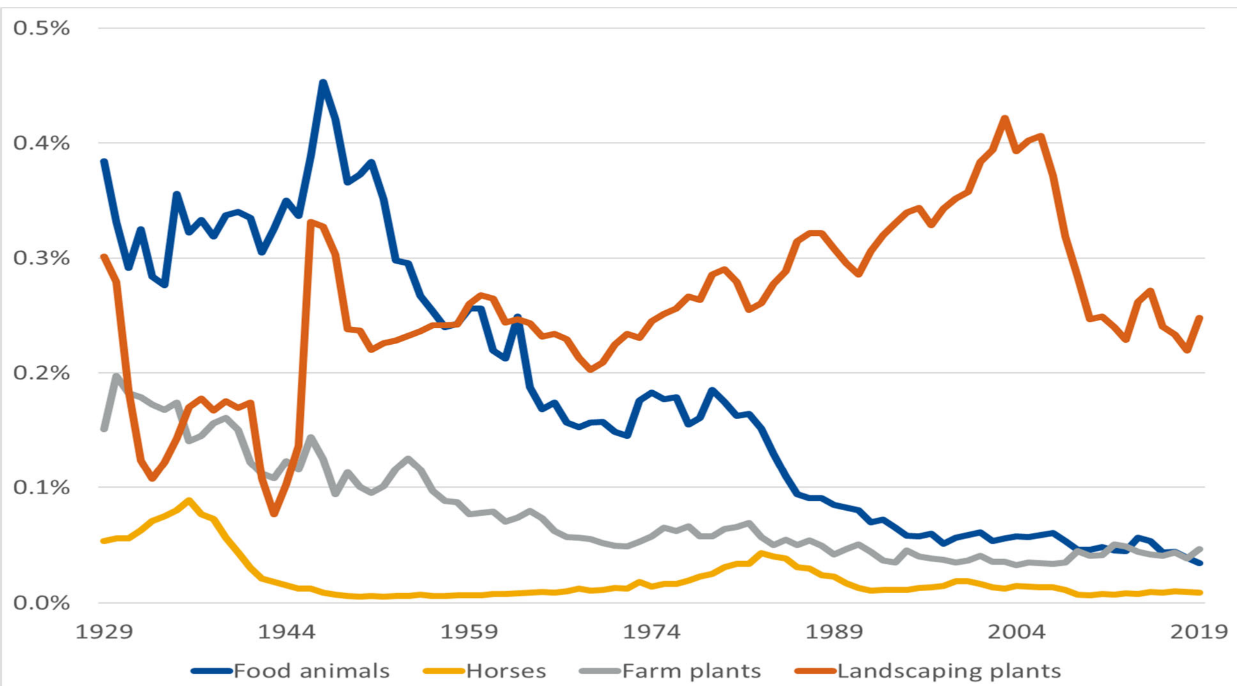


Figure 1 shows that the investment in cultivated farm assets has grown slower than overall GDP. The slow growth for food animals and farm plants is consistent with slow growth for the overall farm sector.

[10] Data on grass and clover seed disappearance is available after 1968, but it is no longer a good proxy for pasture investment because homeowners started using grass seed for lawn maintenance.

[11] Lawns are often grown from seed, and therefore reported sod sales are always lower than total lawn investment.

The end result is that the composition of cultivated assets has changed over time. In 1929, all four categories of cultivated assets contributed significantly to net investment. But in 2019, only landscaping plants contribute much to the measured investment.

Figure 1 also shows that the impact of capitalizing cultivated assets has been volatile over time. Most recently, landscaping investment grew rapidly in the early 2000s and then plummeted in the Great Recession. Hence, the housing bubble and bust becomes a little more dramatic when landscaping plants are capitalized. Further back, measured investment in the late 1940s increases sharply when livestock and landscaping are capitalized. These investments slightly offset the huge decrease in military spending after World War II, so the growth for that decade becomes a little smoother. Neither the 2000s revision nor the 1940s revision is large enough to change the overall business cycle. In the long-term, capitalizing cultivated assets reduces average nominal GDP growth before 1990 by 0.01 percentage point per year but does not change average nominal GDP growth after 1990. This downward revision to historical GDP growth very slightly ameliorates the recent economic slowdown.

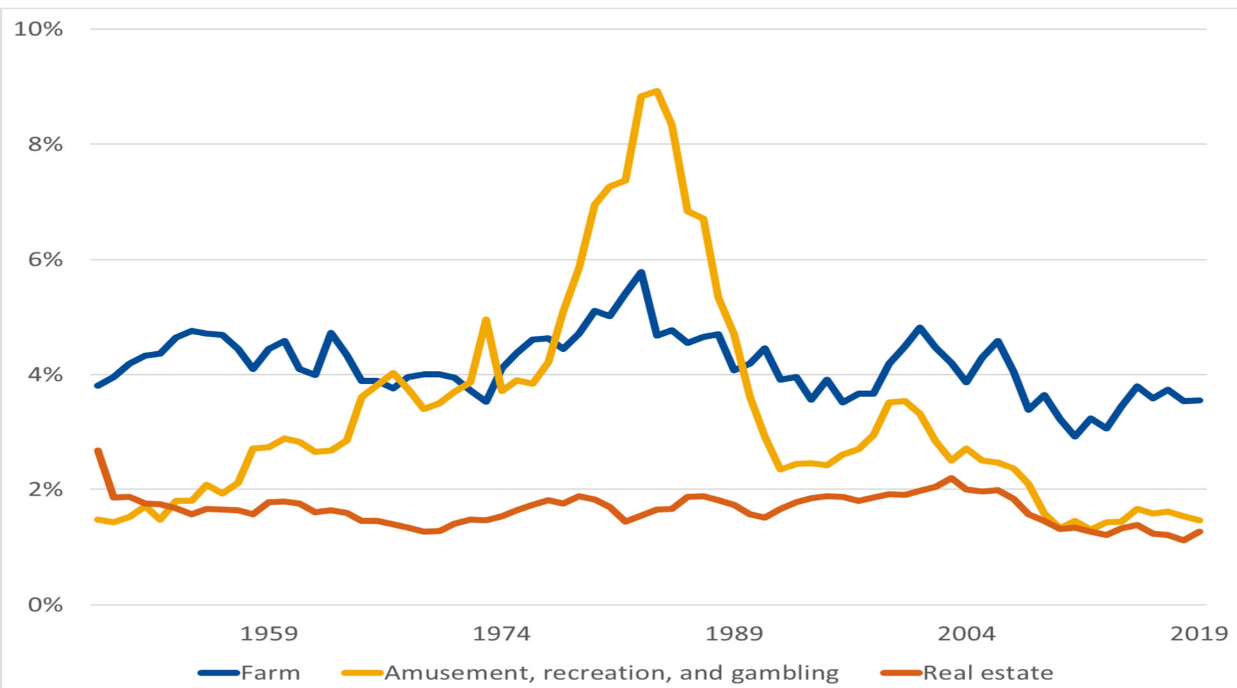
Investment by industry: data sources and estimates

The farm sector is assumed to own all food animals, farm horses, farm mules, alfalfa pastures, and grass pastures. The amusement, gambling, and recreation sector is assumed to own all racehorses. Fruit and nut trees can be planted in either farm orchards or home gardens, so they are split between the farm sector and the real estate sector. Before 2009, this paper uses USDA historical estimates of home food production and expert judgment to measure the share of fruit and nut trees that are owned by the real estate sector. After 2009, this paper assumes that the dramatic growth in fruit and nut tree sales reported in the 2014 and 2019 Censuses of Horticultural Specialties is due to a growing usage of fruit and nut trees in home gardens.

Landscaping trees are owned by every sector. This paper uses class of customer data from the 2012 Economic Census for nursery wholesalers (NAICS 424930) and nursery retailers (NAICS 444220) to split young tree purchases between construction companies, governments, private businesses for planting, and households. Trees purchased by construction companies are then allocated between industries and government in proportion to nominal investment in structures. Trees purchased by private businesses for planting are allocated across industries in proportion to nominal investment in nonresidential structures and trees purchased by government are allocated across government divisions in proportion to investment in highways, amusement, and education structures.[12] Finally, trees purchased by households are assumed to be used for residential landscaping. Before and after the benchmark year of 2012, BEA's pre-existing estimates of structures investment are used to extrapolate annual splits.

Like landscaping trees, landscaping lawns are owned by every sector. A Virginia survey (Barnes et al. 2006) splits the stock of lawns between ten usage categories: golf courses, buildings, churches, cemeteries, highway roadsides, airports, parks, public schools, private schools, and single-family lawns. Golf course landscaping is assumed to be owned by the amusement, gambling, and recreation sector. Similarly, single family lawns are assumed to be owned by the real estate sector. This paper then uses a Maryland survey giving further detail on lawns by building type (Bennet and McCarthy-Kersey 2006) and BEA's pre-existing estimates of structures investment to split the remaining eight categories between the many industries that own landscaping. Before and after the benchmark year of 2001, BEA's pre-existing estimates of structures investment by category are used to extrapolate annual splits.

Figure 2. Revision to Industry Investment as a Share of Industry Gross Output



[12] Private structures investment is from table 3.7 https://apps.bea.gov/iTable/iTable.cfm?ReqID=10&step=2 and government structures investment is from table 7.5 https://apps.bea.gov/iTable/iTable.cfm?ReqID=10&step=2.

Figure 2 shows how each industry is impacted by cultivated assets. Since the industry accounts start in 1948, the cultivated asset share for farms has hovered around 4 percent. Similarly, the cultivated asset share for real estate has hovered around 1 percent except for a slight downward trend after the housing bubble burst. As a result, long-term growth rates for those two industries do not change much when cultivated assets are capitalized. In contrast, the amusement, gambling, and recreation industry shows a spike in the 1980s due to a bubble in racehorse investment. However, readers should note that amusement, gambling, and recreation sector is very small and therefore the bubble shown in Figure 2 has minimal impact on aggregate GDP. In contrast, the real estate sector is larger and the small revisions to its output shown in Figure 2 has a noticeable impact on aggregate GDP.

3. Prices and Real Investment for Cultivated Assets

The capital price indexes calculated in this section are sometimes volatile. These volatile prices are based on auction prices and other arms-length transaction prices that are tracked by the USDA and other organizations, so they should not be dismissed as simply noise. Instead, agricultural commodity prices are genuinely volatile and have been volatile for centuries (Jacks et al. 2011). Food animals are currently tracked in livestock inventories, and so a portion of their price volatility is already included in the NIPAs. Nevertheless, later figures will show that capitalizing cultivated assets sometimes changes short-term GDP price growth noticeably. This paper will accept these volatile results without smoothing, but the discussion focuses on long-term trends rather than short-term volatility.

Unadjusted prices per unit of capital: data sources and estimates

Long-lived food animal prices are taken from USDA statistics. Dairy cow prices are taken from the USDA price index for replacement milk heifers. Beef cow prices are benchmarked to a recent paper studying bred heifer prices between 2010 and 2018 (Smith et al. 2021) and then extrapolated forwards and backwards based on estimated cost for feeder heifer calves. This extrapolator is consistent with a theoretical paper arguing that young animals used for breeding are similar to young animals used for meat (Rosen et al. 1994). Bull prices are benchmarked to a recent survey on bull costs (Beef Magazine 2020) and extrapolated using beef cow prices.[13] Sheep and goat prices are taken from the USDA's

[13] One bull can naturally inseminate fifteen to twenty five beef cows per year, and artificially inseminate a much larger number of cows per year. As a result, bulls are a small investment category despite their higher unit price.

annual estimates of value per head. Finally, honeybee prices are benchmarked to reported values in the 1940 Census of Agriculture and then extrapolated forward and backward using packaged hive prices (USDA Honey Report; Rucker and Thurman 2012; Rucker et al. 2019)[14] and honey prices.

Horse prices are taken from the Jockey Club's time series of mean auction prices for thoroughbred yearlings, which is available from 1981 onwards. Mean prices from the Keeneland yearling auctions[15] are used to extrapolate racehorse prices from 1944 to 1980 and the total prize money offered at the Belmont stakes is used to extrapolate racehorse prices before 1944. This paper also includes farm horses and farm mules in its historical price index. Prices for those animal categories are based on a USDA price series that goes until 1960 (Department of Commerce 1975) and then extrapolated forward using estimated inventory values in the Census of Agriculture and pasture price indexes.

Landscaping lawn prices are based on sod prices reported in the Census of Horticultural Specialties. That survey gives prices per acre of sod sold for the years 1998, 2009, 2014, and 2019. A survey of Georgia sod producers is used to interpolate prices between those years. Before 1998, this paper uses Census of Agriculture data on revenue per acre of land in sod nurseries, BEA's pre-existing price index for "flowers, seeds, and potted plants," and farm pasture prices as extrapolators.

Fruit, nut, and landscaping tree prices are based on revenue and output data reported in the Census of Horticultural Specialties. This paper calculates unit prices for fruit and nut tree by simply dividing nominal revenue with a count of young trees. Similarly, this paper calculates unit prices for landscaping trees by simply dividing the nominal revenue with a count of young trees.[16] Between years with data, nursery revenue per acre and landscaping lawn prices are used as proxies to interpolate prices.

Pasture prices are based on cost estimates published by Iowa State University (Duffy 2000–2014; Plastina 2015–2020). Those cost estimates give annual estimates of planting cost per acre for alfalfa pastures and periodic estimates of planting cost per acre for grass pastures. For years when grass

[14] Bee packages require weeks of care before they can work, so they are much less valuable than mature hives.

[15] Keeneland conducts two separate auctions for yearlings. Higher quality animals are sold at the July sale and other animals are sold in September. This paper combines both auctions to get an average price per animal.

[16] Fruit and nut tree prices include grapevines because they are also long-lived woody plants – but do not include berry plant prices because that category includes short-lived strawberry plants. Landscaping tree prices include ornamental bushes but do not include other landscaping species because those species are not tracked consistently.

pasture prices are not available, alfalfa pasture prices are used as an interpolator. Before 2000, input costs and estimated hay revenue are used as proxies to extrapolate prices.

Quality-adjusted prices: data sources and estimates

The unadjusted prices calculated in the earlier section are not suitable for usage in the national accounts. One major issue is that measured prices per unit are very sensitive to the exact quantity measure tracked. For example, tree prices on a per acre basis do not always match tree prices on a per plant basis. Accordingly, this paper will not report the unadjusted price indexes in the main body of the paper or use the unadjusted price indexes to calculate overall GDP prices or other aggregate statistics. But appendix B contains unadjusted prices by subcategory for interested readers.

This paper assumes that quality-adjusted capital stock is linear with real output. It may be true that economic theory recommends measuring the quality-adjusted capital stock by comparing market prices for similar items with slightly different product attributes. However, the detailed microdata necessary to implement this method consistently across the nine decades studied in this paper could not be located. Instead, this paper assumes a Leontief production function where real cultivated asset services, real labor inputs, and real intermediate inputs all grow proportionally. By design, this simple production function allows the quality-adjusted capital stock to be estimated from aggregate output.

For food animals, real output per unit is calculated from annual statistics published by the USDA. For dairy cows milk output is taken directly from the USDA's annual milk report. Between 1929 and 2019, milk output per cow and assumed dairy cow quality more than quadrupled.[17] For beef cows, this paper multiplies the total calf crop with the average slaughter weight for steers at federally inspected slaughterhouses to calculate a measure of potential meat output.[18] Between 1929 and 2019, potential meat output per cow and assumed beef cow quality almost doubled. This paper uses similar potential meat output data to calculate quality for sheep and goats.[19] Bulls are used in both milk production and meat production, so their quality is calculated as a weighted average of dairy cow quality and beef cow

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[17] This rapid quality growth only applies if slaughtered animals are negative investment, and so their scrap value is not part of food animal output. Figure A.2 of appendix A calculates prices if slaughtered animals are CFC.

[18] Dairy cows also contribute to the calf crop, and so the ratio of calves to cows may not track beef cow fertility. Many calves are used for breeding or slaughtered for veal, so the potential meat output exceeds meat production.

[19] Historically, the wool produced by sheep and goats was an important source of clothing. But modern American sheep and goats are raised primarily for meat and the wool is a secondary product.

quality. Data on the pollination services provided by honeybees could not be located, so this paper assumes that their quality has been steady.

Horse quality is determined by the population share for each equine type. Thoroughbred racehorses require much more care and training than ordinary farm horses. Hence, the average quality of the horse population rises when thoroughbreds account for a larger share of the population. In addition, farm mules are also slightly harder to breed than farm horses, and so the replacement of a farm horse with a farm mule raises average equine quality slightly.

Farm plant quality is calculated from annual statistics published by the USDA. Quality for alfalfa pastures is taken directly from the USDA's series tracking hay yields per acre of alfalfa pasture, and quality for grass pastures is taken directly from the USDA's series tracking hay yields per acre of non-alfalfa pasture.[20] Fruit and nut tree quality is measured similarly, but it requires more calculations. This paper first calculates real farm orchard output based on the nominal revenue reported in the USDA's *Fruit and Nut Yearbook* and the USDA's price indexes for fruit and tree nuts.[21] The paper then estimates the number of trees in farm orchards using the nominal investment numbers shown in figure 1, the estimated share of fruit and nut trees in the farm sector, per unit costs calculated in the earlier section, and lifespan estimates from figure 7 and figure 8 of a government report (Gideon 1990). Fruit and nut tree quality is assumed to equal real fruit and nut revenue per working farm orchard plant.

Landscaping tree quality is partially determined by the population share for each species. The paper uses relative price data from the Horticultural Census to calculate quality for each tree species. Aggregate landscaping tree quality is then calculated using a chained index with the basket reset each Horticultural Census and trimmed of outliers. The paper also assumes that the steady efforts of entrepreneurs and hobbyists have increased quality for each landscaping species by an average of 0.5 percent per year from 1929 to 2019 due to the steady efforts of entrepreneurs. For example, the Dutch development of rare tulip varieties created one of the first known bubbles in economic history (Mackay 1841) and the development of new rose varieties was once a popular activity (Moser and Rhodes 2012).

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[20] This category includes wild grass, grain fields, and other plants which can be harvested for hay. In practice, grass pastures account for the large majority of non-alfalfa hay production in recent years—so grass pasture yields have tracked overall non-alfalfa hay yields. Historical yield data is adjusted to focus on grass pastures only.

[21] https://quickstats.nass.usda.gov/ provides three price indexes for fruit and tree nuts, each of which is calibrated to a different time period. This paper combines the price indexes: "index for price received, 2011", "index for price received, 1990-1992", and "index for price received, 1910-1914" to get prices from 1909 to 2019.

Figure 3. Quality-Adjusted Prices, Relative to Overall GDP Prices

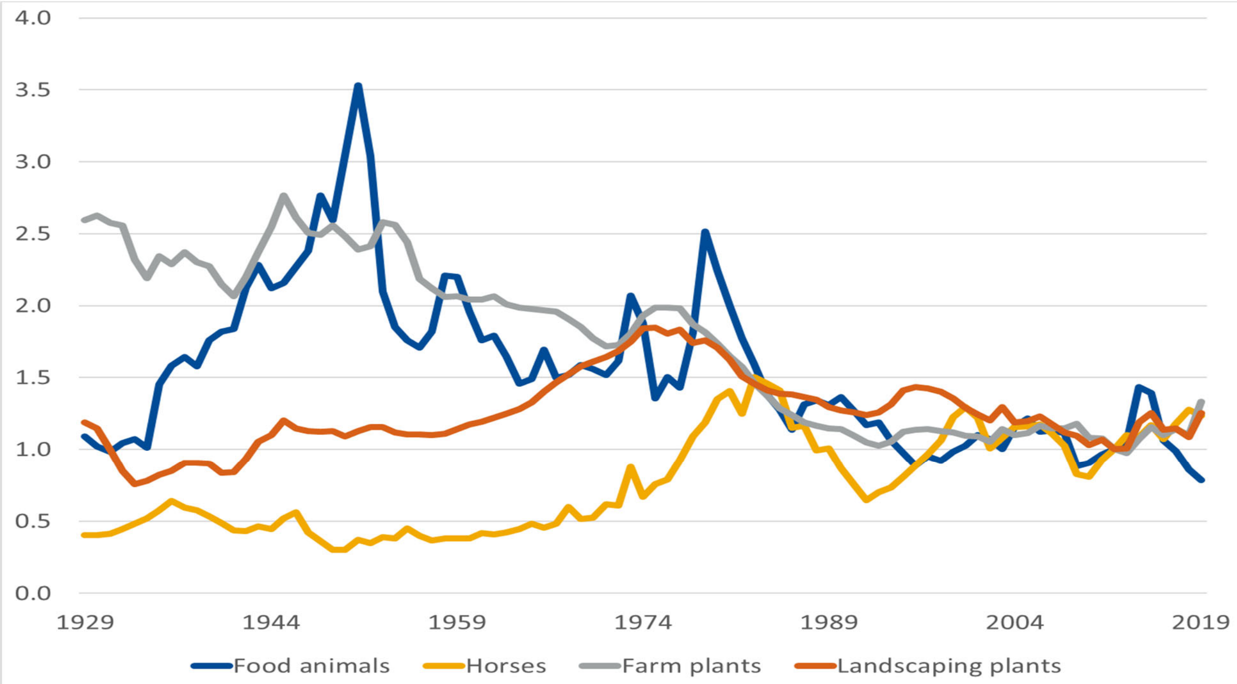


Figure 3 shows that prices for cultivated assets mostly track overall GDP prices after 1990. In addition, the earlier deviations from overall GDP prices are not consistent across categories or over time. As a result, capitalizing cultivated assets has little impact on average price growth from 1929 to 2019. Figure 1 showed earlier that capitalizing cultivated assets modestly lowered nominal GDP growth before 1990 but had little impact on recent nominal GDP growth. The graphs below show the same result for GDP quantity growth before 1990 and recent GDP quantity growth.

Capitalizing long-lived plants also has implications for measured land price growth. The official guidelines for national accounting and the integrated BEA/BLS industry-level production account currently assume that land is a natural resource whose real value is fixed over time (United Nations Statistics Division 2008, sec. 10.166–10.185). As a result, any increase to its nominal value is entirely attributed to price growth. Figure 1 of this paper shows that some of the nominal value increase observed for land should instead be attributed to new investment in cultivated plants, which are bundled with land. Focusing on the real estate sector, this paper calculates that land price growth falls by 0.1 percentage point per year when landscaping is tracked. Land is not a produced asset, so this revision to prices has no effect on measured GDP or other core components of the national accounts.

Figure 4. Revision to GDP Prices, Relative to Overall GDP Prices

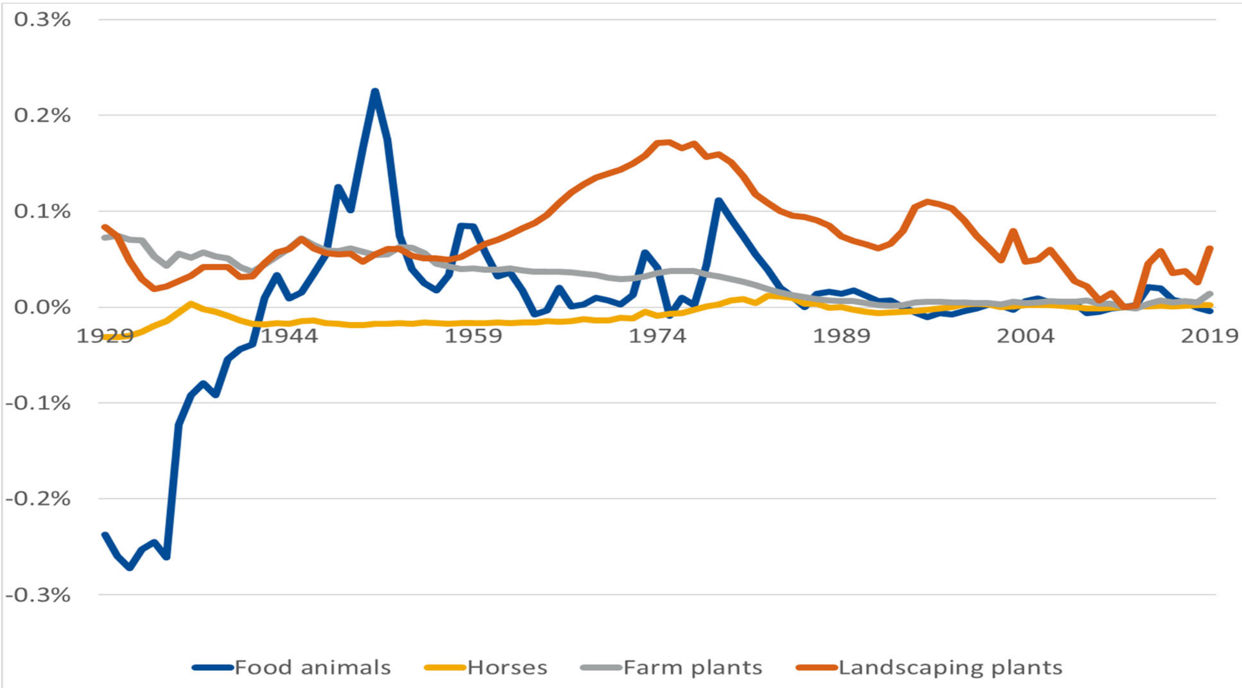
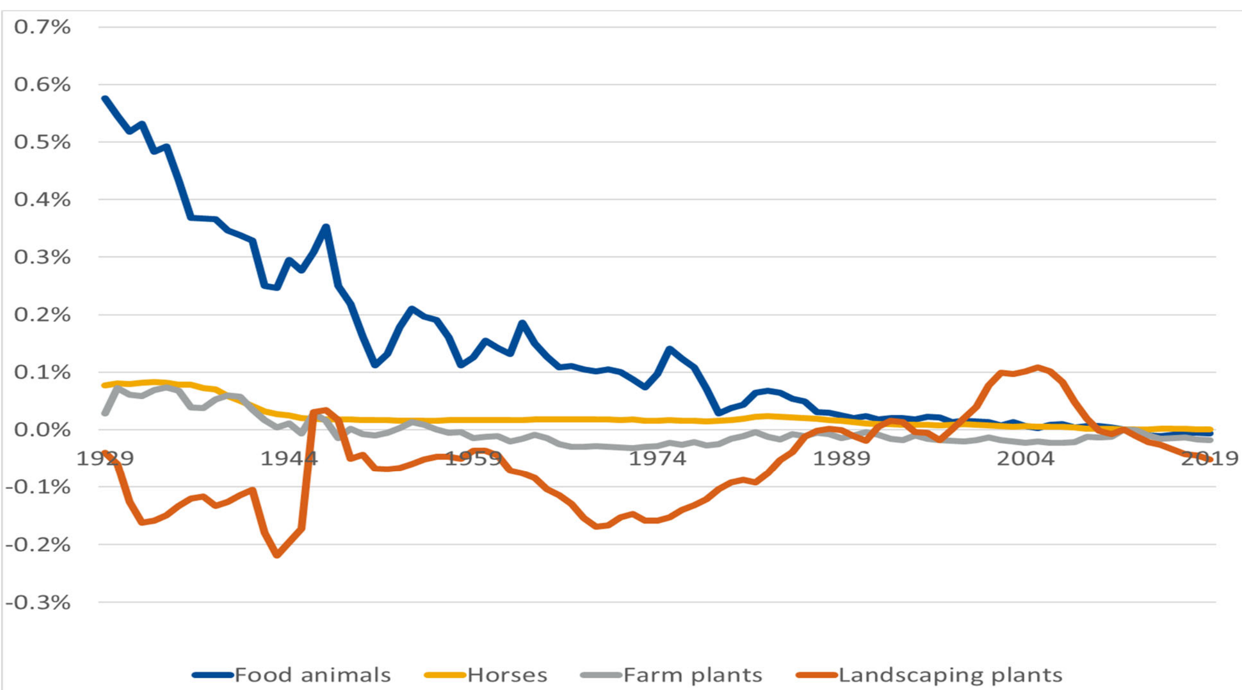


Figure 5. Revision to GDP Quantities, Relative to Overall GDP Quantities



4. Depreciation Rates, Capital Stock, Consumption of Fixed Capital (CFC), and Net Savings

Depreciation rates: data sources and estimates

This paper assumes a fixed geometric rate for each subcategory studied. To be clear, this assumption is a simplification. A literature review found many papers that estimated non-geometric depreciation schedules for certain cultivated assets, and one historic study even found that dairy cows and farm work horses experienced real value increases early in their service life (McDowell 1916).[22] Similarly, some USDA data suggests that depreciation rates may have changed over the past century. For example, dairy cow slaughter rates rose from 12 percent of the population in 1929 to 23 percent of the population in 2019. However, BEA's standard practice is to assume a fixed geometric rate for each asset (Katz 2015). That fixed geometric rate covers physical wear, obsolescence, and other contributors to the CFC. This paper follows that standard practice.

Food animal depreciation rates are calculated from slaughter and nonslaughter deaths for the period 2005 to 2019. Slaughter deaths generally occur after a negative health shock like infertility and are considered depreciation equal to the difference in market value between an animal sold for slaughter and a replacement animal. Nonslaughter deaths are considered depreciation equal to the full cost of a replacement animal. Based on those assumptions, this paper calculates that dairy cows depreciate at 11 percent per year, beef cows depreciate at 5 percent per year, bulls depreciate at 16 percent per year, sheep and goats depreciate at 10 percent per year, and honeybees depreciate at 53 percent per year.

Horse depreciation rates are based on USDA research estimating farm horse values by age (McDowell 1916). Reliable data on racehorse values by age could not be located, so this paper assumes that racehorses depreciate at the same rate as farm horses.[23] Data on farm mule values also could not be located, but the industry literature suggests that mules live slightly longer than horses (Leste-Lassere 2018). Combining all equine categories, this paper calculates depreciation of 5 percent per year.

Farm plant depreciation rates are taken from pre-existing research. For fruit and nut trees, the primary source is a Treasury report that gives depreciation schedules for many different species (Gideon 1990).

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[22] This early value increase is treated as negative depreciation, which is canceled out by positive depreciation later. Both measured investment and measured CFC would be unambiguously higher if it was treated as new investment.

[23] It may be true that most races are won by young horses, but successful racers produce valuable foals for decades.

This paper simplifies by aggregating and smoothing depreciation across all species and all ages. For alfalfa pastures, depreciation rates are based on USDA estimates of the alfalfa acreage leaving service each year.[24] For grass pastures, depreciation rates are based on an academic lifespan estimate (Barnhart and Duffy 2012). This paper calculates that fruit and nut trees depreciate at 5 percent per year, alfalfa pastures depreciate at 15 percent per year, and grass pastures depreciate at 10 percent per year.

Landscaping tree depreciation is calculated from pre-existing research. One study calculated an annual mortality rate of 4.2 percent per year for urban trees in Baltimore (Nowak et al. 2004). Another study estimated a value of $261 per mature tree in the Chicago area (Morton Arboretum 2020), approximately 50 percent higher than the $171 cost of establishing a new tree. This value increase for surviving trees is consistent with the higher value for large trees seen in the appraisal literature (Purcell and Ling 2019). Combining these two studies, this paper calculates that a cohort of young trees depreciates at 1 percent per year as some trees die and the surviving trees grow.

Finally, landscaping lawn depreciation is calculated based on a study that found that almost no lawns exited the population from 1998 to 2004 (Barnes et al. 2006). To be clear, individual patches of a lawn often die due to pet urine, insects, or other external factors. But reseeding small bare patches is considered maintenance rather than new investment (Bennet and McCarthy-Kersey 2006). As a result, a properly maintained lawn can survive almost indefinitely. For now, this paper assumes that lawns depreciate at 1 percent per year.

Estimates of capital stock, CFC, and net saving

This section calculates capital stock by combining the nominal investment numbers shown in figure 1 with the price indexes shown in figure 3 and the depreciation rates estimated in the previous section. The capital stock numbers shown in figure 6 are then multiplied by depreciation rates to get CFC in figure 7. Finally, net savings in figure 8 are calculated as the difference between the investment numbers shown in figure 1 and the CFC numbers shown in figure 7. To review national accounting rules, measured output for the private business sector does not depend directly on either measured CFC or measured savings. Accordingly, the increase to CFC shown in figure 7 and the increase to net savings shown in figure 8 have only a limited impact on the headline GDP statistics.

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[24] USDA does not report alfalfa acreage leaving service directly, but it can be readily calculated by simply comparing total alfalfa acreage in the current year with past year alfalfa acreage and newly planted acreage.

Figure 6. Revision to Measured Capital Stock as a Share of Nominal Fixed Assets

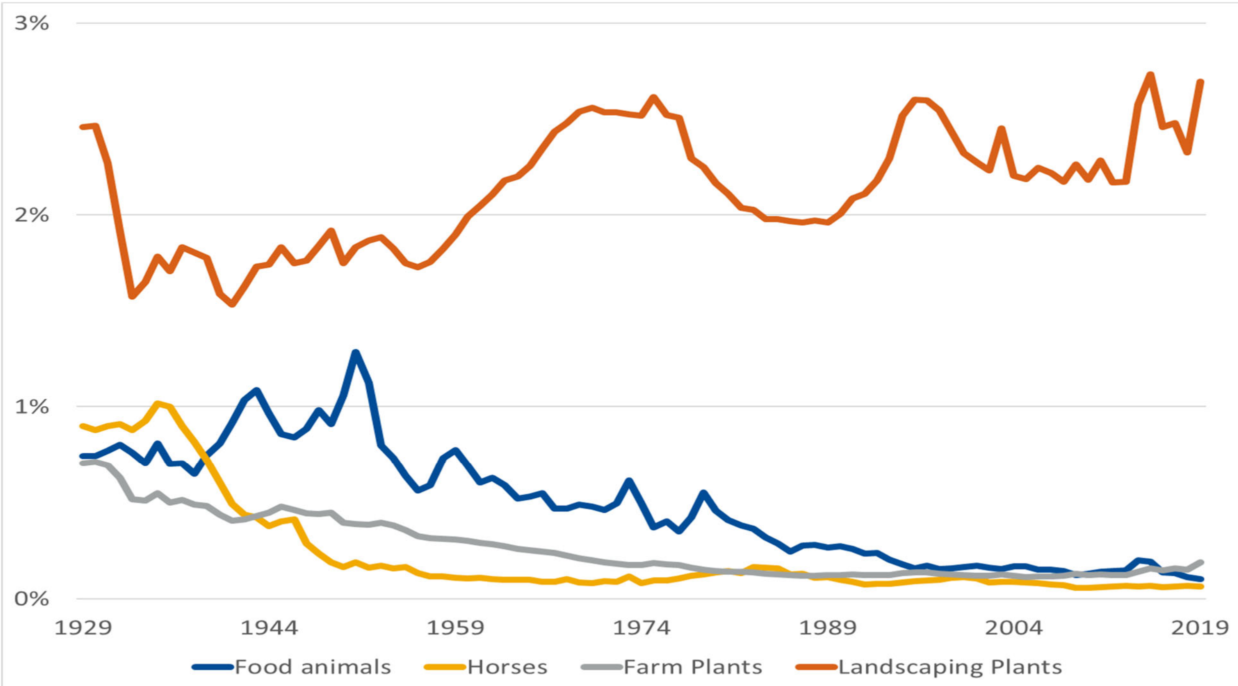


Figure 7. Revision to Measured CFC as a Share of Nominal GDP

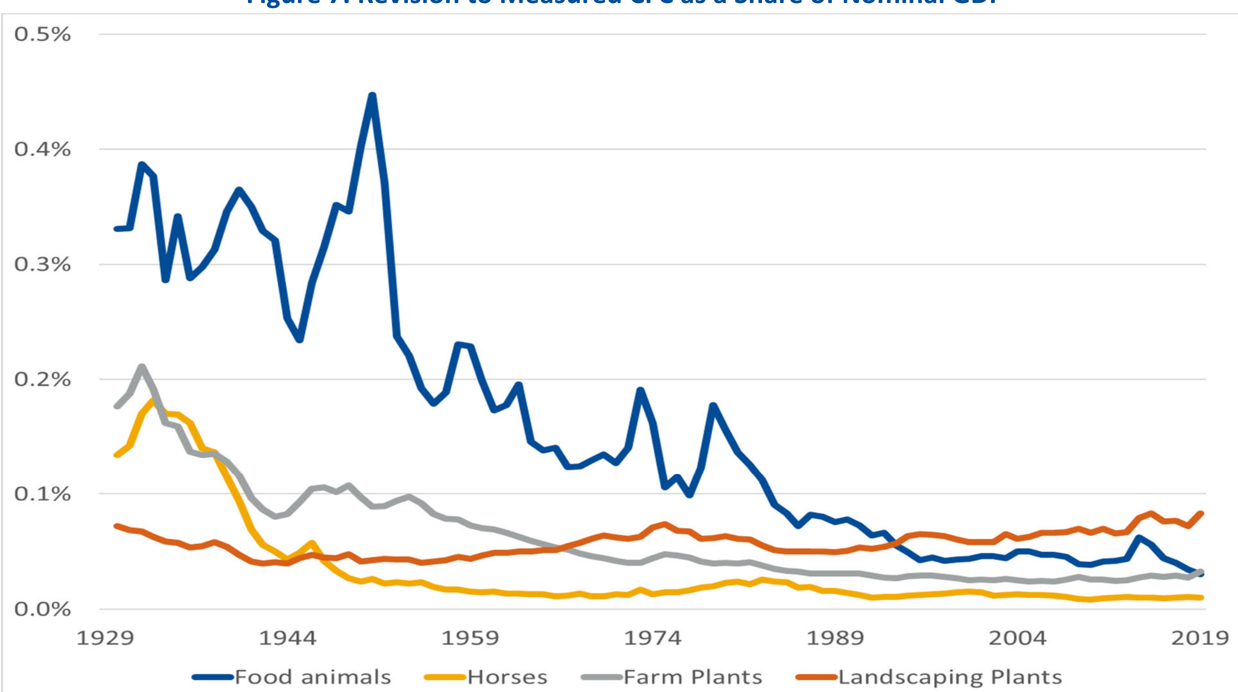
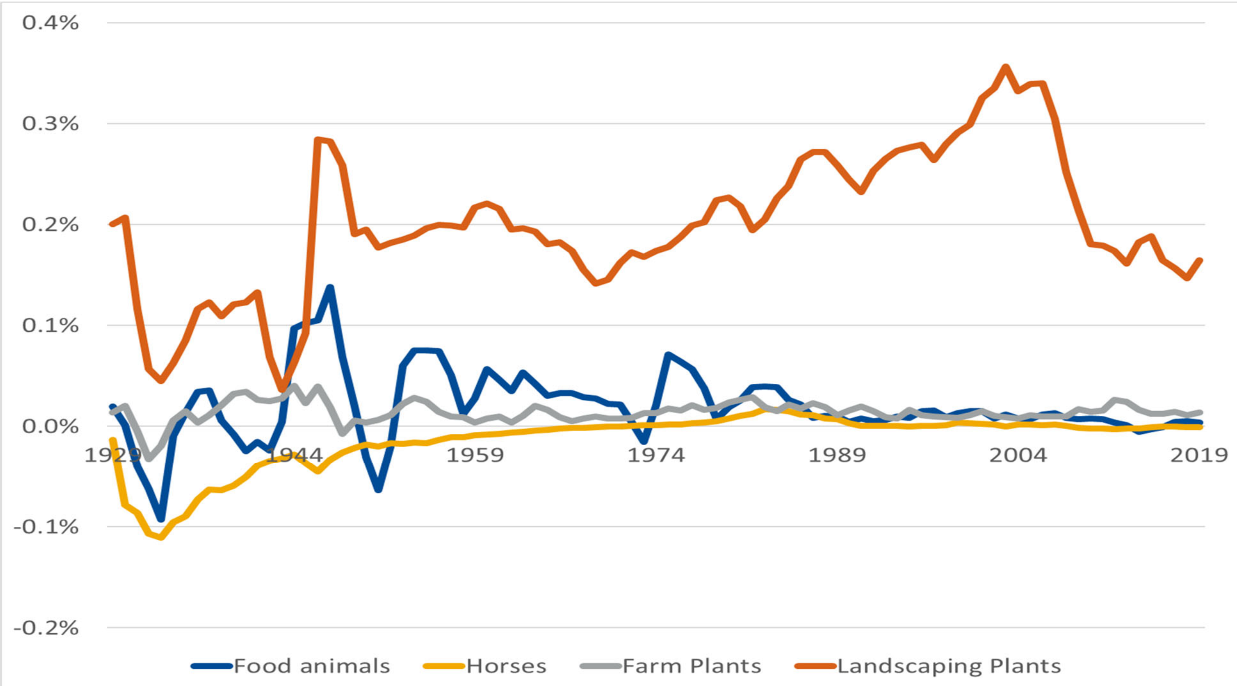


Figure 8. Revision to Measured Savings as a Share of Nominal GDP



5. Total Factor Productivity (TFP)

The productivity calculations in this paper are based on existing industry-level production accounts that track labor, capital services, and intermediate inputs for 61 separate private business sector industries (Garner et al. 2020). Capitalizing cultivated assets requires four separate changes to the production accounts. First, measured output increases by the newly tracked value of own-account cultivated assets. Second, measured intermediate inputs decreases by the newly tracked value of purchased cultivated assets. Third, capital services increases by the newly tracked services associated with cultivated assets. Finally, capital services from livestock inventory and land are revised in response to the new nominal values and price trends caused by tracking cultivated assets. This paper uses the data in appendix B, a theoretical formula, and expert judgment to recalculate measured output, measured capital services inputs, and TFP for each of the 61 private sector industries tracked. Private sector TFP is then calculated as the Domar-weighted sum of each individual industry TFP.

Capitalizing cultivated assets has a much smaller impact on predicted capital services than it does to measured capital stock. In the United States, long-lived plants are almost always tracked together with the underlying land. Similarly, most food animals are already tracked in livestock inventories. In order to avoid double-counting, this paper removes the capital value of cultivated assets from measured land values and measured inventories values.[25] Total measured wealth stock only rises by the previously untracked value of horses ($42 billion in 2019) and honeybees ($1 billion in 2019). On the one hand, the nominal value of land and livestock inventories are always lower when cultivated assets are tracked separately. On the other hand, calculated price growth for land falls – which raises the predicted capital services from each dollar of land. The net impact to predicted capital services is theoretically ambiguous and depends on the parameters assumed.

Figure 9. Revision to Aggregate TFP Index, as a Share of Original Private Sector TFP Index

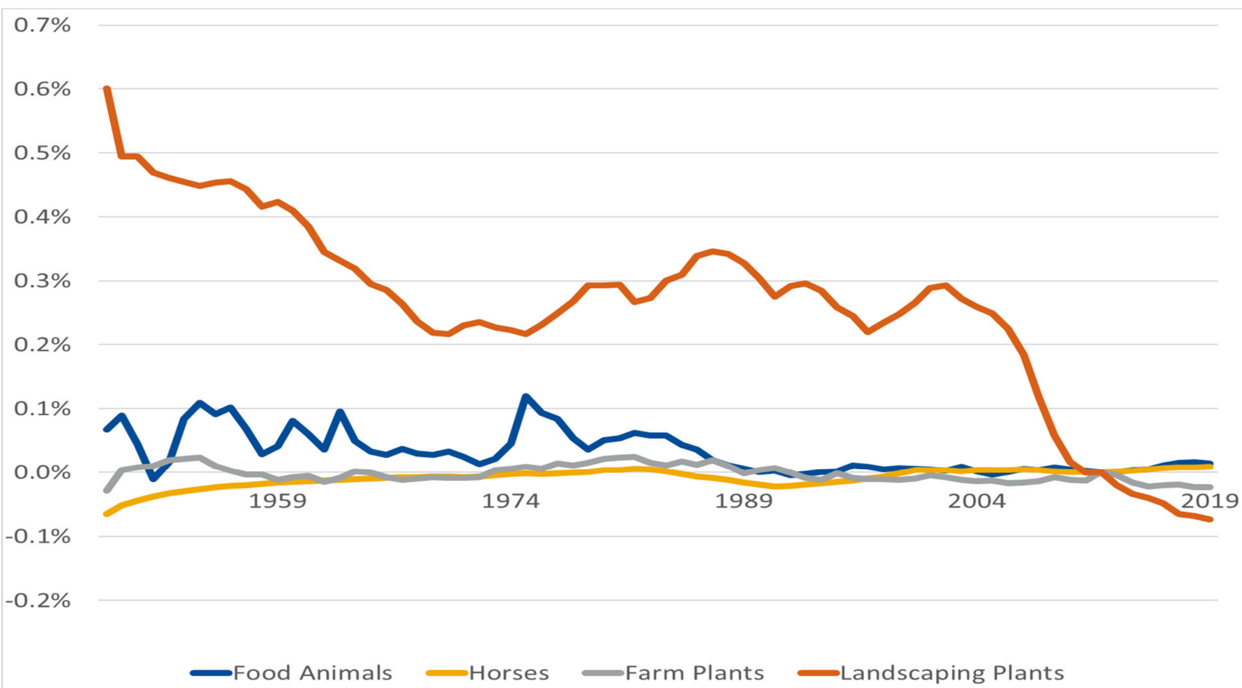


Figure 9 shows that capitalizing food animals, horses, and farm plants has little impact on measured productivity growth. Intuitively, the newly recognized capital services for these categories track the

[25] The calculated value of long-lived food animals increases by $8 billion in 2019 due to the usage of measurement techniques when they are tracked as capital rather than inventory. This result is sensitive to the parameters assumed.

newly recognized investment so that measured industry output and measured industry inputs both go up by the same amount. This null result is robust to minor changes in the formula used to calculate TFP.

In contrast, figure 9 shows that capitalizing landscaping plants lowers long-term productivity growth substantially. This decrease occurs despite the minimal change to GDP quantities shown in figure 5. Rather, productivity growth falls because tracking landscaping plants raises measured input growth for the real estate sector without changing measured output growth. Intuitively, the real stock of landscaping plants has grown faster than other real estate sector inputs like labor, structures or land. As a result, measured capital services for the real estate sector grow noticeably faster when landscaping plants are tracked. The qualitative result in figure 9 is relatively robust, but the size of the productivity decline is quite sensitive to the assumed rate of return on real estate capital.

Conclusion

The System of National Accounts *2008* (United Nations Statistics Division 2008, sec. 10.88-95) recommends that cultivated assets should be tracked as capital in the national accounts. This recommendation has been widely accepted and most European Union countries currently track some cultivated assets in their measures of capital (Jager 2017). In addition, the U.S. agricultural productivity accounts have also considered tracking cows in their measures of capital (Ball and Harper 1990). However, this recommendation is not currently implemented in either the U.S. National Economic Accounts (Bureau of Economic Analysis 2019) or the U.S. agricultural productivity accounts (Shumway et al. 2015) because of challenges inherent in identifying reliable source data and different conceptual traditions.

This preliminary paper explores how tracking food animals, horses, farm plants, and landscaping plants might affect the U.S. National Economic Accounts and the integrated BEA/BLS industry-level production account. The paper found that real GDP growth before 1990 decreases slightly when cultivated farm assets are capitalized, the 2000s housing bubble and bust appears slightly more dramatic when landscaping is capitalized, and measured productivity growth falls noticeably when landscaping plants are included as capital in the industry-level production account. More conceptual and practical work is needed before those cultivated asset categories could be fully integrated into either the agricultural statistics, the national accounts, or the industry-level production account.

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Appendix A: Food Animal Statistics When Slaughtered Animals Are Tracked as Consumption of Fixed Capital (CFC)

Figure A.1. Cattle Investment as a Share of Nominal Gross Domestic Product (GDP), Alternative Method vs. System of National Accounts (SNA) Method

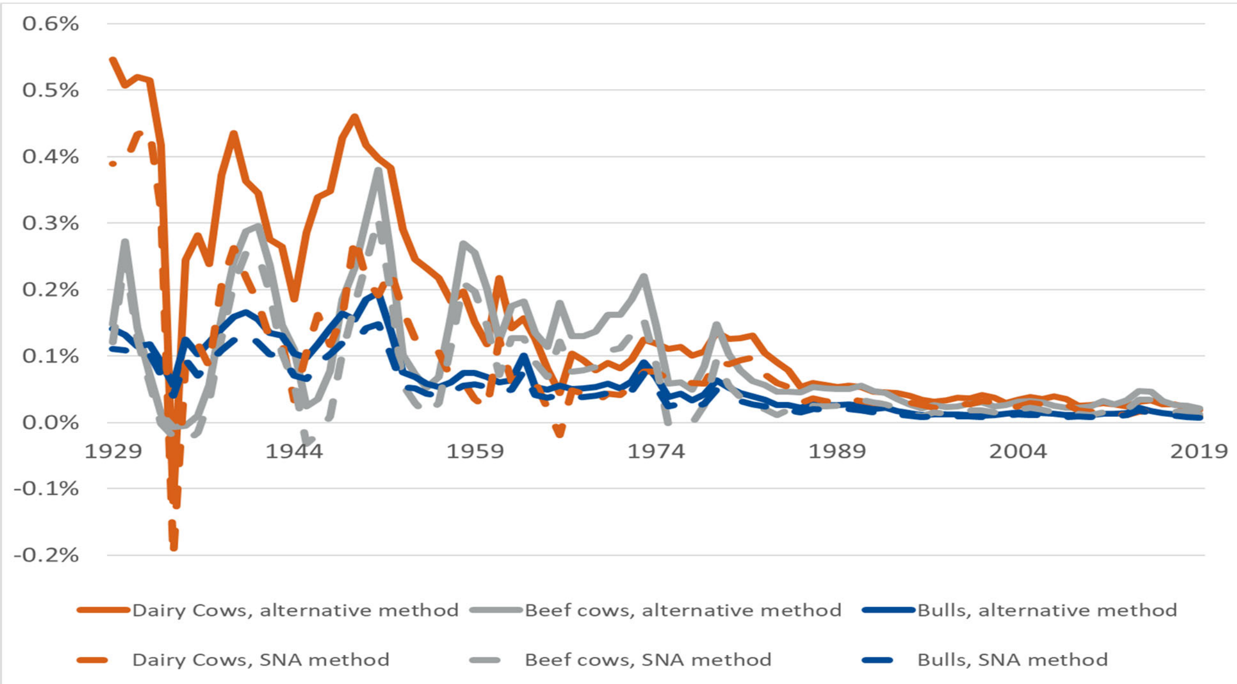

Figure A.1 shows that measured investment is always higher when slaughter is treated as CFC. On a percentage basis, measured investment is slightly less volatile when slaughter is treated as CFC. But this lower volatility is canceled out by the larger absolute values so that both treatments produce similar revisions to short-term GDP growth. National accountants who are interested in simplifying their calculations may choose to treat slaughter as CFC without any major short-term distortions.

Figure A.2 Cattle Prices Relative to Overall GDP Prices, Alternative Method vs. SNA Method

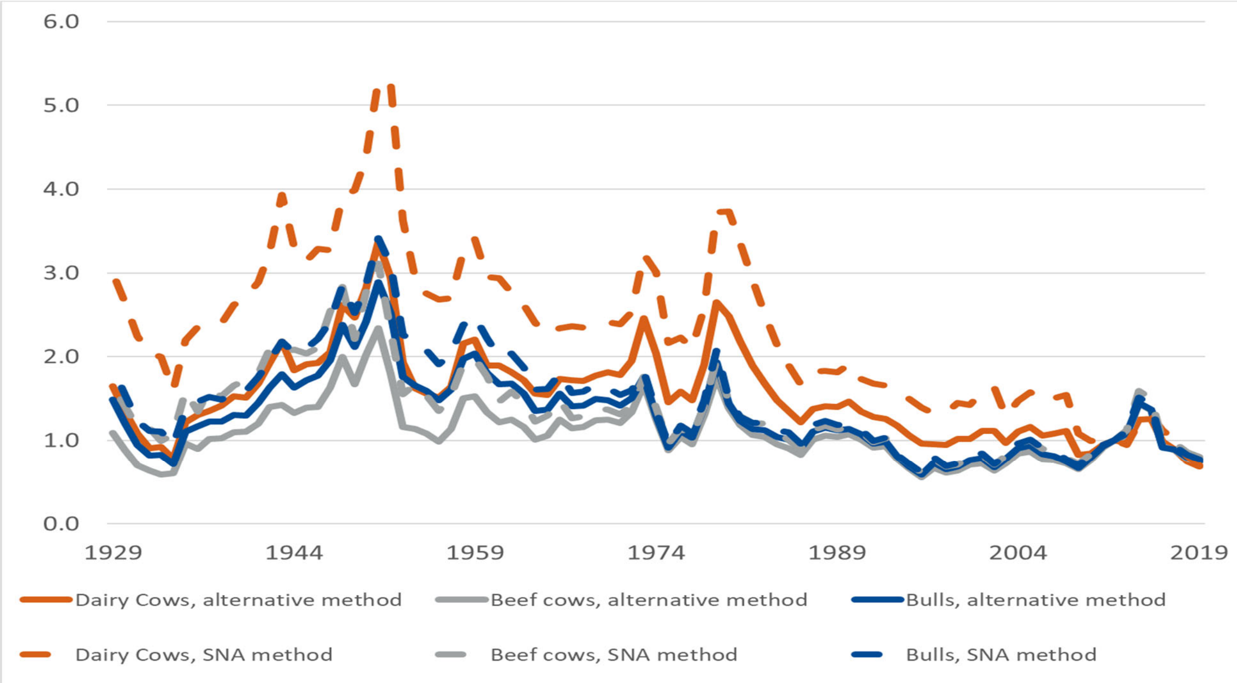

Figure A.2 shows that quality-adjusted prices for dairy cows are quite sensitive to the treatment of slaughtered cows but quality-adjusted prices for beef cows and bulls are not similarly sensitive. These different results can be explained by the divergence in quality growth for these two animal categories. Over the past century, milk output per cow has more than quadrupled but calf output per cow has only grown 23 percent. As a result, quality-adjusted prices for dairy cows have grown much slower than quality-adjusted prices for beef cows. Accordingly, combining previously estimated cow costs with an index for slaughter prices has a large impact on dairy cow prices but little impact on beef cow prices.

In the long-term, overall GDP prices move similarly when slaughtered cows are treated as CFC and when slaughtered cows are treated as negative investment. However, the two treatments sometimes produce very different impacts on short-term price growth. These differences can be attributed to the volatile prices for agricultural commodities that were previously discussed in figure 3.