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IZA DP No. 17157

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ABSTRACT

Constructing BEA Highways and Streets Net Wealth Stocks with Detailed Types of Investment and Engineering-Based Estimates of Depreciation

This paper builds on a previous paper by the authors (Kornfeld and Fraumeni, 2022) that primarily used U.S. Federal Highway Administration Highway Statistics data to disaggregate investment in highways and streets into more detailed types to produce updated estimates of net wealth stocks and depreciation. Major components of highways and streets other than pavement: grading, bridges and other structures, traffic management, safety, and environmental, are set equal to comprehensive revision updated versions of those derived in the earlier paper. All capital outlays are controlled to current BEA estimates. The engineering-based depreciation patterns are very dissimilar to the BEA patterns. The engineering-based net wealth pavement stock depreciation patterns fall from an efficiency level of about 0.055 to zero after 20 years of life; the BEA Hulten-Wykoff-based net wealth pavement stock depreciation patterns are at approximately the same efficiency level after 62 years. BEA adopted Hulten-Wykoff default depreciation rates in the absence of other information (Fraumeni, 1997). Engineering-based pavement depreciation rates for highways and streets were generated by Picher (Fraumeni, 1999, 2007).

JEL Classification: E01

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Introduction

Replacing U.S. Bureau of Economic Analysis (BEA) highways and streets depreciation with depreciation based on a more disaggregated level of capital outlays, with or without engineering-based estimates of pavement depreciation, has a substantial impact on highway and streets constant-price wealth stocks. In a previous paper (Kornfeld and Fraumeni, 2022), *Highway Statistics* (HS) and other data was used to disaggregate investment in highways and streets into more detailed types.[1] [2] The alternative BEA estimates assembled in this previous paper produce lower wealth stocks than the official fixed assets BEA estimates. In this paper, two additional scenarios are presented: 1) the substitution of Picher-based pavement profiles for pavement geometric rates of depreciation and 2) the introduction of varying imputed rates of geometric depreciation applied to the more detailed capital outlays. Both resulted in even lower wealth stocks than those presented in the previous paper.[3]

First, the data sources and methodology underlying the BEA official highways and streets fixed assets and those depending on a more detailed disaggregation of capital outlays in Kornfeld and Fraumeni (2022) are summarized. Next, the data sources and methodology underlying the Picher pavement profiles, which underpin Fraumeni (1999, 2007a, 2007b) estimates, are described. Finally, comparisons are presented between three sets of estimates with different pavement figures: official BEA, alternative BEA, and Picher-based. In addition, wealth stocks are constructed with varying geometric rates of depreciation. In all four sets of estimates, constant-price investment in highways and streets is the same.

1. Official BEA and Alternative BEA Sources and Methodologies

BEA's fixed assets accounts (FAAs). The FAAs (official BEA) provide annual estimates of fixed investment (also known as gross fixed capital formation), economic depreciation (consumption of fixed capital or CFC), and net wealth capital stocks (net of depreciation) for highways and streets and over 100 other government and private fixed assets (structures, equipment, and intellectual property products). The FAAs provide highways and streets publicly available data in current- and constant-prices from 1901 (investment) or 1925 (wealth stocks and CFC) to the present.[4]

Official BEA and alternative BEA constant-price net stocks and CFC for highways and streets use the perpetual inventory method (PIM). A simplified PIM can be expressed as:

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[1] *Highway Statistics* is an annual compendium of highways and street data published by the U.S. Federal Highway Administration (U.S. Department of Transportation, annual).

[2] Other data used, following Fraumeni (1999, 2007a, 2007b), for example, includes an unpublished cost allocation study obtained from Jacoby of the U.S. Federal Highway Administration (Jacoby, unpublished) and derivation of a benchmark based on the Eastman report (National Highway Users Conference, 1940).

[3] All stock estimates in this paper are net stocks estimates. All estimates of investment (capital outlays) stocks, and depreciation are in constant-price millions of 2017 dollars.

[4] BEA (bea.gov) produces the U.S National Income and Product Accounts (the NIPAs, or national accounts) The main web page for the FAAs is https://apps.bea.gov/iTable/index_FA.cfm . The highways and streets data was last updated on November 3, 2023; it currently extends through 2022.

$$K_{jt} = K_{j(t-1)}(1-\delta_j) + I_{jt}(1-\delta_j/2)$$

where: K_{jt} = constant-price net stock for year *t* for asset type *j*

δ_j = annual depreciation rate for asset type *j*

I_{jt} = constant-price investment for year *t* for asset type *j*

The PIM can be rewritten as

$$K_{jt} = K_{j(t-1)} + I_{jt} - M_{jt} \quad \text{and} \quad M_{jt} = K_{j(t-1)}\delta_j + I_{jt}\delta_j/2$$

where: M_{jt} = constant-price depreciation or CFC for year t for asset type j.

Constant-price estimates of investment which enter PIM are obtained by dividing estimates of current-price investment by an average-year price index. The same constant-price estimates of investment are used in all official BEA, alternate BEA, Picher-based, a varying imputed geometric rate calculations.

Official, alternative BEA, and varying imputed geometric measures are wealth stock measures which assume a geometric pattern occurs. When a geometric pattern is assumed, there is no difference between wealth and productive stocks. BEA adopted a geometric pattern for most assets, including highways and streets, after a survey article by Fraumeni (1997) was published. This article summarized research by Hulten and Wykoff and others (Hulten and Wykoff, 1981a, 1981b). Picher measures are converted from productive stock measures to wealth stock measures for this paper.

The data source for FAA highways and streets investment is primarily the Census Bureau's Surveys of State and Local Government Finances (GF)[5] [6]. Capital outlays are divided into "purchase of equipment, land, and existing structures, including capital leases" and "construction." "Construction" (category F) is defined as "production, additions, replacements, or major structural alterations to fixed works." BEA classifies only capital outlays for "construction" for highways and toll highways as investment in highways and streets.[7]

Alternative BEA. The construction of the alternative BEA highways and streets investment is described in detail in Kornfeld and Fraumeni (2022). The methodology in the 2022 paper and

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[5] For more information on the NIPA measures of fixed investment, see the NIPA handbook chapters 6 and 9. BEA also uses data from the Census Bureau's monthly survey of construction spending to extrapolate estimates for the months before the next round of GF data is available. In the NIPAs and FAAs, state and local governments are responsible for almost all fixed investment in highways and streets; the federal government provides capital grants for this purpose but is directly responsible for only about one percent of this investment.

[6] See Kornfeld and Fraumeni (2022) for more information on the construction of investment estimates, including the price measures to deflate current dollar capital outlays.

[7] To clarify the distinction between construction and maintenance and repair, the GF survey instructions state that "if the term refers to activities that materially extend the life or add value to the property, then they are classified under construction; otherwise, they are classified under current operations.

this paper are identical.[8] Estimates of six capital outlay categories: paving, grading, bridgework, other structures, safety, traffic operation and control systems, and environmental enhancement and other, were built up primarily from HS data. The substantial effort to create these capital outlays began with development of estimates for interstate highways, non-interstate state roads, and local roads. With incomplete information, for a few years and particularly for local roads, a number of assumptions were made to construct a full set of estimates consistent with the BEA definition of capital outlays. Each category in the previous paper (Kornfeld and Fraumeni, 2022) was assigned a geometric rate. These rates and services are listed in Table 1. The geometric rate and the service life for the official BEA estimates are also listed. In all cases, the default declining structures balance rate of .91 for structures is assumed, based on the research by Hulten and Wykoff (1981a, 1981b) as summarized by Fraumeni (1997). Estimates of highways and streets stocks and depreciation presented in this paper begin in 1921.

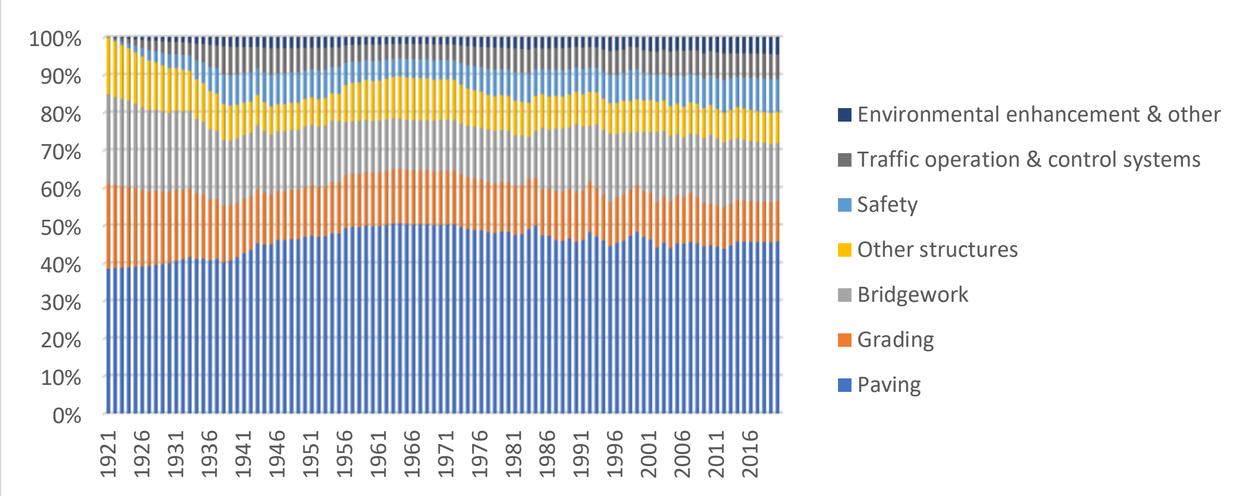
Table 1: Service Lives Assumptions and Geometric Rates

Alternative BEA	**Service life (years)**	**Geometric rate of depreciation**
Paving	20	.0455
Grading	80	.0114
Bridgework	50	.0182
Other structures	50	.0182
Safety	15	.0607
Traffic management	15	.0607
Environment/other	50	.0182
Official BEA	45	.0202

Figure 1 shows the shares of constant-price outlays. Paving is the largest share of capital outlays across all years.

[8] In this paper the estimates the latest FAA data is used and the results are extended through 2021.

Figure 1: Shares of Capital Outlays, All Highways and Streets, 1921–2021



2. Picher-based pavement sources and methodologies

In the Fraumeni reports (Fraumeni 1999, 2007a, 2007b), investment and productive stocks were estimated for three categories: pavement, grading, and structures, separately for interstate highways, non-interstate state roads, and local roads. The alternative BEA estimates, in this and the previous paper, used much of the same HS data as Fraumeni did. Aside from not compiling information on safety, traffic operation and control systems, and environmental enhancement and other categories, the main difference between the Fraumeni methodology and the alternative BEA methodology is in the construction of pavement estimates. Picher, a consulting engineer on the Fraumeni projects, estimated efficiency profiles for pavement with an assumed lifetime of 20 years, as contrasted with an infinite lifetime with a geometric rate of depreciation. The equations and the lifetime he used to develop efficiency profiles separately for interstate highways, non-interstate state roads, and local roads are consistent with the latest Federal Highway Administration *Project Development and Design Manual* (PDDM) (U.S. Department of Transportation, various years).[9]

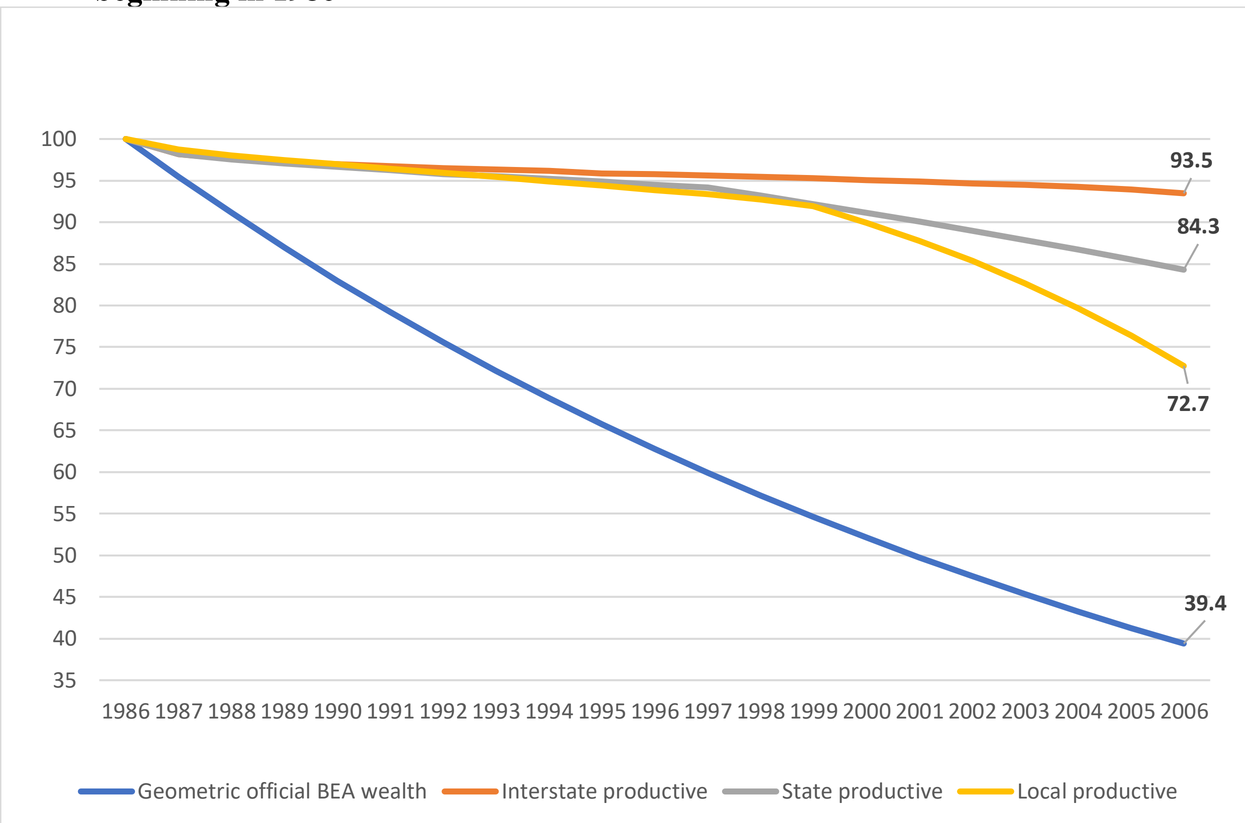
Picher-based productive stock estimates were converted to wealth stock estimates to allow a comparison to the official BEA and alternative BEA wealth stocks. Productive stocks depend on the efficiency of an asset only in the current period, whereas wealth stocks depend on the efficiency of an asset in the current and all future periods. One way to understand the difference between productive and wealth stocks is to use the example of a lightbulb. Lightbulbs normally shine with full brightness, are 100% efficient, until they suddenly go out and have zero efficiency. If a lightbulb lasts for four years before it stops shining, if one were to buy a used lightbulb, say one that was two years old, the price for that used lightbulb would be less than the price for a brand-new lightbulb. Productive stocks incorporate the lightbulb at 100% efficiency until it goes out. Wealth stocks incorporate the idea of a price that declines as a lightbulb is used. Future prices decline even with the future always 100% efficiency levels. Future efficiency levels are discounted to the present when wealth stocks are constructed, but not when

[9] An attempt was made to update the Picher efficiency profiles, but not having the services of an engineer proved to be a barrier to doing so.

productive stocks are constructed. Accordingly, productive stocks are always greater than wealth stocks if the annual efficiency levels are the same, except in the special case of a geometric rate. Productive stocks are used in productivity studies; wealth stocks are used to calculate depreciation that enters into GDP as GDP is an income concept.

The first step in this process is to create wealth stock profiles from the productive stock efficiency profiles. Figure 2 shows the official BEA wealth (= productive) profile and the Picher interstate highways, non-interstate state roads, and local roads productive efficiency profiles beginning in 1986.[10] [11] The Picher productive efficiency age 20 levels increase by about 10 percent from local, to non-interstate state, to interstate. The official geometric wealth BEA profile level is always lower than that for any of the three Picher productive efficiency profiles.[12]

Figure 2: Official BEA Wealth & Picher Productive Efficiency Profiles for Pavement, beginning in 1986



[10] The official BEA profile continues on to infinity, it is truncated in Figure 2 and Figure 3 to facilitate comparison with the Picher productive efficiency profiles. The last year shown in Figure 2 is 2006, the last year for which the productive Picher profiles have a positive value.

[11] In figures 2 and 3 and in subsequent figures, the title non-interstate is truncated as state.

[12] The appendix has figures for all of the Picher productive efficiency and derived wealth profiles. The profiles are shown beginning in 1986 in figure 2 and 3 as the three types of stocks: interstate, non-interstate state, and local, all have profiles beginning in 1986.

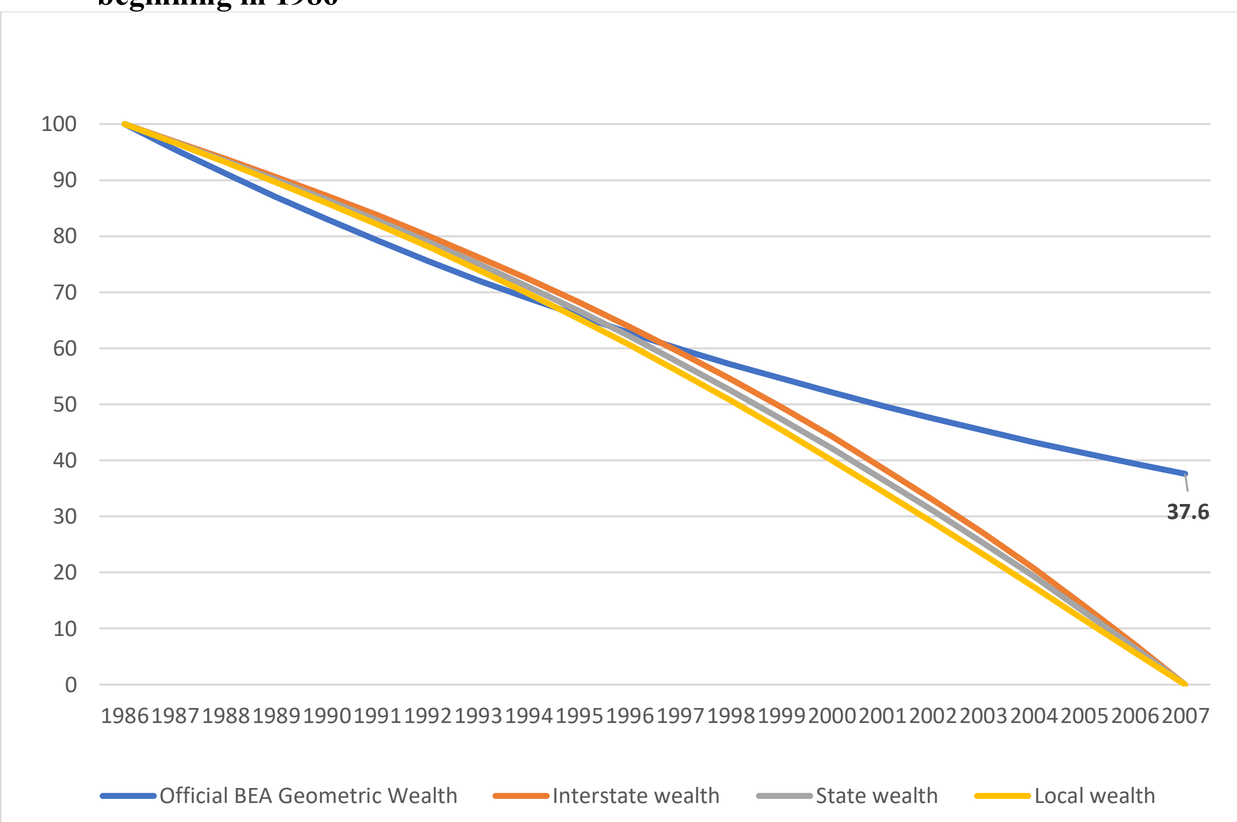
Wealth profiles are constructed with the following equation.

$$wp_t=[\sum_{\lambda=t}^{20} pe_{\tau}/(1+r)^{\tau-t}]/[\sum_{\lambda=0}^{20} pe_{\tau}/(1+r)^{\tau}]$$

where: wp_t is the wealth profile for time *t*,
τ is the age of the pavement,
the maximum number of years that a pavement is efficient is 20 years of age,
pe_t is the productive efficiency for time *t*,
r is the discount rate, set equal to .05.

Figure 3 shows the official BEA wealth profile and the Picher interstate highways wealth, non-interstate state roads wealth, and local roads wealth profiles beginning in 1986. As already noted productive efficiency profiles only depend on efficiency in the current year, whereas wealth profiles depend on current and future efficiency discounted to the present. The official BEA geometric wealth profile level is lower than that for any of the three Picher profiles levels until 1994.[13] There is very little difference between the three Picher wealth profiles.

Figure 3: Official BEA Wealth & Picher Wealth Profiles for Pavement, beginning in 1986



[13] This figure continues for one more year than figure 2 as 2007 is the year in which the wealth efficiency profile declines to zero.

Annual Picher-based wealth stocks are constructed from the sum of depreciated investments, where the Picher-based wealth profiles determine the annual level of depreciated investments:

The equations below are the equations used in the 1961 and 1962 wealth stock calculations

$S_{1961}=I_{1961}+I_{1960}wp41_{age=1}+I_{1959}wp41_{age=2}+I_{1958}wp41_{age=3}\ldots+I_{1941}wp41_{age=20}$,

$S_{1962}=I_{1962}+I_{1961}wp61_{age=1}+I_{1960}wp41_{age=2}+I_{1959}wp41_{age=3}\ldots+I_{1942}wp41_{age=20}$.

where: I is investment,

wp41is the wealth profile beginning in 1941,

wp61is the wealth profile beginning in 1961,

and as before, the maximum number of years that a pavement is efficient is 20 years of age.

The 1961 stock only depends on the wealth profile beginning in 1941. The 1961 component of the1962 stock depends on the wealth profile beginning in 1961as the 1961 investment is one year of age in 1962. All other components depend on the wealth profile beginning in 1941as these components arise from investments made during the 1942-1960 time periods. The 1941 investment is fully depreciated by 1962, so this investment does not appear in the 1962 stock equation. With each stock year after 1962, one additional wealth profile beginning in 1961 component appears. The last time a wealth profile beginning in 1941component appears is in 1980. Each stock calculation has 20 components with the investment made before the stock year weighted by a wealth profile term. Depreciation is measured as the annual decline in the level of a profile adjusted investment in the wealth stock equation, including when the level falls to zero.

3. Comparison of Official BEA, Alternative BEA, and Picher-based estimates

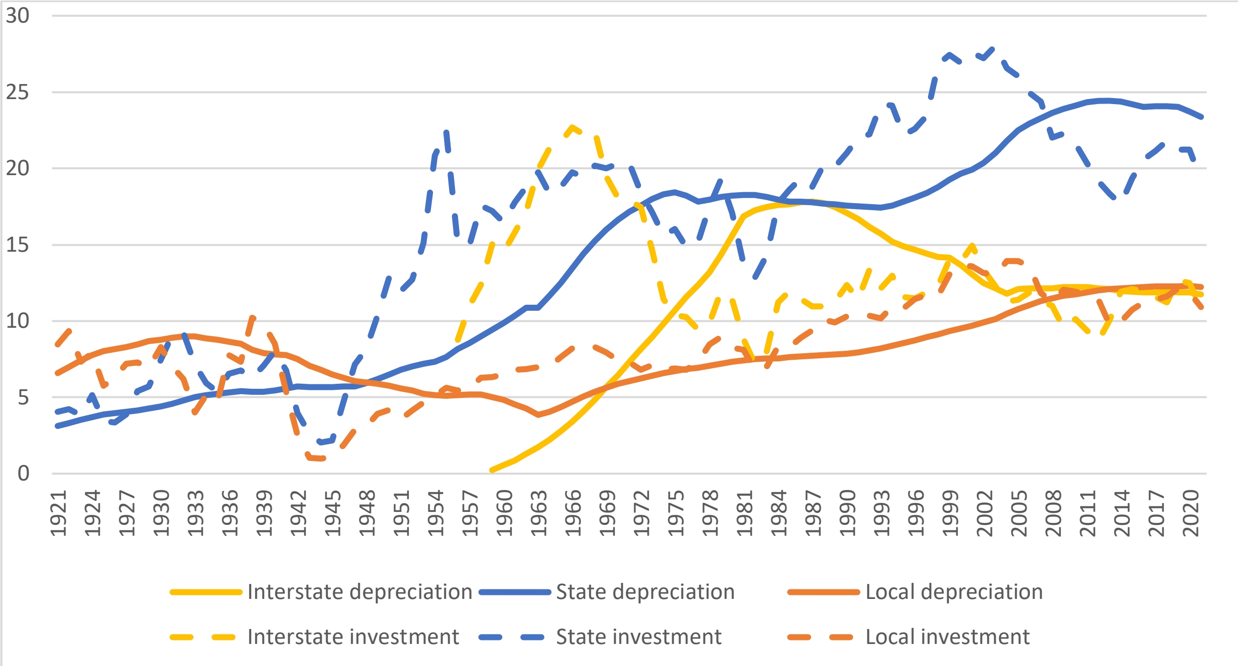
Pavement depreciation

The only difference between the alternative BEA estimates and the Picher-based estimates are the pavement measures. Consequently, any differences between the stock and depreciation estimates arise from the differential pavement estimates. Figure 4 shows that paving depreciation and investment in interstate, non-interstate state, and local highways and streets substantially differ.[14] [15] Capital outlays for the interstate system begin in 1956 as the interstate system construction began in that year. Depreciation is less volatile than investment.

[14] Investment for 2011 and 2015-7 were interpolated.

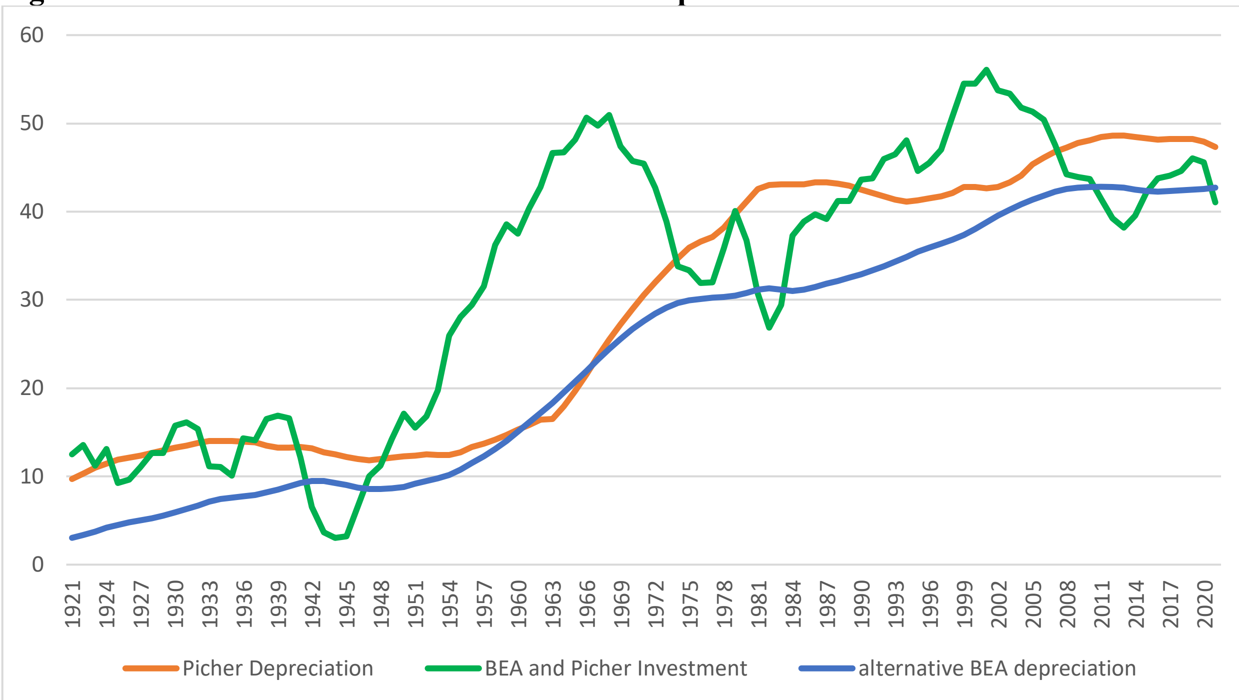
[15] In the beginning of the construction of the interstate system, some state roads were transferred to the interstate system. Figure 4 allocates depreciation and investment to the system under which investment occurred. Depreciation is determined from the state Picher-type profiles when the road was originally considered a state road as it is the original pavement design specifications that determine the efficiency of the road. However, this transferred road depreciation is overestimated for state roads and underestimated for the interstate during the early years of the interstate system as the depreciation is not reallocated after the road is transferred.

Figure 4: Picher Pavement Investment and Wealth Stock Depreciation, 1921-2021 millions of 2017 Dollars



Some of the volatility of the investment series disappears when total paving investment is graphed (Figure 5). The biggest increase in investment begins in 1945, during the post-World War II period. Since Picher pavement lasts only through age 20, but alternative BEA pavement last forever (see figure 3 as an example), Picher depreciation of increased paving beginning in post-World War II is almost always larger than alternative BEA depreciation.

Figure 5: Picher & Alternative BEA Pavement Depreciation & BEA and Picher Investment



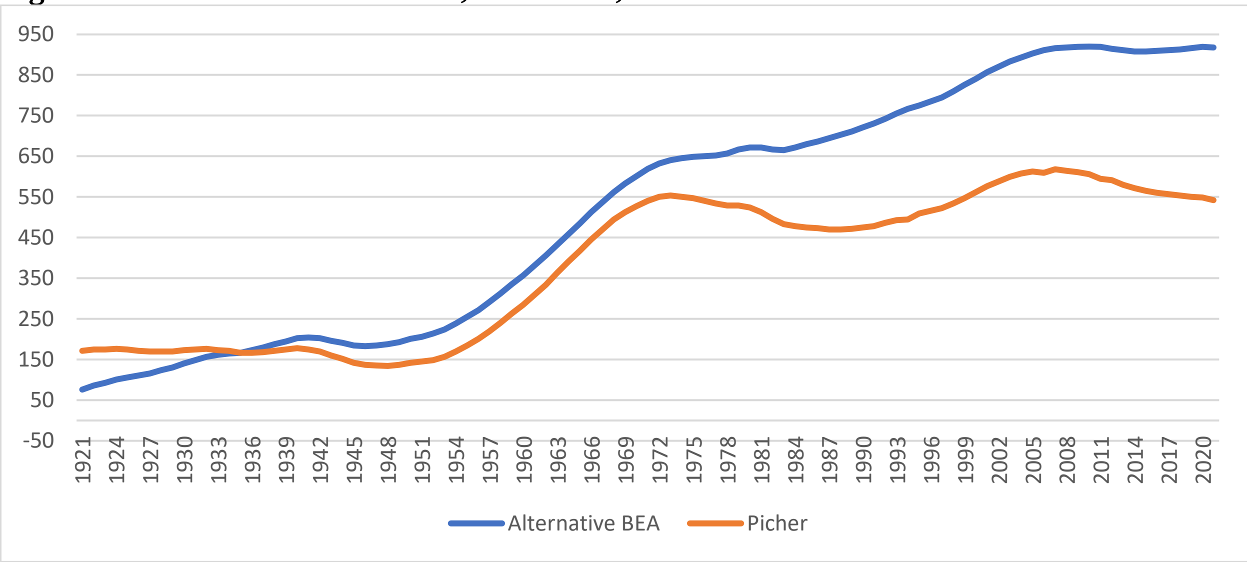
In order to estimate Picher-based depreciation of wealth stocks, paving investment had to be estimated prior to 1921 as 1921-1940 depreciation arises from capital outlays made from 1899-1920.[16] Accordingly, highways and streets investment was estimated back to 1899 as FAA chain-type quantity highways and streets investment indexes begin in 1901. In the alternative and official BEA cases the rate of depreciation does not vary by the age of the asset or by whether the outlay is for interstate, non-interstate state or local roads, however a 1921 non-interstate state and local stock benchmark is needed as the FFA highways and streets begin in 1925. This was produced backwards from 1925 from the FAA chain-type quantity highways and streets investment indexes. Pavement shares of official BEA wealth stocks in 1921 are adopted from Fraumeni (1999, 2007a, 2007b) to determine the 1921 alternate BEA pavement benchmark.[17]

Figure 6 shows the alternative BEA and Picher-based pavement wealth stocks. By the end of the period, alternative BEA pavement stocks are substantially higher than Picher-based wealth stocks, at a level of over 900 million versus almost 550 million, although until 1936 the Picher-based pavement wealth stocks were higher than the alternative BEA pavement stocks.

[16] Because originally a 1920 benchmark was desired, the Picher-based profiles were modified to have a lifetime of 21 years for only the 1921 profiles, by starting the profiles in 1920 instead of 1921. This was done by interpolating the original profiles between age 0 (1921) and age 1 (old 1922) for a new age 1 (new 1921), then shifting the values by one year subsequently. The Picher value for new age 1 (1921) is the interpolated value. The Picher value for new age 2 (1922) is set to the original value for age 1, the Picher value for new age 3 (1923) is set to the original value for age 2, and so forth. Accordingly, from 1923 to 1940 there is no impact on depreciation; there is an impact of deprecation only in 1921 and 1922.

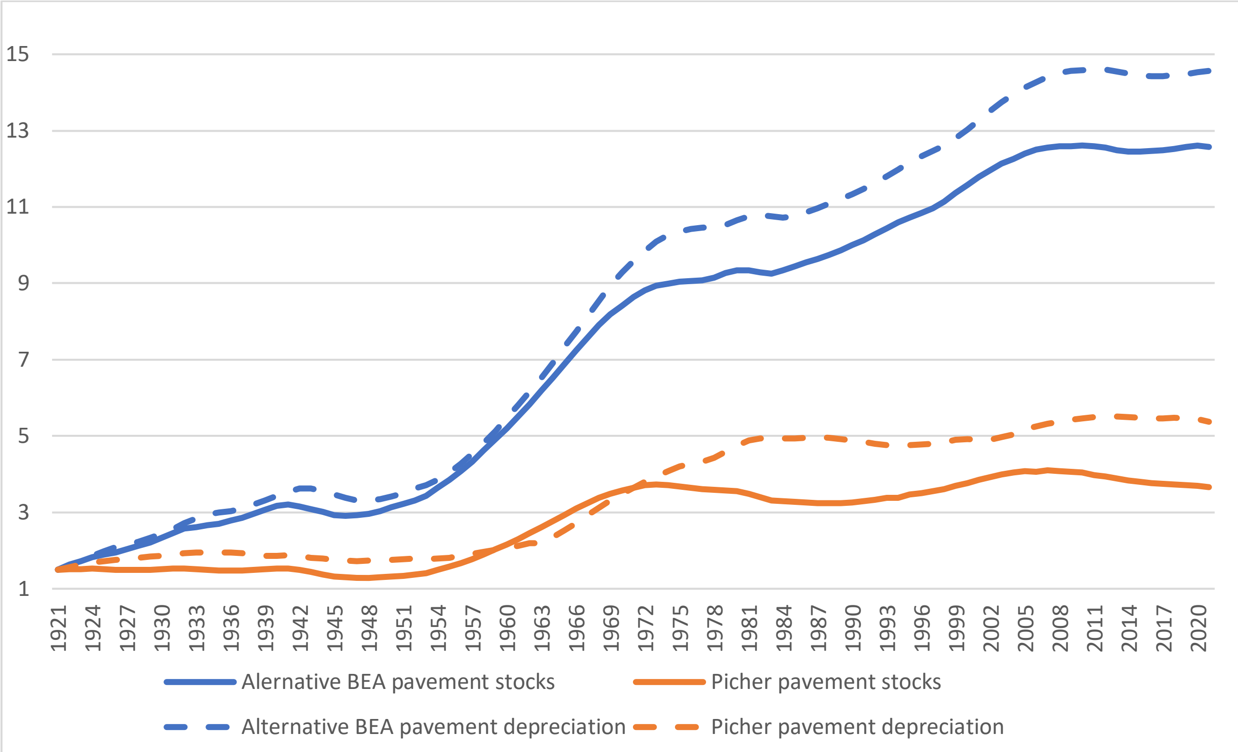
[17] In case depreciation and wealth stocks are desired beginning in 1901, highways and streets investment is estimated back to 1880 using the average growth rate of highways and street investment between 1901 and 1920. These early investment estimates were then scaled after PIM was applied to match 1901 highways and stocks wealth stocks.

Figure 6: Pavement Wealth Stock, 1921-2021, millions of 2017 dollars



To get a better sense of the nature of the pavement depreciation of wealth stocks as both are impacted by backward estimated investment and the 1921 assumed share of 1921 pavement with few detailed HS breakouts before 1981 (Kornfeld and Fraumeni, 2022), figure 7 shows the pavement wealth stocks and depreciation of pavement stocks with both sets of estimates normalized to 1.0 in 1921. Alternative BEA wealth pavement stocks grow at a faster rate than Picher wealth pavement stocks as the BEA depreciation rate is on average lower than the Picher depreciation rate. Alternative BEA wealth pavement depreciation grows at a faster rate than Picher wealth pavement depreciation because BEA wealth depreciation is a constant percentage, at the geometric rate, of the BEA wealth pavement stocks.

Figure 7: Wealth Pavement Stock and Depreciation, millions of 2017 dollars, normalized to 1.0 in 1921, 1921-2021



The growth in Picher pavement stocks and depreciation is much lower than the alternative BEA pavement stocks and depreciation growth. As in previous figures, figure 7 clearly shows the impact of the construction of the interstate system which began in 1956.

In the following figures and table, two scenarios are added. The analysis in this paper seems to indicate that the official BEA geometric rate of depreciation for highways and streets is too low. Using the alternative BEA approach described above would be difficult for three reasons: the HS data by detailed type does not go far enough back in time to be used as a basis for 1901 investment by detailed type, Picher-type profiles would have to be constructed with a beginning year later than 1986, and developing the alternative BEA stocks on an annual basis would be a substantial effort. Alternatively, the official BEA geometric rates could be varied occasionally as is already done for at least one BEA fixed asset. For the two scenarios, which might be the starting point for the development of new official BEA highway and streets geometric rates, imputed geometric rates are constructed. For one scenario the imputed geometric rates are calculated by dividing alternative BEA depreciation by alternative BEA stocks; for the other scenario imputed geometric rates are calculated by dividing alternative BEA depreciation with Picher-type wealth profiles by alternative BEA stocks with Picher-type wealth profiles (see figure 8 and table 2). Except for 1921 in the alternative BEA scenario without Picher, an average rate is imputed for a range of years. In the alternative BEA scenario with Picher, there are two obvious trends that are driven by the Picher-type patterns, which are not part of the other scenario. There are a number of trends in this scenario, most notably from 1930 to 1963 and 1964 to 1983, but the averages for these two time periods are almost identical (see table 2). In the earlier period there were historically relatively low paving investment, both in share of total capital outlays and in the level of capital outlays (see figure 1 and 5). This investments'

Figure 8: Wealth Stock with Imputed Geometric Rates, 1921-2021

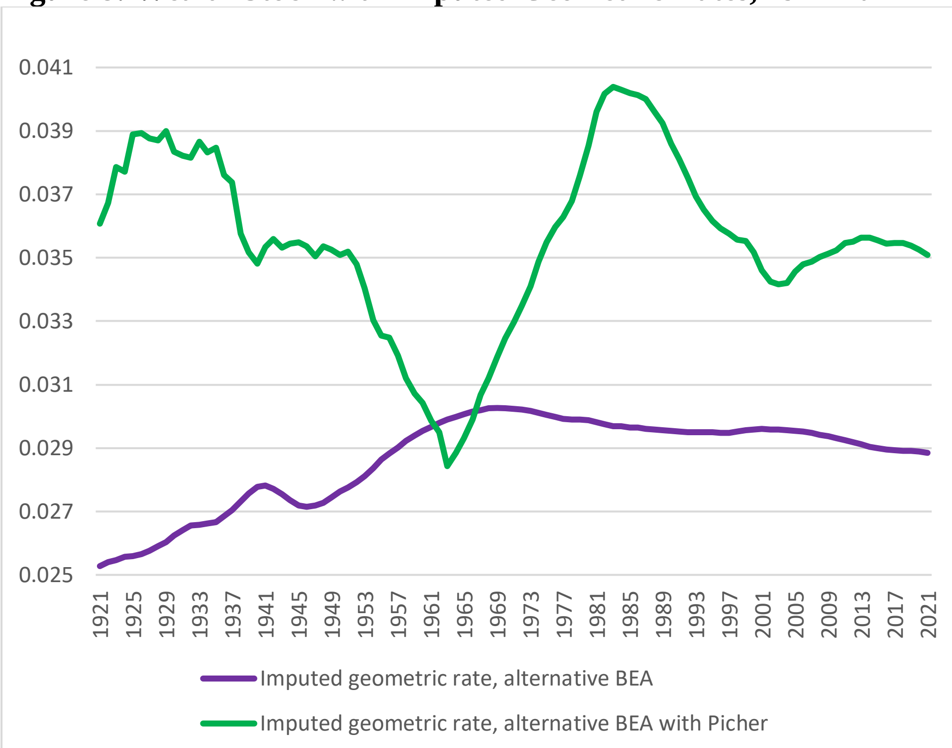


Table 2: Imputed Geometric Rates, 1921-2021

Years for average rate	**Average rate**	**Range of imputed rates, first year to last year**
Official BEA, alternative BEA		
1921	.0253	.0253
1922-1970	.0278	from .0254 to .0303
1971-2021	.0301	from .0302 to .0288
Official BEA, alternative BEA, with Picher		
1921-1924	.0371	from .0361 to .0377
1925-1929	.0389	from .0389 to .0390
1930-1963	.0347	from .0384 to .0284
1964-1983	.0345	from .0289 to .0404
1984-2004	.0371	from .0403 to .0342
2005-2021	.0353	from .0346 to .0351

pavement profile declined to zero after 20 or 21 years. After World War II and during the construction of the interstate system beginning in 1956, the share of paving outlays in total capital outlays and the level of investment increased significantly. All of the imputed rates are higher than the official BEA geometric rate currently being used, which is listed in table 1:

.0202. Stock streams are computed for each of the imputed geometric rate periods. Then the stock streams are summed to form the wealth stock series shown in figures 9 and 10.

In both figures 9 and 10, the official BEA wealth stock is significantly different from the other variations. As expected, the versions with imputed geometric rates are very similar to those from which the imputations are derived. Alternative BEA is very similar to official BEA with imputed geometric rates based on the alternative BEA estimates and alternative BEA with Picher pavement is very similar to official BEA with imputed geometric rates based on the alternative BEA with Picher pavement estimates. The exception is in the 2000's in the versions without Picher pavement. This could be fixed by breaking the 1971 to 2021 period into two subperiods. In figure 10, in which the series are normalized to 1.0 in 1921, the official BEA wealth stock and the alternative BEA with Picher pavement wealth stocks have quite different growth rates than the other three wealth stocks. When Picher-type pavement wealth stocks are included in highways and streets stock, the 1921 wealth stock is higher than any other of the wealth stocks (see figure 9). Normalization to 1.0 with this higher 1921 stock tilts the line in figure 10 downwards. The 1921 wealth stock is higher because Picher pavement stocks are generated for all years before 1921 in which the wealth profile of pavement resulting from outlays made in years before 1921 are nonzero in 1921. Figures 9 and 10 show that an imputed geometric approach could be used in the official series, but there is a choice of the basis for the imputation as those with Picher pavement stocks are lower in almost all years than those without Picher pavement stocks.

Figure 9: Wealth Stock, Including with Imputed Geometric Rates, 1921-2021, millions of 2017 dollars

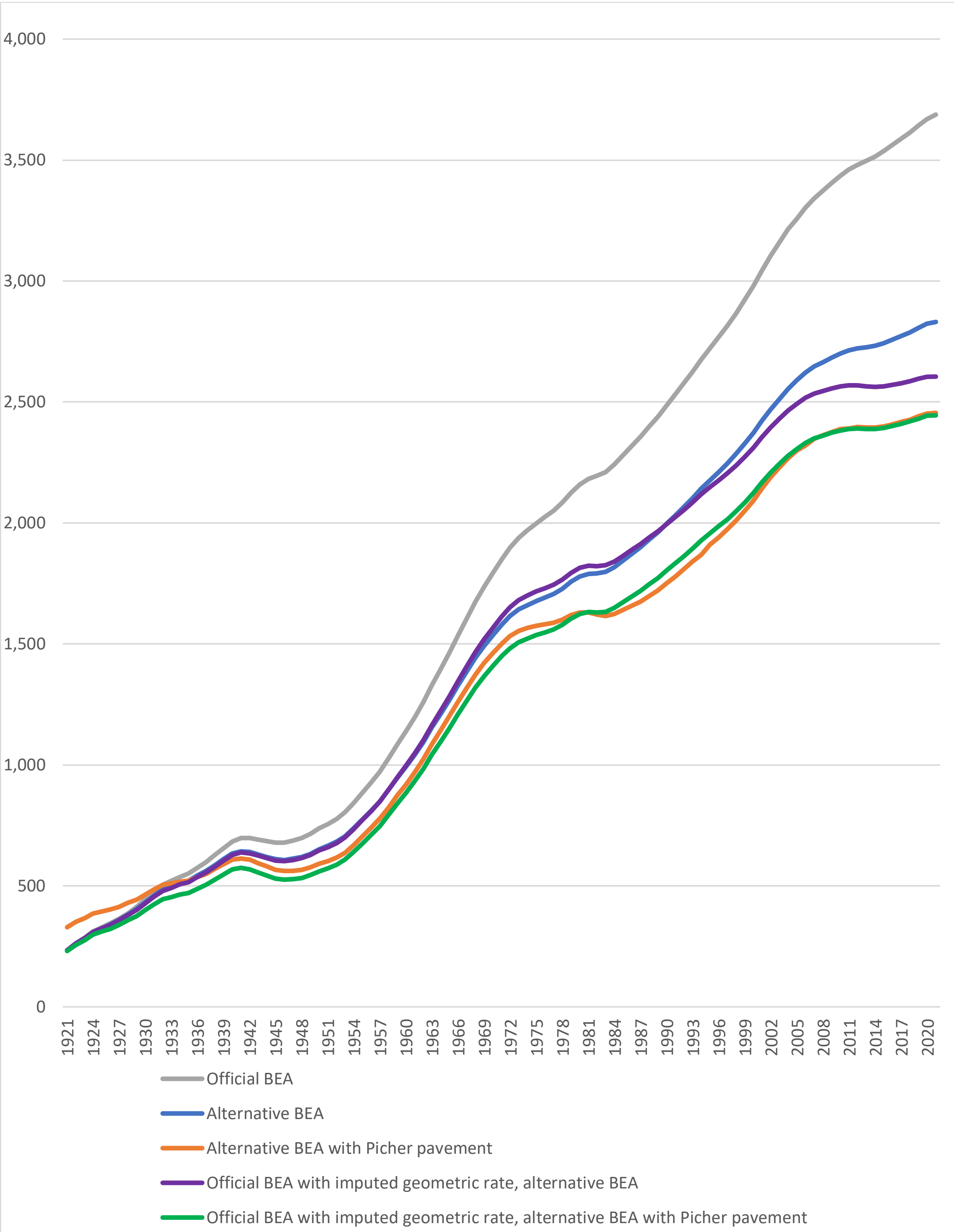
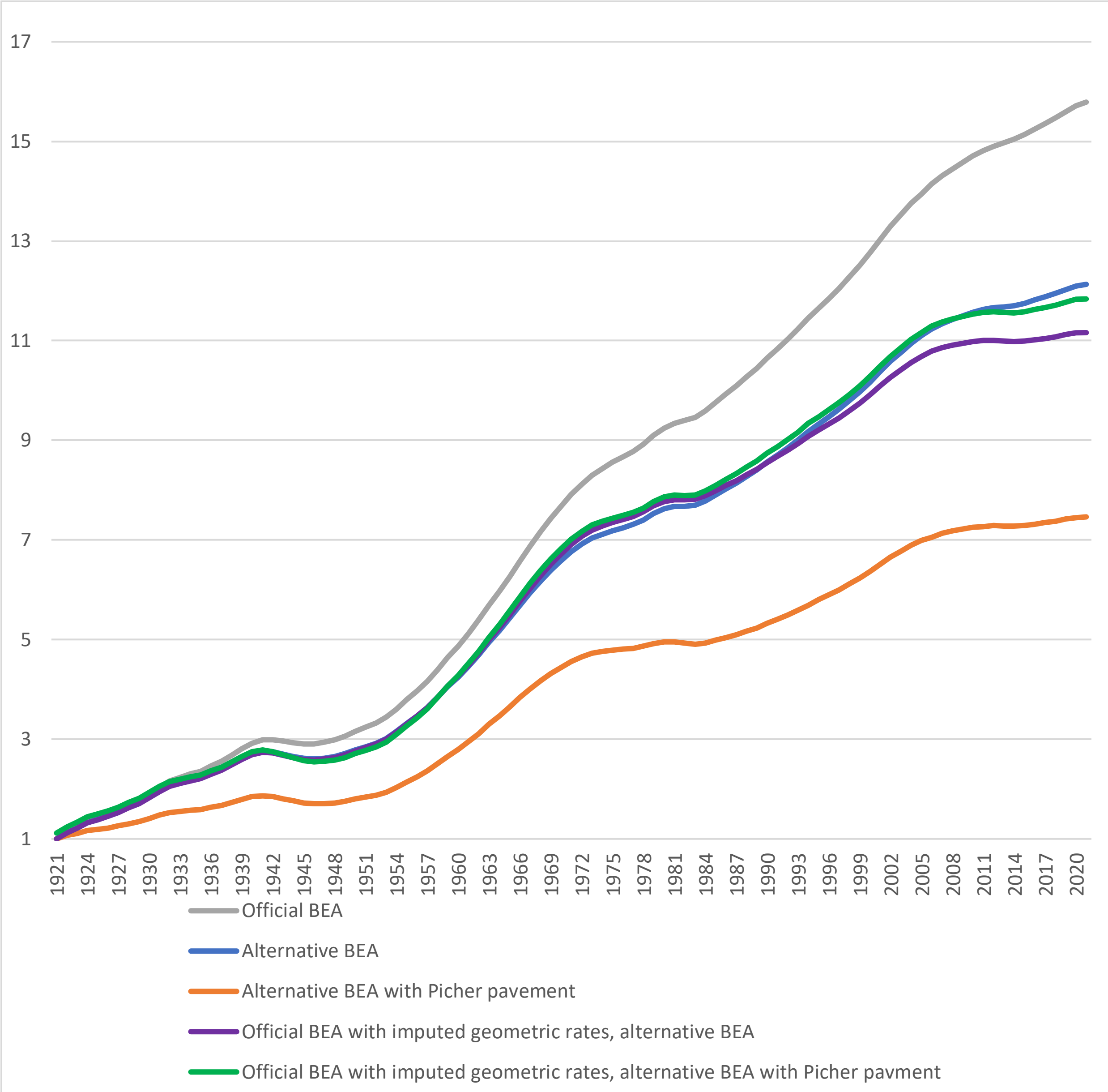


Figure 10: Wealth Stock, Including with Imputed Geometric Rates, 1921-2021, millions of 2017 dollars, normalized to 1.0 in 1921



4. Conclusion

Introducing a more detailed level of disaggregation of highways and streets BEA investment suggests that the official BEA geometric depreciation rate is too low. Whether or not the Picher-based estimates become the basis for pavement depreciation, a more disaggregated level of investment significantly reduces the level of wealth stocks. Two open questions are whether geometric rates shown in table 1 are the correct rates for the disaggregated components and which of the imputed geometric rates scenarios would be an appropriate basis for geometric rates. As figures 9 and 10 demonstrate, it is possible to construct alternative BEA wealth stocks with varying imputed geometric rates that resemble the alternative BEA wealth stocks. The official BEA geometric rate is currently set to the structures default rate. The additional information presented in this paper suggests that the official depreciation rate for highways and streets may be too low, and the estimate of capital stocks of highways and streets may be too high.

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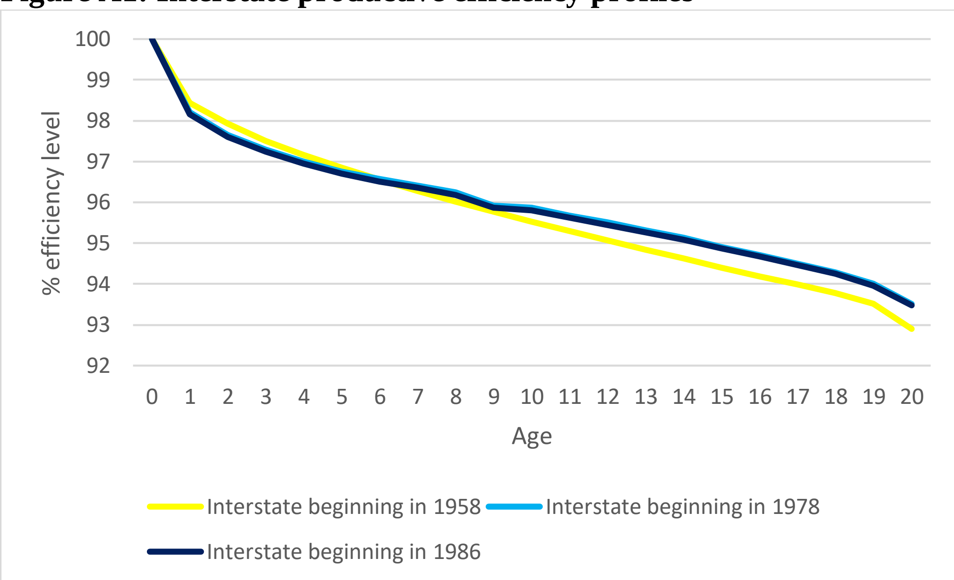
Appendix: Picher productive efficiency profiles and Picher-type wealth profiles

1. Productive efficiency profiles

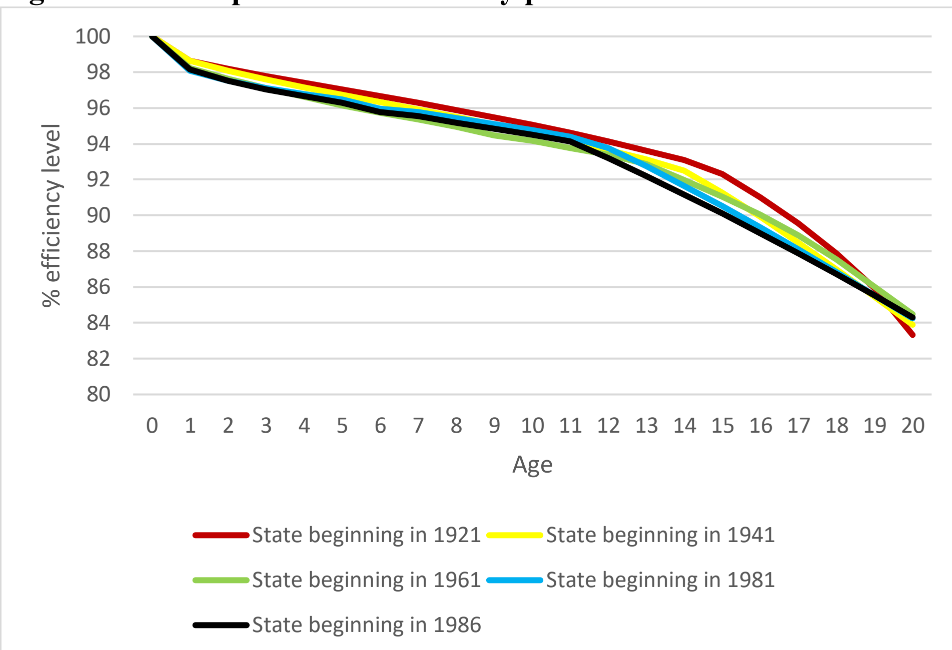
In figure A1, an efficiency profile is shown starting in 1958, as Picher started the first efficiency profile in 1958. However, since capital outlay for interstates started in 1956, in the actual calculations for this paper, the efficiency levels between 1956 and 1959 were interpolated. Starting in 1959, the age of the pavement is increased by 2 compared to that in the original Picher, so the age 3 efficiency level for this paper is set equal to original Picher age 1 efficiency level, the age 4 efficiency level for this paper is set equal to original Picher age 2 efficiency level, the age 5 efficiency level for this paper is set equal to original Picher age 3 efficiency level, and so forth so in the last efficiency age, the age 22 efficiency level for this paper is set equal to original Picher age 20 efficiency level. The last year for which the efficiency level is nonzero for both the profile beginning in 1956 and 1958 is 1977. In the estimates in Fraumeni (1999, 2007a, 2007b), it was assumed that it took two years before vehicles traveled on pavement because of the time it took to complete an interstate. In this paper, paving capital outlay is entered into the stocks in the year the paving capital outlay is made. Note that the profiles beginning in 1978 and 1986 are almost identical, and the profile beginning in 1958 is very similar to the other two. As is true for interstate, non-interstate, and local profiles, 1986 was the last beginning year for a profile constructed as this is the last profile sequence for which Picher had complete data.

Figure A1: Interstate productive efficiency profiles



For non-interstate and local profiles, it was desired for this paper to have a 1920 starting value for the estimates. Accordingly, the efficiency levels between 1920 and 1922 are interpolated. Starting in 1922, the age of the pavement is increased by 1 compared to that in the original Picher, so the age 2 efficiency level for this paper is set equal to original Picher age 1 efficiency level, the age 3 efficiency level for this paper is set equal to original Picher age 2 efficiency level, the age 4 efficiency level for this paper is set equal to original Picher age 3 efficiency level, and so forth so in the last efficiency age, the age 21 efficiency level for this paper is set equal to original Picher age 20 efficiency level. The last year for which the efficiency level is nonzero for both the profile beginning in 1920 and 1921 is 1940. The profiles beginning in all years are very similar, although for ages 13 through 16, the efficiency levels of the profiles beginning in 1921 and 1941 are slightly greater than the others (see figure A2).

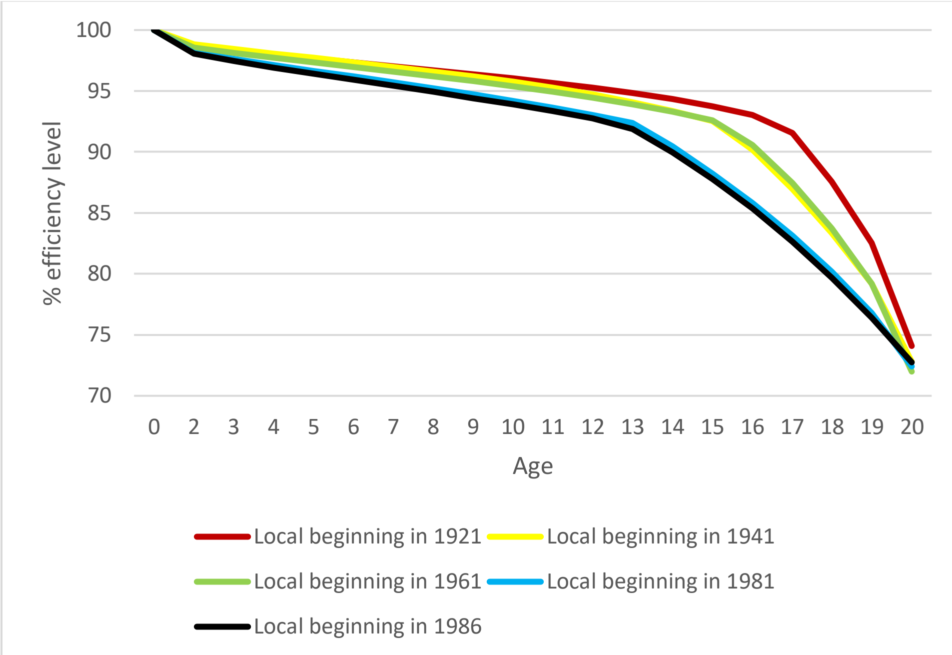
Figure A2: State productive efficiency profiles



The biggest difference between efficiency profiles is for local productive efficiency profiles (see figure A3). The profiles beginning in 1941 and 1961 and the profiles beginning in 1981 and 1986 are very similar. However, there are clear differences between the efficiency profile beginning in 1921, the efficiency profiles beginning in 1941 and 1961, and the efficiency profiles beginning in 1981 and 1986, except in the first few years of age and the last year of age.

As previously noted for productive efficiency profiles beginning in 1986, the difference between local, non-interstate state, and interstate age 20 levels are about 10.

Figure A3: Local productive efficiency profiles



2. Wealth profiles

Because wealth profiles are derived from future productive efficiency levels using present discounted values, as expected the wealth profiles show a much lower level than the productive efficiency levels.

In figure A4, the interstate profiles beginning in 1978 and 1986 cannot be distinguished from each other as the difference in the levels is so small. A wealth profile beginning in 1956 is shown as it is this profile that is used in the construction of wealth stocks. As expected, this profile is different from the other two as the pavement lasts two more years of age.

In figures A5 and A6, none of the profiles can be distinguished from each other, except that for beginning in 1920 as the pavement last one more year of age.

Without updating the Picher productive profiles for later years, one cannot be certain, but the small differences between the wealth profiles may indicate that wealth profiles for later beginning years, if they are estimated with updated productive efficiency profiles, may be indistinguishable from those with earlier beginning years.

Figure A4: Interstate wealth profiles

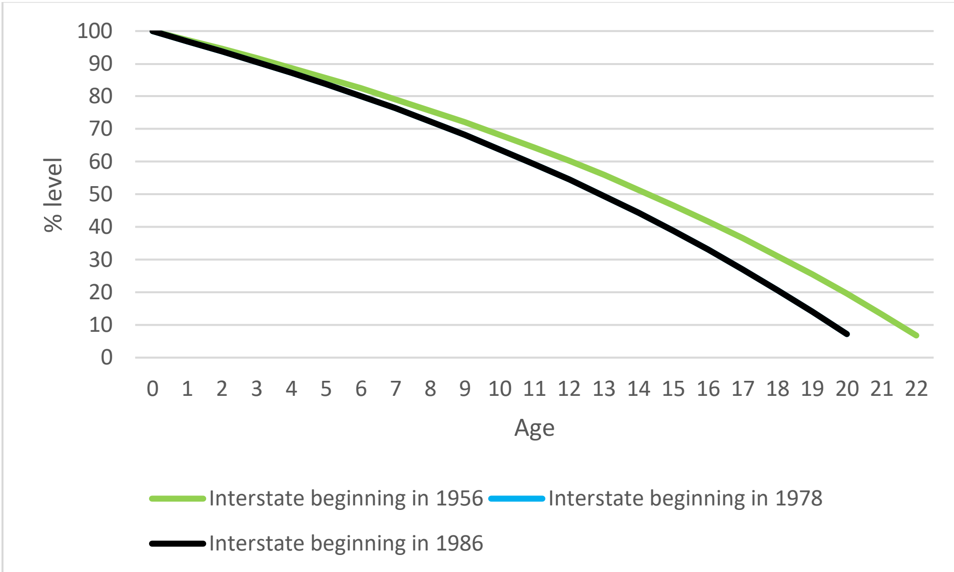


Figure A5: State wealth profiles

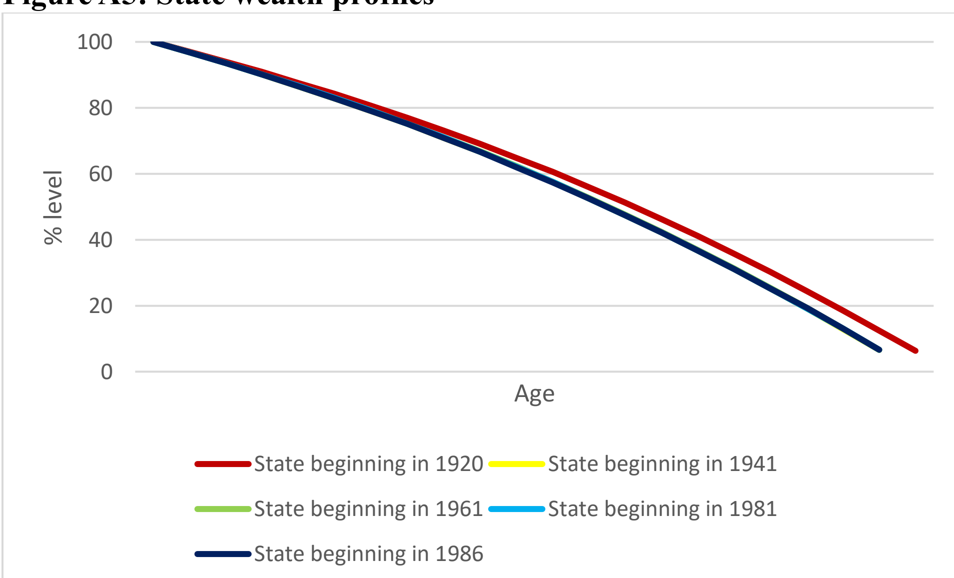


Figure A6: Local wealth profiles