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## Manuscript Details

Manuscript number
Title
Article type

ECOLEC_2017_1058
The role of energy in production
Research paper

Abstract
In this paper, we introduce a production function that is consistent with the Laws of Thermodynamics, and which acknowledges that production without energy is impossible. We start by exploring how the fundamental role of energy in production came to be lost from economics for almost a quarter of a millennium.

| Keywords | Energy, Production Function, Laws of Thermodynamics, History of Economic <br> Thought |
| :--- | :--- |
| Manuscript category | Analysis |
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| Corresponding Author's <br> Institution | Kingston University |
| Order of Authors | Steve Keen, Bob Ayres |

## Submission Files Included in this PDF

File Name [File Type]
TitlePage.docx [Title Page (with Author Details)]
KeenAyres2017RoleOfEnergyInProduction.doc [Manuscript File]
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Data for: The role of energy in production
Data for GDP, energy, capital (per head) and the employment rate for the USA from 1960

The role of energy in production
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# The role of energy in production <br> \author{ Steve Keen, Kingston University; debunking@gmail.com 

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## Introduction

"Land is the source or matter from which all wealth is drawn; man's labor provides the form for its production, and wealth in itself is nothing but the food, conveniences, and pleasures of life." (Cantillon 1755, p. 21)

So began the first major work of the only School of Thought in economics to accord energy, as then understood, its pivotal role in production: the Physiocrats. Though their halcyon days pre-dated the development of the Laws of Thermodynamics by a century, their model of production was compatible with them, since it acknowledged that a surplus of outputs over inputs was only possible because of the exploitation of the observable productivity of land-which as we now know is the consequence of plants absorbing solar energy.

In this paper, we introduce a production function that is consistent with the Laws of Thermodynamics, and which acknowledges that production without energy is impossible. We start by exploring how the fundamental role of energy in production came to be lost from economics for almost a quarter of a millennium.

## Energy and the Physiocrats

Energy was not explicitly mentioned by the Physiocrats as the source of production, for the simple reason that the word itself was only introduced into the language of science by Thomas Young in 1807—well after their School had ceased to exist:

> Hence is derived the idea conveyed by the term living or ascending force; for since the height to which a body will rise perpendicularly, is as the square of its velocity, it will preserve a tendency to rise to a height which is as the square of its velocity ... The same idea is somewhat more concisely expressed by the term energy, which indicates the tendency of a body to ascend or to penetrate to a certain distance, in opposition to a retarding force." Emphasis added. (Young 1807, p. 34. Emphasis added)

The starting point of Physiocratic thought was the proposition that a "net product" was possible only because the Husbandman exploited "this superfluity that nature accords him as a pure gift" (Turgot 1774, p. 9). Their insight (and its limitations as well) sprang from the fact that the primary raw materials and products of agriculture are identical-seed corn generates a corn plant containing many more corn seeds than were planted:

Land aided by human labor, naturally produces 4, 10, 20, 50, 100, 150 times the amount of wheat sown, depending on the fertility of the soil and the industry of the inhabitants. (Cantillon 1755, p. 170)

At the same time, not all that was harvested could be consumed, so there while outputs exceeded inputs, there was a necessary sense in which less than was produced was available as the net product:

Today, land in Europe yields on the average six times what is sown, so that five times the seed remains for the consumption of the people. (Cantillon 1755, p. 87)

The flaw in the Physiocratic perception was that, while they realized that non-agricultural manufacturing inputs were needed to enable "Husbandmen" to harvest the surplus the land generated, manufacturing was not seen as productive in itself. The fact that manufacturing was also driven by "this superfluity that nature accords him as a pure gift" was obscured by the fact that the outputs of manufacturing (from wheat and lace to wooden and metal products) differed in kind from the inputs. Inputs were raw materials derived from nature, as well as intermediate products and energy in the form of both labor and solar-derived energy from (at that time) windmills, water wheels, wood and coal; outputs were qualitatively incommensurable elaborately transformed products (plus material waste). Consequently, in the most famous Physiocratic work, Quesnay's Tableau Economique, manufacturing was shown as "sterile". Though it was vital in enabling the productive class of Husbandmen to extract a surplus or "produit net" from the soil, Quesnay labelled expenditure on manufacturing as "sterile" in the belief that it did not generate a surplus itself, whereas agriculture did (see Figure 1).

Figure 1: An English translation of Quesnay's Tableau Economique (Quesnay 1759)


Total Reproduction . . . . . . . . . 600 L. of revenue; besides the annual expenditures of 600 L . and the interest on the original advances of the Husbandman, amounting to 300 L., which the land restores. Thus the reproduction is 1500 L ., including the revenue of 600 L . which is the basis of the calculation, apart from taxes deducted, and the advances required for its annual reproduction, \&c.
Land therefore had the primary role, in Physiocratic economics, of generating a surplus. The role of labor was to convert that surplus into different forms, but not to create that surplus in the first instance. The valuation of labor itself was reduced to the amount of land needed to sustain it:
"Land provides the matter, and labor the form, of all commodities and merchandise, and as those who work must subsist on the production of the land, it seems that some par value or ratio between labor and the production of the land might be found." (Cantillon 1755, p. 56)

By these examples, and others of the same sort that could be added, it is seen that the value of the day's work has a relation to the product of the soil. The intrinsic value of any thing may be measured by the quantity of land used in its production and the quantity of labor which enters into it, that is to say, by the quantity of land of which the product is allotted to the laborers." (Cantillon 1755, p. 64)

## How energy was lost from economics

Despite meeting Turgot and Quesnay while travelling in France (as a tutor to the Duke of Buccleuch) and being impressed by Physiocratic thought, Adam Smith completely abandoned their perspective
that land was the source of wealth. He argued, to the contrary, that labor was the cause of wealth, and that "division of labor" was the cause of increase in wealth:

THE annual labor of every nation is the fund which originally supplies it with all the necessaries and conveniences of life which it annually consumes, and which consist always, either in the immediate produce of that labor, or in what is purchased with that produce from other nations. (Smith 1776, p. 10)

Smith entertained arguments that gave agriculture a superior role to manufacturing, and attributed non-labor inputs-including both Nature and "laboring cattle"-as potential sources of surplus:

No equal capital puts into motion a greater quantity of productive labor than that of the farmer. Not only his laboring servants, but his laboring cattle, are productive laborers. In agriculture, too, Nature labors along with man; and though her labor costs no expense, its produce has its value, as well as that of the most expensive workmen...

The laborers and laboring cattle, therefore, employed in agriculture, not only occasion, like the workmen in manufactures, the reproduction of a value equal to their own consumption, or to the capital which employs them, together with their owner's profits, but of a much greater value. Over and above the capital of the farmer and all its profits, they regularly occasion the reproduction of the rent of the landlord. This rent may be considered as the produce of those powers of Nature, the use of which the landlord lends to the farmer. (Smith 1776, pp. 283-4)

Despite these snippets, via Ricardo and ultimately Marx, the Classical School became identified with the assertion that labor was the only source of a surplus of outputs over inputs. Marx derived his conclusion in two ways: one which focused upon the factors that were unique to labor, and a second which was based on properties that, in Marx's analysis, labor shared with all other commodities (Marx 1857 [1993]; Keen 1993).

The former method distinguished between the capacity of labor to perform work, which Marx called labor, and the means of subsistence which Marx called labor-power, and which he identified with the minimum wage:

The worker receives means of subsistence in exchange for his labor-power, but the capitalist receives in exchange for his means of subsistence labor, the productive activity of the worker, the creative power whereby the worker not only replaces what he consumes but gives to the accumulated labor a greater value than it previously possessed. (Marx 1847, p. 85)

The latter method argued that the surplus from labor emanated the difference between the usevalue of labor and its exchange-value::

The past labor that is embodied in the labor power, and the living labor that it can call into action; the daily cost of maintaining it, and its daily expenditure in work, are two totally different things. The former determines the exchange value of the labor power, the latter is its usevalue. The fact that half a [working] day's labor is necessary to keep the
laborer alive during 24 hours, does not in any way prevent him from working a whole day. Therefore, the value of labor power, and the value which that labor power creates in the labor process, are two entirely different magnitudes; and this difference of the two values was what the capitalist had in view, when he was purchasing the labor power...

What really influenced him was the specific use-value which this commodity possesses of being a source not only of value, but of more value than it has itself. This is the special service that the capitalist expects from labor power, and in this transaction he acts in accordance with the 'eternal laws' of the exchange of commodities. The seller of labor power, like the seller of any other commodity, realises its exchange value, and parts with its use-value." (Marx 1867, p. 188. Emphasis added)

However, with respect to machinery, Marx argued that capital does not produce a surplus, but simply imparts to the product the value that it lost in depreciation:

However useful a given kind of raw material, or a machine, or other means of production may be, though it may cost $£ 150$....yet it cannot, under any circumstances, add to the value of the product more than $£ 150$ " (Marx 1867, p. 199)

This led to Marx's mathematical formulations for value production which attributed the generation of a surplus of outputs over to inputs solely to labor: the value of labor-power ( $v$, effectively a subsistence wage), ${ }^{1}$ the value imparted to a product by a worker ( $v+s$ ), the rate of surplus value $(s / v)$, the value of machinery in production ( $c$, effectively its depreciation during use) the value the machine imparts to a product (also $c$ ), and the rate of profit ( $s /(c+v)$ ), and the "organic composition of capital ( $c / v$ ).

Writing long after the concept of energy had been developed, Marx did link energy to the value of labor power, and the production of surplus value by labor to its consumption and processing of that energy:

> Creation of value is transformation of labor-power into labor. Labor-power itself is energy transferred to a human organism by means of nourishing matter. (Marx 1867, Chapter 9, Footnote 2. Emphasis added)

Marx and Engels were also aware of the concept of energy and the very early work on the Laws of Thermodynamics (Burkett and Foster 2006). However, the role of energy in production was not explicitly recognised in their mathematical concepts of value.

Marx used Classical Economics to critique capitalism and advocate socialism (rather than, as did Smith and Ricardo, to champion capitalism over feudalism). This played a role in the decline of the Classical School and the rise of the Neoclassical. In Neoclassical economics, labor and capital are

[^0]treated, both as creating output, and as sharing in the distribution of income from that output, via the marginal productivity theory of production and distribution.

The archetypical representation of this joint theory of production and distribution is the CobbDouglas production function (Cobb and Douglas 1928). In contrast to the Classical school, the production of output was seen as a joint function of the two inputs (capital and labor) while, at the same time, the concept of a surplus of outputs over inputs became invisible.

Describing the actual production system as $P$ and their model of it as $P^{\prime}$, Cobb and Douglas stated that:
it is possible to apply mathematical analysis to the fictitious production $P^{\prime}$ but not to the actual production $P$ unless we make (or conceal) certain further assumptions. Let us choose the following assumptions and let their justification rest on what we deduce from them:
(A) The Physical Volume of Production is proportional to the Volume of Production due to manufacturing alone.
(B) Any departure of $P$ from $P^{\prime}$ may be represented by a change in the value of the coefficient of $L^{3 / 4} C^{1 / 4}$ so that always

$$
P=b \cdot L^{3 / 4} C^{1 / 4}
$$

where the value of $b$ is independent of the value of $L$ and $C$. (Cobb and Douglas 1928, p. 155)

Their deductions were that:
I. The marginal productivity of labor is $3 / 4 \mathrm{P} / \mathrm{L}$.
II. The marginal productivity of capital is $1 / 4 \mathrm{P} / \mathrm{C}$.
III. The productivity of total labor is $3 / 4 \mathrm{P}$.
IV. The total productivity of capital is $1 / 4 \mathrm{P}$.

This imputes three-fourths of the product to labor and one-fourth to capital for the period in question.
V. The elasticity of the product with respect to small changes in labor alone is $3 / 4$.
VI. The elasticity of the product with respect to small changes in capital alone is $3 / 4$.

This means that a small percentage change in labor alone has three times the effect that would be made by the same small percentage change in capital alone. (Cobb and Douglas 1928, pp. 155-6)

Cobb and Douglas did acknowledge that it would be desirable to include natural resources in the production function:
> we should ultimately look forward to including the third factor of natural resources in our equations and of seeing to what degree this modifies our conclusions and what light it throws upon the laws of rent. (Cobb and Douglas 1928, p. 165)

However, while other factors were introduced—such as time as a proxy for technological change (Solow 1956; Solow 1957) positive externalities from endogenous technical change (Romer 1990) and human capital (Mankiw, Romer et al. 1992; Mankiw, Phelps et al. 1995) -both natural resources and energy remained absent from what remains, despite logical criticisms (Shaikh 1974; McCombie 2000; Felipe and McCombie 2007), the canonical Neoclassical model of production: the CobbDouglas Production Function with neutral technical change $(A(t))$ and constant returns to scale in the two factors of production Labor $(L(t))$ and Capital $(K(t))$ :

$$
\begin{equation*}
Y=A \cdot K^{\alpha} \cdot L^{1-\alpha} \tag{0.1}
\end{equation*}
$$

The absence of real (material) resource flows and transformations in mainstream economic theory was first pointed out by Kenneth Boulding (Boulding, 1950, 1964, 1966). (Boulding 1945; Boulding 1973; Boulding 1992). Aptly living in Colorado, it was also Boulding who pointed out that the "cowboy economy" - where natural resources were effectively unlimited-was likely to be replaced by the "spaceship economy" where physical resources would become an absolute constraint (Boulding 1987; Boulding 1992). But work on developing a production function in which energy played a pivotal role fell predominantly to researchers whose training was in fields other than economics.

## Bringing energy back into economics

Georgescu-Roegen (Georgescu-Roegen 1979) was the first to propose a formula to include natural resources in a production function, by adding them to the standard Cobb-Douglas function (Georgescu-Roegen 1979, p. 17):

$$
Q=K^{\alpha} \cdot H^{\beta} \cdot R^{\gamma}, \alpha+\beta+\gamma=1
$$

However, he observed a weakness with this formula, in that it implies that output could still be positive with virtually zero input of resources:

> With this formula, one easily shows that Q may be sustained with H constant and with as little $R$ as one may wish, provided $K$ is sufficiently large. The argument obviously ignores the fact that an increased $K$ requires an increased amount of natural resources for producing the additional capital and for maintaining the entire capital stock. (Georgescu-Roegen 1979, p. 17)

Since Georgescu-Roegen (Georgescu-Roegen 1970; Georgescu-Roegen 1975; Georgescu-Roegen 1979; Georgescu-Roegen 1990; Georgescu-Roegen 1999; Georgescu-Roegen 2003), researchers who have made the major contributions to incorporating energy into production functions include Ayres, Costanza, Hannon, Joyce, Kummel, Lindenberger, van den Bergh, Voudouris and Warr (Ayres and Kneese 1969; Hannon 1975; Ayres 1978; Hannon, Costanza et al. 1986; Ayres 1995; Costanza, d'Arg

[^1]et al. 1997; Kummel 2011; Lindenberger and Kümmel 2011; Ayres and Voudouris 2014; Kümmel, Lindenberger et al. 2015).

The link between energy consumption and economic growth was first broached by the geographer Hannon and his student Joyce (Hannon and Joyce 1981). They introduced energy as a third factor of production, and allowed positive returns to scale.

Hannon and colleagues also extended the Leontief Input-Output model to reflect the inter-sectoral flows of energy, and carried out a series of interesting impact analyses (Hannon, 2010). Kummel, a theoretical physicist, conceived of the economy in thermodynamic terms, and argued for including energy $E$ (based on conventional IEA energy statistics) as a third factor of production (Kuemmel, 1989; Kuemmel, Lindenberger, \& Eichhorn, 2000; Kuemmel, Strassl, Gossner, \& Eichhorn, 1985).

In that work Kummel et al introduced an explicit production function, including capital $K$, labor $L$ and energy $E$ (known as the LinEx production function) as an alternative to the traditional two factor production functions (Cobb-Douglas and CES) used by Neoclassical economic modelers. It is equivalent to Georgescu-Roegen's formula with an initial level of output $Y_{0}$ and energy $E$ taking the place of natural resources:

$$
\begin{align*}
Y & =Y_{0} \cdot K^{\alpha} \cdot L^{\beta} \cdot E^{1-\alpha-\beta} \\
& =Y_{0} \cdot E \cdot\left(\frac{K}{E}\right)^{\alpha} \cdot\left(\frac{L}{E}\right)^{\beta} \tag{0.3}
\end{align*}
$$

Definition of parameters $a$ (representing capital efficiency) and $c$ (representing the energy demands of the capital stock when fully utilized) led to the LinEx form-so-called because it was linear in energy and exponential in the form of the parameters and input ratios:

$$
\begin{equation*}
Y=Y_{0} \cdot E \cdot e^{\left(a \cdot\left(2-\frac{L+E}{K}\right)+a \cdot c \cdot\left(\frac{L}{E}-1\right)\right)} \tag{0.4}
\end{equation*}
$$

The Kummel version of the LINEX production function yielded very good fits between the model and growth data for Germany, the UK and the US for periods of several decades. The results showed that the output elasticity of energy E was larger than the cost share (and larger than the output elasticity of labor, $L$ ), contradicting the standard textbook cost-share theorem that the output elasticity of a factor of production must be equal to its cost share in the GDP. Kuemmel et al proved mathematically that the output elasticity of energy, as a factor of production, can be larger than its cost share. It followed that energy was much more important as a factor of production than neoclassical economic growth theory assumed.

A modification of Kuemmel's LINEX model, whereby energy is replaced by "useful work" U (in the thermodynamic sense) was introduced (Ayres \& Warr, 2005, 2009). The most significant output of that work was to explain the Solow residual quite well for the US, by means of a LinEx model covering the entire $20^{\text {th }}$ century, using only two parameters. Again, the output elasticity of work $U$ was greater than the cost share (an improved version, bringing the model up to date and taking into account ICT capital explicitly, uses four factors but only three parameters (Warr \& Ayres, 2012).

## A production function in which energy is essential

However, the weakness noted by Georgescu-Roegen-that production can hypothetically occur with little or no energy input, given appropriate values for L, K and exponents (Georgescu-Roegen 1979, p. 17) -applies to all the production function alternatives noted above. Economics still requires a
production function that acknowledges the essential role of energy, since though economics cannot be reduced to applied thermodynamics (Anderson 1972), it also cannot be incompatible with the Laws of Thermodynamics without, as Eddington put it, having no choice but "to collapse in deepest humiliation":
> "If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations then so much the worse for Maxwell's equations. If it is found to be contradicted by observations well, these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation." (Eddington 1928, p.37)

An equation in which energy plays an essential role, and which is compatible with the Laws of Thermodynamics, can easily be derived by observing that the very idea of either labor or capital without energy is an impossibility. Labor without energy is a corpse; Capital without energy is a sculpture. Instead, labor and capital are means by which available energy ${ }^{3}$ is harnessed to generate output, which in its essence is useful work.

$$
\begin{equation*}
Y(E)=F(L(E), K(E)) \tag{0.5}
\end{equation*}
$$

The amount of energy which is actually converted by labor and capital into useful work depends on two factors: the energy required for the maintenance and reproduction of both labor and capital; and the efficiency with which the remaining available energy (known as Exergy) is applied to do work. ${ }^{4}$ Denoting the energy consumed per year by labor and machinery as $E_{L}$ and $E_{K}$ respectively, the exergy made available as $E x_{L}$ and $E x_{K}$, and the efficiency with which this exergy is employed as $e_{L}$ and $e_{K}$, we have:

$$
\begin{equation*}
Y(E)=F\left(L \cdot E_{L} \cdot \frac{E x_{L}}{E_{L}} \cdot e_{L}, K \cdot E_{K} \cdot \frac{E x_{K}}{E_{K}} \cdot e_{K}\right) \tag{0.6}
\end{equation*}
$$

Where $L$ stands for units of unskilled labor and $K$ stands for "units" of homogeneous capital (on which see Harcourt 1972 but also see below). Putting this in Cobb-Douglas form with constant returns to scale yields:

$$
\begin{equation*}
Y=A \cdot\left(K \cdot E_{K} \cdot \frac{E x_{K}}{E_{K}} \cdot e_{K}\right)^{\alpha} \cdot\left(L \cdot E_{L} \cdot \frac{E x_{L}}{E_{L}} \cdot e_{L}\right)^{1-\alpha} \tag{0.7}
\end{equation*}
$$

Dispensing with the now superfluous A term, this yields Equation (0.8) where the first two terms are the capital and labor inputs as in the standard CDPF, and the last two represent the energy harnessed by capital and labor respectively.

[^2]\[

$$
\begin{equation*}
Y=K^{\alpha} \cdot L^{1-\alpha} \cdot\left(E_{K} \cdot \frac{E x_{K}}{E_{K}} \cdot e_{K}\right)^{\alpha} \cdot\left(E_{L} \cdot \frac{E x_{L}}{E_{L}} \cdot e_{L}\right)^{1-\alpha} \tag{0.8}
\end{equation*}
$$

\]

This equation can be expressed in several different ways, depending on the topic being considered. In economic modelling, the ratios of exergy to energy can be defined $x_{L}=E x_{L} / E_{L}<1$ and $x_{K}=E x_{K} / E_{K}<1$ to yield:

$$
\begin{equation*}
Y=\left(K^{\alpha} \cdot L^{1-\alpha}\right) \cdot\left(E_{L} \cdot x_{L} \cdot e_{L}\right)^{1-\alpha} \cdot\left(E_{K} \cdot x_{K} \cdot e_{K}\right)^{\alpha} \tag{0.9}
\end{equation*}
$$

Expressed this way, the explanation for the "Solow Residual" is obvious: it is the increasing capacity over time of machines to harness energy. Improving technology has of course been essential to that increased capacity, but that technology itself has depended on increasing levels of energy throughout to achieve the measured increase in useful work per person over time.

In contrast, the energy input $E_{L}$ per unit of labor L obviously has a maximum, and the energy output per unit of unskilled labor can be treated as constant over time. The energy input $E_{K}$ per unit of "capital" K—which of course is an aggregate term for numerous different units of specialized machinery in different industries-and its exergy output, on the other hand, have risen from low levels in the machinery of the early Industrial Revolution to extremely high levels for advanced machinery today-and it will undoubtedly grow further in future.

Equation (0.9) recognises the necessary link between energy and machinery that Georgescu-Roegen noted was absent from his equation (0.2), but the separation of the "quantity" of capital from the amount of energy implies that one could have a very large quantity of capital processing a very small amount of energy. Of course, one cannot. The concept of a composite entity called capital is also highly problematic and subject to severe measurement problems (Sraffa 1960; Samuelson 1966; Harcourt 1972). However, these problems can be eliminated if the product $K \cdot E_{K}$ is replaced by $\mathrm{E}_{K}=K \cdot E_{K}$, where $\mathrm{E}_{K}$ represents the energy usage. We thus replace two unknown but related quantities with one well-defined quantity for which time series exist for many countries (see for example
http://databank.worldbank.org/data/reports.aspx?source=2\&series=EG.USE.PCAP.KG.OE\&country=, which provides data on per capita energy use in kg of oil equivalent). We therefore propose Equation (0.10), which we use in a preliminary empirical examination below:

$$
\begin{equation*}
Y=\left(\mathrm{E}_{K} \cdot x_{K} \cdot e_{K}\right)^{\alpha} \cdot\left(L \cdot E_{L} \cdot x_{L} \cdot e_{L}\right)^{1-\alpha}{ }_{5} \tag{0.10}
\end{equation*}
$$

## Preliminary fitting to data

Since the data is in per capita form, Equation (0.10) needs to be converted to GDP per capita.
Defining $N$ as the population, and $\Lambda=\left(E_{L} \cdot x_{L} \cdot e_{L}\right)^{1-\alpha}$ as the energy contribution of a unit of labor ${ }^{6}$,

[^3]we now have what we have christened the Energy-Aware Cobb-Douglas Production Function (EACDPF):
\[

$$
\begin{equation*}
\frac{Y}{N}=\Lambda \cdot \lambda^{1-\alpha} \cdot\left(\frac{\mathrm{E}_{K}}{N}\right)^{\alpha} \cdot\left(x_{K} \cdot e_{K}\right)^{\alpha} \tag{0.11}
\end{equation*}
$$

\]

The exergy/energy ratio and efficiency terms for capital are clearly variable over time, but unfortunately must be ignored in this examination since we do not have data for them.

In GDP per capita form, the standard Cobb-Douglas Production Function (CDPF) is Equation (0.12):

$$
\begin{equation*}
\frac{Y}{N}=A \cdot \lambda^{1-\alpha} \cdot\left(\frac{K}{N}\right)^{\alpha} \tag{0.12}
\end{equation*}
$$

We perform a simple regression of the change GDP per capita in the USA (Figure 2) against Equations (0.13) (where data is not available for $\hat{x}_{K}$ and $\hat{e}_{K}$ ) and (0.14):

$$
\begin{gather*}
\hat{Y}_{P C}=(1-\alpha) \cdot \hat{\lambda}+\alpha \cdot \hat{\mathrm{E}}_{P C}+\alpha \cdot\left(\hat{x}_{K}+\hat{e}_{K}\right)  \tag{0.13}\\
\hat{Y}_{P C}=(1-\alpha) \cdot \hat{\lambda}+\alpha \cdot \hat{K}_{P C} \tag{0.14}
\end{gather*}
$$



Both equations include the employment rate (Figure 3), which trended up from 1950 till 2000 and has since trended down.


The different inputs to the equations for which data exist are the imputed level of capital stock per person (Figure 4) and the recorded energy consumption per person (Figure 5)

Capital Stock to Population Ratio USA

https://fred.stlouisfed.org/series/RKNANPUSA666NRUG \& EMRATIO\#
While imputed capital per head is shown as rising continuously, recorded energy usage per head has been much more volatile, rising rapidly from 1960 till 1973, then falling, rising and falling sharply once more over the periods of OPEC I and OPEC II (the two fourfold increases in the oil price per barrel in 1973/4 and 1989/90 respectively). Since then, a slight rise in per capita energy consumption terminated in 2000, leading to a fall in energy consumption that resulted in energy consumption per head falling to mid-1960s levels by 2015. These extreme swings in total energy consumption per capita involve substantial changes (generally improvements) in the exergy/energy and efficiency of exergy usage by capital components of Equation (0.9), for which data is not available.

Figure 5: US Energy use per head


Though the capital stock and energy per head data series are very different, their changes are moderately correlated-see Figure 6.

Rates of Change (Correlation 0.5)


Despite the absence of critical exergy-energy and efficiency data, the Energy-Augmented CobbDouglas Production Function performs notably better than the standard Cobb-Douglas Production Function. The correlation coefficient of Equation (0.13) is 0.81 ; the correlation coefficient of Equation (0.14) is 0.73 . ${ }^{7}$

[^4]Correlation of per capita GDP change \& change in CDPF facto


Correlation of per capita GDP change \& change in EACDPF fact


## Evaluating existing production functions

This Energy-Augmented CDPF fulfils an ambition that Cobb and Douglas expressed, of "including the third factor of natural resources in our equations and of seeing to what degree this modifies our conclusions and what light it throws upon the laws of rent" (Cobb and Douglas 1928, p. 165). The EACDPF clearly extends Cobb and Douglas's work by making it compatible with the Laws of Thermodynamics, which is essential if a production function is to be taken seriously at all as a description of the physical process of production, as Eddington so emphatically put it (Eddington 1928).

However, many of the implications which have been customarily drawn from the CDPF can no longer be supported. The primary casualty here is the implicit link between the CDPF and the marginal productivity theory of income distribution. Numerically, the marginal contribution of labor to production in Equation (0.9) reduces to the exergy contribution of a single worker, which is of the order of 1000 calories per day: clearly the wage far exceeds this value. Epistemologically, the very concept of the marginal productivity of labor and capital in the absence of energy no longer makes sense: instead both factors are means to harness available energy, and it is the change in the
amount of energy they harness that is the true source of a change in the level of output-but energy per se does not receive a payment.

In this light, the distribution of income does not reflect the marginal productivity of the inputs, but is instead reflective of the ability of labor and the owners of machinery to bargain over the allocation of the surplus generated in production by harnessing the energy we find on this open system we call Planet Earth.

This has both positive and negative consequences for a perennial of economic debate, the question of whether or not labor is "exploited" by capital. The initial negative-at least for customary debate-is that the argument that the wage is the marginal product of labor, and therefore no exploitation is occurring, must be dispensed with. The positive however is that, since the wage is far higher than labor's marginal productivity, clearly it cannot be argued that labor is being exploited by capital. But nor can it be argued that labor "exploits" capital. Instead, both labor and capital-where the latter is properly defined in this context as the owners of machinery, rather than the machinery itself-exploit the energy that the collective functioning of labor and machinery are able to convert into useful work.

The Marxist proposition that all surplus comes from labor, and its corollary that a machine adds nothing to production beyond its own depreciation ("However useful a given kind of raw material, or a machine, or other means of production may be, though it may cost $£ 150 \ldots$ yet it cannot, under any circumstances, add to the value of the product more than $£ 150$ ", Marx 1867) can also be dispensed with. These propositions, put into the form of Equation (0.8), equate Marx's concept of the rate of surplus value $s / v$ to the Exergy/Energy ratio for labor, and argue that the exergy contribution of machinery to production is zero:

$$
\begin{equation*}
Y=K^{\alpha} \cdot L^{1-\alpha} \cdot\left(E_{K} \cdot \frac{0}{E_{K}} \cdot e_{K}\right)^{\alpha} \cdot\left(v \cdot \frac{s}{v} \cdot e_{L}\right)^{1-\alpha} \tag{0.15}
\end{equation*}
$$

The only way this can be shown to produce non-zero output at all is if the $\alpha$ exponent is set to zero, yielding:

$$
\begin{equation*}
Y=L \cdot s \cdot e_{L} \tag{0.16}
\end{equation*}
$$

This in turn implies that income per capita is of the order of 1000 calories per day, which is an empirical absurdity to add to the logical absurdities that have bedevilled the Labor Theory of Value since its inception (Böhm-Bawerk 1896; Steedman 1977; Keen 1993).

Post-Keynesian production theory fares rather better than both Neoclassical and Marxist theories. Post-Keynesian modellers generally use production functions where output is the minimum of either a capital to output ratio, or an output to labor ratio, where the latter applies if capacity utilization $u_{K}$ is below its maximum level:

$$
\begin{equation*}
Y=\min \left(\frac{K}{v}, a \cdot L\right) \tag{0.17}
\end{equation*}
$$

In place of the Neoclassical presumption of smooth factor substitutability, Post Keynesian theory argues for an inflexible (though variable over the long term) ratio a between utilized machinery and labor:

$$
\begin{equation*}
Y=u_{K} \cdot \frac{K}{v}=a \cdot L \tag{0.18}
\end{equation*}
$$

This approach can be made energy-aware by acknowledging that output is proportional to the exergy output of machinery, while employment is proportional to output, and the energy input to machinery has grown exponentially over time:

$$
\begin{align*}
Y\left(E_{K}\right) & =U_{K} \cdot E_{K} \cdot x_{K} \cdot e_{K} \\
& \left(=u_{K} \cdot K \cdot E_{K} \cdot x_{K} \cdot e_{K}\right)  \tag{0.19}\\
L & =a \cdot Y\left(E_{K}\right) \\
E_{K}(t) & =E_{0} \cdot e^{\alpha \cdot t}
\end{align*}
$$

The role of energy can also be expressed in a Sraffa-Leontief style production function, with the energy inputs for labor and commodity inputs shown separately: this is more realistic than the EACDPF form, and could also provide some closure on the Capital Controversies debates (Sraffa 1960, Samuelson 1966, Pasinetti 2000, Pasinetti, Fisher et al. 2003, Pasinetti 2005), since while machinery is clearly heterogeneous, from this energy-aware perspective, all machines have a homogenous purpose-to turn energy into useful work-and in our electric-power-dominated production system, most machines have a homogeneous energy input as well.

## Conclusion and Future Work

This energy-aware production function has many more implications than can be explored in this preliminary note. The equation is clearly compatible with the Laws of Thermodynamics, since as well as acknowledging that production without energy is impossible, energy embodied in useful work is clearly less than the total energy inputs. It can be expanded to include the role of raw materials as distinct from energy in production. And it provides a clear link between economics and ecology.

Crucially, it forces us to perceive the roles of both capital and labor with respect to energy as the Physiocrats once perceived the role of Husbandmen with respect to the land, as the means by which the we harvest "that independent and disposable part, which the earth produces as a free gift to the proprietor over and above what he has disbursed", out of which "he is enabled to live without labor, and which he can carry wherever he will" (Turgot 1774, pp. 15-16).

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| Date | GDP per ćEmploymerCapital stocEnergy per Change pe Change pe Change pe Cobb Doug |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1960 | 17323.76 | 0.563 | 100 | 5641.741 |  |  |  |  |
| 1960.083 | 17380 | 0.56 | 100.5427 | 5630.809 |  |  |  |  |
| 1960.166 | 17362.38 | 0.562 | 101.1713 | 5621.416 |  |  |  |  |
| 1960.25 | 17303.65 | 0.554 | 101.8687 | 5613.56 |  |  |  |  |
| 1960.333 | 17253 | 0.564 | 102.6178 | 5607.243 |  |  |  |  |
| 1960.416 | 17244.11 | 0.564 | 103.4019 | 5602.464 |  |  |  |  |
| 1960.5 | 17248.7 | 0.565 | 104.204 | 5599.223 |  |  |  |  |
| 1960.583 | 17223 | 0.562 | 105.0075 | 5597.521 |  |  |  |  |
| 1960.666 | 17138.48 | 0.561 | 105.7958 | 5597.356 |  |  |  |  |
| 1960.75 | 17027.59 | 0.564 | 106.5523 | 5598.73 |  |  |  |  |
| 1960.833 | 16938 | 0.558 | 107.2607 | 5601.642 |  |  |  |  |
| 1960.916 | 16906.74 | 0.561 | 107.9045 | 5606.091 |  |  |  |  |
| 1961 | 16928.17 | 0.557 | 108.4675 | 5612.08 | 8.47\% | -0.53\% | -2.28\% | 1.32\% |
| 1961.083 | 16986 | 0.557 | 108.9381 | 5619.589 | 8.35\% | -0.20\% | -2.27\% | 1.69\% |
| 1961.166 | 17064.71 | 0.555 | 109.3227 | 5628.534 | 8.06\% | 0.13\% | -1.71\% | 1.08\% |
| 1961.25 | 17151.92 | 0.556 | 109.6323 | 5638.814 | 7.62\% | 0.45\% | -0.88\% | 2.18\% |
| 1961.333 | 17236 | 0.552 | 109.8777 | 5650.327 | 7.07\% | 0.77\% | -0.10\% | 0.17\% |
| 1961.416 | 17308.92 | 0.552 | 110.0699 | 5662.971 | 6.45\% | 1.08\% | 0.38\% | 0.02\% |
| 1961.5 | 17376.97 | 0.556 | 110.2195 | 5676.643 | 5.77\% | 1.38\% | 0.74\% | 0.25\% |
| 1961.583 | 17450 | 0.552 | 110.3374 | 5691.243 | 5.08\% | 1.67\% | 1.32\% | -0.07\% |
| 1961.666 | 17535.29 | 0.553 | 110.4341 | 5706.668 | 4.38\% | 1.95\% | 2.32\% | 0.03\% |
| 1961.75 | 17629.83 | 0.55 | 110.5202 | 5722.817 | 3.72\% | 2.22\% | 3.54\% | -0.93\% |
| 1961.833 | 17728 | 0.553 | 110.6064 | 5739.588 | 3.12\% | 2.46\% | 4.66\% | 0.11\% |
| 1961.916 | 17824.01 | 0.555 | 110.703 | 5756.878 | 2.59\% | 2.69\% | 5.43\% | -0.15\% |
| 1962 | 17911.27 | 0.553 | 110.8206 | 5774.586 | 2.17\% | 2.90\% | 5.81\% | 0.00\% |
| 1962.083 | 17983 | 0.554 | 110.9672 | 5792.613 | 1.86\% | 3.08\% | 5.87\% | 0.06\% |
| 1962.166 | 18035.22 | 0.557 | 111.1413 | 5810.869 | 1.66\% | 3.24\% | 5.69\% | 0.69\% |
| 1962.25 | 18075.19 | 0.557 | 111.3388 | 5829.267 | 1.56\% | 3.38\% | 5.38\% | 0.52\% |
| 1962.333 | 18113 | 0.554 | 111.5561 | 5847.718 | 1.53\% | 3.49\% | 5.09\% | 0.65\% |
| 1962.416 | 18155.05 | 0.557 | 111.7892 | 5866.136 | 1.56\% | 3.59\% | 4.89\% | 1.07\% |
| 1962.5 | 18193.04 | 0.556 | 112.0343 | 5884.433 | 1.65\% | 3.66\% | 4.70\% | 0.41\% |
| 1962.583 | 18215 | 0.553 | 112.2876 | 5902.522 | 1.77\% | 3.71\% | 4.38\% | 0.58\% |
| 1962.666 | 18214.41 | 0.557 | 112.5452 | 5920.315 | 1.91\% | 3.74\% | 3.87\% | 1.02\% |
| 1962.75 | 18206.51 | 0.557 | 112.8034 | 5937.726 | 2.07\% | 3.76\% | 3.27\% | 1.47\% |
| 1962.833 | 18212 | 0.555 | 113.0585 | 5954.665 | 2.22\% | 3.75\% | 2.73\% | 0.83\% |
| 1962.916 | 18245.58 | 0.552 | 113.3066 | 5971.047 | 2.35\% | 3.72\% | 2.37\% | 0.18\% |
| 1963 | 18297.99 | 0.552 | 113.544 | 5986.784 | 2.46\% | 3.67\% | 2.16\% | 0.48\% |
| 1963.083 | 18354 | 0.552 | 113.7686 | 6001.813 | 2.52\% | 3.61\% | 2.06\% | 0.36\% |
| 1963.166 | 18403.65 | 0.551 | 113.9839 | 6016.173 | 2.56\% | 3.53\% | 2.04\% | -0.17\% |
| 1963.25 | 18458.15 | 0.553 | 114.195 | 6029.927 | 2.57\% | 3.44\% | 2.12\% | 0.10\% |
| 1963.333 | 18534 | 0.555 | 114.4069 | 6043.139 | 2.56\% | 3.34\% | 2.32\% | 0.77\% |
| 1963.416 | 18639.12 | 0.553 | 114.6248 | 6055.873 | 2.54\% | 3.23\% | 2.67\% | 0.10\% |
| 1963.5 | 18747.11 | 0.553 | 114.8535 | 6068.191 | 2.52\% | 3.12\% | 3.05\% | 0.22\% |
| 1963.583 | 18823 | 0.554 | 115.0981 | 6080.158 | 2.50\% | 3.01\% | 3.34\% | 0.76\% |
| 1963.666 | 18845.77 | 0.554 | 115.3636 | 6091.836 | 2.50\% | 2.90\% | 3.47\% | 0.22\% |
| 1963.75 | 18850.2 | 0.555 | 115.6548 | 6103.29 | 2.53\% | 2.79\% | 3.54\% | 0.36\% |
| 1963.833 | 18885 | 0.555 | 115.9768 | 6114.582 | 2.58\% | 2.69\% | 3.70\% | 0.65\% |
| 1963.916 | 18983.12 | 0.554 | 116.3344 | 6125.777 | 2.67\% | 2.59\% | 4.04\% | 0.94\% |
| 1964 | 19114.43 | 0.553 | 116.7324 | 6136.938 | 2.81\% | 2.51\% | 4.46\% | 0.84\% |
| 1964.083 | 19233 | 0.553 | 117.1739 | 6148.138 | 2.99\% | 2.44\% | 4.79\% | 0.88\% |
| 1964.166 | 19305.8 | 0.556 | 117.6541 | 6159.488 | 3.22\% | 2.38\% | 4.90\% | 1.49\% |


| 1964.25 | 19351.34 | 0.555 | 118.1661 | 6171.11 | 3.48\% | 2.34\% | 4.84\% | 1.14\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1964.333 | 19401 | 0.559 | 118.7034 | 6183.124 | 3.76\% | 2.32\% | 4.68\% | 1.48\% |
| 1964.416 | 19475.22 | 0.561 | 119.2592 | 6195.652 | 4.04\% | 2.31\% | 4.49\% | 2.10\% |
| 1964.5 | 19550.65 | 0.556 | 119.8269 | 6208.814 | 4.33\% | 2.32\% | 4.29\% | 1.49\% |
| 1964.583 | 19593 | 0.557 | 120.3999 | 6222.731 | 4.61\% | 2.34\% | 4.09\% | 1.56\% |
| 1964.666 | 19583.32 | 0.557 | 120.9717 | 6237.526 | 4.86\% | 2.39\% | 3.91\% | 1.62\% |
| 1964.75 | 19564.06 | 0.557 | 121.5357 | 6253.318 | 5.08\% | 2.46\% | 3.79\% | 1.54\% |
| 1964.833 | 19593 | 0.556 | 122.0854 | 6270.229 | 5.27\% | 2.55\% | 3.75\% | 1.45\% |
| 1964.916 | 19708.45 | 0.557 | 122.6142 | 6288.379 | 5.40\% | 2.65\% | 3.82\% | 1.76\% |
| 1965 | 19870.8 | 0.556 | 123.1157 | 6307.89 | 5.47\% | 2.79\% | 3.96\% | 1.77\% |
| 1965.083 | 20021 | 0.557 | 123.585 | 6328.825 | 5.47\% | 2.94\% | 4.10\% | 1.91\% |
| 1965.166 | 20115.97 | 0.557 | 124.0237 | 6351.012 | 5.41\% | 3.11\% | 4.20\% | 1.49\% |
| 1965.25 | 20176.65 | 0.559 | 124.4351 | 6374.223 | 5.31\% | 3.29\% | 4.26\% | 1.87\% |
| 1965.333 | 20240 | 0.56 | 124.8223 | 6398.227 | 5.15\% | 3.48\% | 4.32\% | 1.42\% |
| 1965.416 | 20334.32 | 0.562 | 125.1884 | 6422.797 | 4.97\% | 3.67\% | 4.41\% | 1.38\% |
| 1965.5 | 20453.31 | 0.561 | 125.5365 | 6447.702 | 4.76\% | 3.85\% | 4.62\% | 1.87\% |
| 1965.583 | 20582 | 0.565 | 125.87 | 6472.713 | 4.54\% | 4.02\% | 5.05\% | 2.21\% |
| 1965.666 | 20709.97 | 0.563 | 126.1917 | 6497.601 | 4.32\% | 4.17\% | 5.75\% | 1.89\% |
| 1965.75 | 20844.9 | 0.562 | 126.505 | 6522.137 | 4.09\% | 4.30\% | 6.55\% | 1.70\% |
| 1965.833 | 20999 | 0.564 | 126.8128 | 6546.092 | 3.87\% | 4.40\% | 7.18\% | 2.05\% |
| 1965.916 | 21175.81 | 0.564 | 127.1182 | 6569.236 | 3.67\% | 4.47\% | 7.45\% | 1.86\% |
| 1966 | 21344.11 | 0.566 | 127.4244 | 6591.341 | 3.50\% | 4.49\% | 7.41\% | 2.22\% |
| 1966.083 | 21464 | 0.567 | 127.7338 | 6612.244 | 3.36\% | 4.48\% | 7.21\% | 2.19\% |
| 1966.166 | 21508.99 | 0.566 | 128.0467 | 6632.058 | 3.24\% | 4.43\% | 6.92\% | 2.02\% |
| 1966.25 | 21506.16 | 0.566 | 128.3629 | 6650.962 | 3.16\% | 4.34\% | 6.59\% | 1.73\% |
| 1966.333 | 21496 | 0.568 | 128.6821 | 6669.136 | 3.09\% | 4.23\% | 6.21\% | 1.84\% |
| 1966.416 | 21509.98 | 0.567 | 129.004 | 6686.76 | 3.05\% | 4.11\% | 5.78\% | 1.43\% |
| 1966.5 | 21543.51 | 0.569 | 129.3285 | 6704.014 | 3.02\% | 3.98\% | 5.33\% | 1.82\% |
| 1966.583 | 21583 | 0.569 | 129.6552 | 6721.076 | 3.01\% | 3.84\% | 4.86\% | 1.28\% |
| 1966.666 | 21618.53 | 0.57 | 129.984 | 6738.128 | 3.01\% | 3.70\% | 4.39\% | 1.68\% |
| 1966.75 | 21655.01 | 0.571 | 130.3145 | 6755.349 | 3.01\% | 3.58\% | 3.89\% | 1.95\% |
| 1966.833 | 21701 | 0.571 | 130.6465 | 6772.918 | 3.02\% | 3.47\% | 3.34\% | 1.69\% |
| 1966.916 | 21760.1 | 0.574 | 130.9798 | 6791.015 | 3.04\% | 3.38\% | 2.76\% | 2.09\% |
| 1967 | 21815.9 | 0.573 | 131.3141 | 6809.82 | 3.05\% | 3.31\% | 2.21\% | 1.69\% |
| 1967.083 | 21847 | 0.571 | 131.6492 | 6829.466 | 3.07\% | 3.29\% | 1.78\% | 1.30\% |
| 1967.166 | 21840.65 | 0.57 | 131.9852 | 6849.891 | 3.08\% | 3.28\% | 1.54\% | 1.30\% |
| 1967.25 | 21818.78 | 0.568 | 132.322 | 6870.99 | 3.08\% | 3.31\% | 1.45\% | 1.04\% |
| 1967.333 | 21812 | 0.571 | 132.6598 | 6892.655 | 3.09\% | 3.35\% | 1.47\% | 1.17\% |
| 1967.416 | 21841.67 | 0.57 | 132.9984 | 6914.778 | 3.10\% | 3.41\% | 1.54\% | 1.17\% |
| 1967.5 | 21892.26 | 0.573 | 133.338 | 6937.253 | 3.10\% | 3.48\% | 1.62\% | 1.30\% |
| 1967.583 | 21939 | 0.574 | 133.6786 | 6959.973 | 3.10\% | 3.55\% | 1.65\% | 1.43\% |
| 1967.666 | 21966.17 | 0.574 | 134.0202 | 6982.829 | 3.11\% | 3.63\% | 1.61\% | 1.30\% |
| 1967.75 | 21994.31 | 0.574 | 134.3629 | 7005.715 | 3.11\% | 3.71\% | 1.57\% | 1.17\% |
| 1967.833 | 22053 | 0.575 | 134.7067 | 7028.523 | 3.11\% | 3.77\% | 1.62\% | 1.30\% |
| 1967.916 | 22162.4 | 0.575 | 135.0515 | 7051.147 | 3.11\% | 3.83\% | 1.85\% | 0.91\% |
| 1968 | 22305.04 | 0.576 | 135.3976 | 7073.479 | 3.11\% | 3.87\% | 2.24\% | 1.17\% |
| 1968.083 | 22454 | 0.57 | 135.7446 | 7095.442 | 3.11\% | 3.89\% | 2.78\% | 0.65\% |
| 1968.166 | 22586.5 | 0.573 | 136.0918 | 7117.082 | 3.11\% | 3.90\% | 3.41\% | 1.17\% |
| 1968.25 | 22696.24 | 0.574 | 136.438 | 7138.474 | 3.11\% | 3.89\% | 4.02\% | 1.57\% |
| 1968.333 | 22781 | 0.574 | 136.7822 | 7159.694 | 3.11\% | 3.87\% | 4.44\% | 1.17\% |
| 1968.416 | 22839.32 | 0.578 | 137.1234 | 7180.818 | 3.10\% | 3.85\% | 4.57\% | 1.83\% |
| 1968.5 | 22872.61 | 0.578 | 137.4605 | 7201.922 | 3.09\% | 3.82\% | 4.48\% | 1.43\% |


| 1968.583 | 22883 | 0.576 | 137.7924 | 7223.082 | 3.08\% | 3.78\% | 4.30\% | 1.03\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1968.666 | 22877.26 | 0.575 | 138.118 | 7244.373 | 3.06\% | 3.75\% | 4.15\% | 0.90\% |
| 1968.75 | 22880.64 | 0.575 | 138.4364 | 7265.872 | 3.03\% | 3.71\% | 4.03\% | 0.89\% |
| 1968.833 | 22923 | 0.575 | 138.7465 | 7287.653 | 3.00\% | 3.69\% | 3.95\% | 0.75\% |
| 1968.916 | 23021.2 | 0.576 | 139.0471 | 7309.793 | 2.96\% | 3.67\% | 3.88\% | 0.87\% |
| 1969 | 23139.96 | 0.577 | 139.3373 | 7332.369 | 2.91\% | 3.66\% | 3.74\% | 0.86\% |
| 1969.083 | 23231 | 0.576 | 139.6164 | 7355.399 | 2.85\% | 3.66\% | 3.46\% | 1.50\% |
| 1969.166 | 23260.73 | 0.579 | 139.8849 | 7378.683 | 2.79\% | 3.68\% | 2.99\% | 1.48\% |
| 1969.25 | 23254.4 | 0.579 | 140.1437 | 7401.965 | 2.72\% | 3.69\% | 2.46\% | 1.33\% |
| 1969.333 | 23252 | 0.579 | 140.3938 | 7424.988 | 2.64\% | 3.71\% | 2.07\% | 1.31\% |
| 1969.416 | 23281.04 | 0.578 | 140.636 | 7447.495 | 2.56\% | 3.71\% | 1.93\% | 0.64\% |
| 1969.5 | 23319.27 | 0.58 | 140.8714 | 7469.231 | 2.48\% | 3.71\% | 1.95\% | 0.88\% |
| 1969.583 | 23332 | 0.58 | 141.1006 | 7489.939 | 2.40\% | 3.69\% | 1.96\% | 1.12\% |
| 1969.666 | 23295.34 | 0.581 | 141.3248 | 7509.362 | 2.32\% | 3.66\% | 1.83\% | 1.36\% |
| 1969.75 | 23228.62 | 0.581 | 141.5447 | 7527.243 | 2.25\% | 3.60\% | 1.52\% | 1.34\% |
| 1969.833 | 23162 | 0.581 | 141.7613 | 7543.327 | 2.17\% | 3.51\% | 1.04\% | 1.33\% |
| 1969.916 | 23118.2 | 0.581 | 141.9754 | 7557.357 | 2.11\% | 3.39\% | 0.42\% | 1.18\% |
| 1970 | 23090.31 | 0.581 | 142.188 | 7569.077 | 2.05\% | 3.23\% | -0.21\% | 1.03\% |
| 1970.083 | 23064 | 0.58 | 142.3999 | 7578.349 | 1.99\% | 3.03\% | -0.72\% | 1.02\% |
| 1970.166 | 23031.67 | 0.579 | 142.6118 | 7585.522 | 1.95\% | 2.80\% | -0.98\% | 0.49\% |
| 1970.25 | 23012.65 | 0.579 | 142.8247 | 7591.063 | 1.91\% | 2.55\% | -1.04\% | 0.48\% |
| 1970.333 | 23033 | 0.579 | 143.0391 | 7595.437 | 1.88\% | 2.30\% | -0.94\% | 0.47\% |
| 1970.416 | 23102.79 | 0.575 | 143.2558 | 7599.113 | 1.86\% | 2.04\% | -0.77\% | 0.08\% |
| 1970.5 | 23168.1 | 0.573 | 143.4757 | 7602.558 | 1.85\% | 1.79\% | -0.65\% | -0.44\% |
| 1970.583 | 23159 | 0.574 | 143.6994 | 7606.238 | 1.84\% | 1.55\% | -0.74\% | -0.32\% |
| 1970.666 | 23037.24 | 0.572 | 143.9277 | 7610.621 | 1.84\% | 1.35\% | -1.11\% | -0.70\% |
| 1970.75 | 22891.22 | 0.57 | 144.1614 | 7616.174 | 1.85\% | 1.18\% | -1.45\% | -0.96\% |
| 1970.833 | 22841 | 0.57 | 144.4012 | 7623.365 | 1.86\% | 1.06\% | -1.39\% | -0.95\% |
| 1970.916 | 22966.46 | 0.569 | 144.6478 | 7632.659 | 1.88\% | 1.00\% | -0.66\% | -1.08\% |
| 1971 | 23186.8 | 0.567 | 144.902 | 7644.525 | 1.91\% | 1.00\% | 0.42\% | -1.33\% |
| 1971.083 | 23381 | 0.568 | 145.1644 | 7659.304 | 1.94\% | 1.07\% | 1.37\% | -1.07\% |
| 1971.166 | 23459.57 | 0.566 | 145.435 | 7676.836 | 1.98\% | 1.20\% | 1.86\% | -1.19\% |
| 1971.25 | 23458.93 | 0.564 | 145.7137 | 7696.838 | 2.02\% | 1.39\% | 1.94\% | -1.44\% |
| 1971.333 | 23447 | 0.566 | 146.0004 | 7719.025 | 2.07\% | 1.63\% | 1.80\% | -1.17\% |
| 1971.416 | 23474.45 | 0.566 | 146.2948 | 7743.111 | 2.12\% | 1.89\% | 1.61\% | -0.64\% |
| 1971.5 | 23522.97 | 0.562 | 146.597 | 7768.812 | 2.18\% | 2.19\% | 1.53\% | -0.90\% |
| 1971.583 | 23557 | 0.565 | 146.9066 | 7795.844 | 2.23\% | 2.49\% | 1.72\% | -0.62\% |
| 1971.666 | 23553.49 | 0.566 | 147.2237 | 7823.922 | 2.29\% | 2.80\% | 2.24\% | -0.21\% |
| 1971.75 | 23539.35 | 0.566 | 147.548 | 7852.761 | 2.35\% | 3.11\% | 2.83\% | 0.06\% |
| 1971.833 | 23554 | 0.566 | 147.8795 | 7882.076 | 2.41\% | 3.39\% | 3.12\% | 0.08\% |
| 1971.916 | 23627.74 | 0.568 | 148.2179 | 7911.583 | 2.47\% | 3.65\% | 2.88\% | 0.49\% |
| 1972 | 23754.48 | 0.568 | 148.5632 | 7940.998 | 2.53\% | 3.88\% | 2.45\% | 0.76\% |
| 1972.083 | 23919 | 0.567 | 148.915 | 7970.024 | 2.58\% | 4.06\% | 2.30\% | 0.51\% |
| 1972.166 | 24103.42 | 0.567 | 149.2724 | 7998.319 | 2.64\% | 4.19\% | 2.74\% | 0.79\% |
| 1972.25 | 24279.17 | 0.569 | 149.6341 | 8025.533 | 2.69\% | 4.27\% | 3.50\% | 1.34\% |
| 1972.333 | 24415 | 0.569 | 149.9991 | 8051.312 | 2.74\% | 4.30\% | 4.13\% | 1.08\% |
| 1972.416 | 24490.97 | 0.57 | 150.3661 | 8075.303 | 2.78\% | 4.29\% | 4.33\% | 1.23\% |
| 1972.5 | 24532.42 | 0.57 | 150.734 | 8097.155 | 2.82\% | 4.23\% | 4.29\% | 1.77\% |
| 1972.583 | 24576 | 0.57 | 151.1016 | 8116.516 | 2.86\% | 4.11\% | 4.33\% | 1.38\% |
| 1972.666 | 24652.14 | 0.571 | 151.4679 | 8133.032 | 2.88\% | 3.95\% | 4.66\% | 1.38\% |
| 1972.75 | 24766.37 | 0.57 | 151.8316 | 8146.351 | 2.90\% | 3.74\% | 5.21\% | 1.26\% |
| 1972.833 | 24918 | 0.57 | 152.1917 | 8156.121 | 2.92\% | 3.48\% | 5.79\% | 1.26\% |


| 1972.916 | 25102.14 | 0.572 | 152.5469 | 8161.989 | 2.92\% | 3.17\% | 6.24\% | 1.26\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1973 | 25297.1 | 0.573 | 152.8962 | 8163.604 | 2.92\% | 2.80\% | 6.49\% | 1.39\% |
| 1973.083 | 25477 | 0.571 | 153.2385 | 8160.72 | 2.90\% | 2.39\% | 6.51\% | 1.25\% |
| 1973.166 | 25617.46 | 0.575 | 153.5731 | 8153.526 | 2.88\% | 1.94\% | 6.28\% | 1.78\% |
| 1973.25 | 25700.08 | 0.578 | 153.8994 | 8142.316 | 2.85\% | 1.46\% | 5.85\% | 1.90\% |
| 1973.333 | 25708 | 0.577 | 154.2167 | 8127.388 | 2.81\% | 0.94\% | 5.30\% | 1.76\% |
| 1973.416 | 25638.78 | 0.577 | 154.5243 | 8109.037 | 2.77\% | 0.42\% | 4.69\% | 1.61\% |
| 1973.5 | 25547.82 | 0.58 | 154.8216 | 8087.559 | 2.71\% | -0.12\% | 4.14\% | 1.99\% |
| 1973.583 | 25505 | 0.579 | 155.1081 | 8063.25 | 2.65\% | -0.66\% | 3.78\% | 1.85\% |
| 1973.666 | 25554.84 | 0.578 | 155.3829 | 8036.405 | 2.58\% | -1.19\% | 3.66\% | 1.57\% |
| 1973.75 | 25640.54 | 0.579 | 155.6456 | 8007.32 | 2.51\% | -1.71\% | 3.53\% | 1.81\% |
| 1973.833 | 25680 | 0.581 | 155.8954 | 7976.292 | 2.43\% | -2.20\% | 3.06\% | 2.06\% |
| 1973.916 | 25617.58 | 0.582 | 156.1317 | 7943.615 | 2.35\% | -2.68\% | 2.05\% | 1.90\% |
| 1974 | 25503.63 | 0.582 | 156.3539 | 7909.586 | 2.26\% | -3.11\% | 0.82\% | 1.74\% |
| 1974.083 | 25415 | 0.582 | 156.5618 | 7874.59 | 2.17\% | -3.51\% | -0.24\% | 1.99\% |
| 1974.166 | 25404.75 | 0.582 | 156.7569 | 7839.364 | 2.07\% | -3.85\% | -0.83\% | 1.43\% |
| 1974.25 | 25430.73 | 0.582 | 156.9414 | 7804.734 | 1.98\% | -4.15\% | -1.05\% | 1.01\% |
| 1974.333 | 25427 | 0.58 | 157.1173 | 7771.527 | 1.88\% | -4.38\% | -1.09\% | 0.86\% |
| 1974.416 | 25347.58 | 0.58 | 157.2866 | 7740.569 | 1.79\% | -4.54\% | -1.14\% | 0.84\% |
| 1974.5 | 25226.31 | 0.58 | 157.4513 | 7712.687 | 1.70\% | -4.64\% | -1.26\% | 0.42\% |
| 1974.583 | 25117 | 0.58 | 157.6134 | 7688.707 | 1.62\% | -4.65\% | -1.52\% | 0.53\% |
| 1974.666 | 25056.9 | 0.578 | 157.775 | 7669.456 | 1.54\% | -4.57\% | -1.95\% | 0.38\% |
| 1974.75 | 25017.07 | 0.577 | 157.9381 | 7655.759 | 1.47\% | -4.39\% | -2.43\% | 0.11\% |
| 1974.833 | 24952 | 0.576 | 158.1047 | 7648.444 | 1.42\% | -4.11\% | -2.83\% | -0.29\% |
| 1974.916 | 24832.89 | 0.573 | 158.2767 | 7648.337 | 1.37\% | -3.72\% | -3.06\% | -0.82\% |
| 1975 | 24697.68 | 0.569 | 158.4562 | 7656.264 | 1.34\% | -3.20\% | -3.16\% | -1.34\% |
| 1975.083 | 24601 | 0.564 | 158.6448 | 7672.716 | 1.33\% | -2.56\% | -3.20\% | -1.99\% |
| 1975.166 | 24584.25 | 0.561 | 158.8423 | 7696.848 | 1.33\% | -1.82\% | -3.23\% | -2.37\% |
| 1975.25 | 24635.86 | 0.56 | 159.0485 | 7727.477 | 1.34\% | -0.99\% | -3.13\% | -2.50\% |
| 1975.333 | 24731 | 0.559 | 159.2628 | 7763.421 | 1.37\% | -0.10\% | -2.74\% | -2.37\% |
| 1975.416 | 24846.18 | 0.56 | 159.4848 | 7803.5 | 1.40\% | 0.81\% | -1.98\% | -2.24\% |
| 1975.5 | 24963.16 | 0.558 | 159.714 | 7846.532 | 1.44\% | 1.74\% | -1.04\% | -2.49\% |
| 1975.583 | 25065 | 0.56 | 159.95 | 7891.335 | 1.48\% | 2.64\% | -0.21\% | -2.22\% |
| 1975.666 | 25143.2 | 0.561 | 160.1924 | 7936.728 | 1.53\% | 3.48\% | 0.34\% | -1.82\% |
| 1975.75 | 25222.99 | 0.561 | 160.4407 | 7981.528 | 1.58\% | 4.26\% | 0.82\% | -1.68\% |
| 1975.833 | 25338 | 0.561 | 160.6946 | 8024.555 | 1.64\% | 4.92\% | 1.55\% | -1.54\% |
| 1975.916 | 25507.94 | 0.56 | 160.9534 | 8064.627 | 1.69\% | 5.44\% | 2.72\% | -1.28\% |
| 1976 | 25696.64 | 0.561 | 161.2169 | 8100.562 | 1.74\% | 5.80\% | 4.04\% | -0.62\% |
| 1976.083 | 25854 | 0.564 | 161.4847 | 8131.472 | 1.79\% | 5.98\% | 5.09\% | 0.45\% |
| 1976.166 | 25943.13 | 0.565 | 161.7568 | 8157.642 | 1.83\% | 5.99\% | 5.53\% | 0.99\% |
| 1976.25 | 25980.05 | 0.567 | 162.0335 | 8179.647 | 1.88\% | 5.85\% | 5.46\% | 1.41\% |
| 1976.333 | 25994 | 0.568 | 162.315 | 8198.066 | 1.92\% | 5.60\% | 5.11\% | 1.69\% |
| 1976.416 | 26009.36 | 0.57 | 162.6014 | 8213.476 | 1.95\% | 5.25\% | 4.68\% | 1.83\% |
| 1976.5 | 26031.02 | 0.568 | 162.893 | 8226.453 | 1.99\% | 4.84\% | 4.28\% | 1.84\% |
| 1976.583 | 26059 | 0.57 | 163.19 | 8237.576 | 2.03\% | 4.39\% | 3.97\% | 1.85\% |
| 1976.666 | 26093.52 | 0.57 | 163.4926 | 8247.421 | 2.06\% | 3.91\% | 3.78\% | 1.72\% |
| 1976.75 | 26135.48 | 0.569 | 163.8009 | 8256.566 | 2.09\% | 3.45\% | 3.62\% | 1.59\% |
| 1976.833 | 26186 | 0.569 | 164.1153 | 8265.588 | 2.13\% | 3.00\% | 3.35\% | 1.60\% |
| 1976.916 | 26247.25 | 0.57 | 164.4358 | 8275.064 | 2.16\% | 2.61\% | 2.90\% | 1.88\% |
| 1977 | 26325.72 | 0.57 | 164.7626 | 8285.571 | 2.20\% | 2.28\% | 2.45\% | 1.75\% |
| 1977.083 | 26429 | 0.57 | 165.096 | 8297.534 | 2.24\% | 2.04\% | 2.22\% | 1.36\% |
| 1977.166 | 26561.68 | 0.572 | 165.4356 | 8310.767 | 2.27\% | 1.88\% | 2.38\% | 1.50\% |


| 1977.25 | 26716.45 | 0.574 | 165.781 | 8324.931 | 2.31\% | 1.78\% | 2.83\% | 1.50\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1977.333 | 26883 | 0.576 | 166.1321 | 8339.687 | 2.35\% | 1.73\% | 3.42\% | 1.64\% |
| 1977.416 | 27048.5 | 0.578 | 166.4883 | 8354.697 | 2.39\% | 1.72\% | 4.00\% | 1.65\% |
| 1977.5 | 27190 | 0.579 | 166.8494 | 8369.621 | 2.43\% | 1.74\% | 4.45\% | 2.06\% |
| 1977.583 | 27282 | 0.578 | 167.215 | 8384.122 | 2.47\% | 1.78\% | 4.69\% | 1.67\% |
| 1977.666 | 27306.45 | 0.58 | 167.5848 | 8397.859 | 2.50\% | 1.82\% | 4.65\% | 1.94\% |
| 1977.75 | 27275.07 | 0.581 | 167.9585 | 8410.494 | 2.54\% | 1.86\% | 4.36\% | 2.22\% |
| 1977.833 | 27207 | 0.582 | 168.3356 | 8421.69 | 2.57\% | 1.89\% | 3.90\% | 2.36\% |
| 1977.916 | 27131.16 | 0.586 | 168.7159 | 8431.105 | 2.60\% | 1.89\% | 3.37\% | 2.76\% |
| 1978 | 27115.57 | 0.587 | 169.0991 | 8438.403 | 2.63\% | 1.84\% | 3.00\% | 2.89\% |
| 1978.083 | 27238 | 0.588 | 169.4845 | 8443.296 | 2.66\% | 1.76\% | 3.06\% | 3.03\% |
| 1978.166 | 27539.72 | 0.588 | 169.8713 | 8445.704 | 2.68\% | 1.62\% | 3.68\% | 2.77\% |
| 1978.25 | 27915.85 | 0.588 | 170.258 | 8445.6 | 2.70\% | 1.45\% | 4.49\% | 2.50\% |
| 1978.333 | 28225 | 0.592 | 170.6436 | 8442.956 | 2.72\% | 1.24\% | 4.99\% | 2.76\% |
| 1978.416 | 28365.83 | 0.593 | 171.0267 | 8437.744 | 2.73\% | 0.99\% | 4.87\% | 2.63\% |
| 1978.5 | 28397.19 | 0.595 | 171.4063 | 8429.937 | 2.73\% | 0.72\% | 4.44\% | 2.76\% |
| 1978.583 | 28418 | 0.593 | 171.7811 | 8419.507 | 2.73\% | 0.42\% | 4.16\% | 2.63\% |
| 1978.666 | 28501.57 | 0.594 | 172.1499 | 8406.426 | 2.72\% | 0.10\% | 4.38\% | 2.49\% |
| 1978.75 | 28618.8 | 0.595 | 172.5116 | 8390.667 | 2.71\% | -0.24\% | 4.93\% | 2.48\% |
| 1978.833 | 28715 | 0.597 | 172.865 | 8372.202 | 2.69\% | -0.59\% | 5.54\% | 2.61\% |
| 1978.916 | 28749.13 | 0.598 | 173.2089 | 8351.002 | 2.66\% | -0.95\% | 5.96\% | 2.20\% |
| 1979 | 28734.73 | 0.598 | 173.5423 | 8327.042 | 2.63\% | -1.32\% | 5.97\% | 2.06\% |
| 1979.083 | 28699 | 0.599 | 173.8642 | 8300.366 | 2.58\% | -1.69\% | 5.36\% | 2.05\% |
| 1979.166 | 28666.28 | 0.601 | 174.1757 | 8271.319 | 2.53\% | -2.06\% | 4.09\% | 2.29\% |
| 1979.25 | 28649.57 | 0.6 | 174.478 | 8240.317 | 2.48\% | -2.43\% | 2.63\% | 2.15\% |
| 1979.333 | 28659 | 0.598 | 174.7723 | 8207.779 | 2.42\% | -2.79\% | 1.54\% | 1.37\% |
| 1979.416 | 28698.51 | 0.598 | 175.0599 | 8174.121 | 2.36\% | -3.12\% | 1.17\% | 1.22\% |
| 1979.5 | 28747.21 | 0.599 | 175.3422 | 8139.762 | 2.30\% | -3.44\% | 1.23\% | 1.08\% |
| 1979.583 | 28778 | 0.6 | 175.6202 | 8105.119 | 2.23\% | -3.73\% | 1.27\% | 1.44\% |
| 1979.666 | 28773.83 | 0.598 | 175.8953 | 8070.609 | 2.18\% | -3.99\% | 0.96\% | 1.05\% |
| 1979.75 | 28757.78 | 0.6 | 176.1687 | 8036.65 | 2.12\% | -4.22\% | 0.49\% | 1.16\% |
| 1979.833 | 28763 | 0.599 | 176.4416 | 8003.659 | 2.07\% | -4.40\% | 0.17\% | 0.77\% |
| 1979.916 | 28805.48 | 0.6 | 176.7152 | 7972.054 | 2.02\% | -4.54\% | 0.20\% | 0.76\% |
| 1980 | 28832.7 | 0.601 | 176.9908 | 7942.253 | 1.99\% | -4.62\% | 0.34\% | 0.87\% |
| 1980.083 | 28775 | 0.6 | 177.2691 | 7914.54 | 1.96\% | -4.65\% | 0.26\% | 0.61\% |
| 1980.166 | 28589.3 | 0.6 | 177.5492 | 7888.667 | 1.94\% | -4.63\% | -0.27\% | 0.36\% |
| 1980.25 | 28338.73 | 0.597 | 177.8296 | 7864.254 | 1.92\% | -4.56\% | -1.08\% | 0.11\% |
| 1980.333 | 28113 | 0.594 | 178.1091 | 7840.923 | 1.91\% | -4.47\% | -1.91\% | -0.02\% |
| 1980.416 | 27983.49 | 0.591 | 178.3861 | 7818.291 | 1.90\% | -4.35\% | -2.49\% | -0.40\% |
| 1980.5 | 27948.25 | 0.589 | 178.6594 | 7795.979 | 1.89\% | -4.22\% | -2.78\% | -0.78\% |
| 1980.583 | 27987 | 0.588 | 178.9276 | 7773.607 | 1.88\% | -4.09\% | -2.75\% | -1.03\% |
| 1980.666 | 28082.56 | 0.588 | 179.1893 | 7750.795 | 1.87\% | -3.96\% | -2.40\% | -0.79\% |
| 1980.75 | 28230.13 | 0.589 | 179.4432 | 7727.162 | 1.86\% | -3.85\% | -1.83\% | -0.91\% |
| 1980.833 | 28428 | 0.589 | 179.6879 | 7702.328 | 1.84\% | -3.76\% | -1.16\% | -0.79\% |
| 1980.916 | 28661.52 | 0.59 | 179.922 | 7675.914 | 1.81\% | -3.71\% | -0.50\% | -0.80\% |
| 1981 | 28864.3 | 0.59 | 180.1443 | 7647.538 | 1.78\% | -3.71\% | 0.11\% | -0.93\% |
| 1981.083 | 28957 | 0.591 | 180.3539 | 7616.962 | 1.74\% | -3.76\% | 0.63\% | -0.69\% |
| 1981.166 | 28893.61 | 0.592 | 180.5519 | 7584.51 | 1.69\% | -3.86\% | 1.06\% | -0.58\% |
| 1981.25 | 28761.42 | 0.594 | 180.7397 | 7550.646 | 1.64\% | -3.99\% | 1.49\% | 0.03\% |
| 1981.333 | 28681 | 0.596 | 180.9189 | 7515.836 | 1.58\% | -4.15\% | 2.02\% | 0.65\% |
| 1981.416 | 28734.99 | 0.595 | 181.0911 | 7480.544 | 1.52\% | -4.32\% | 2.69\% | 0.89\% |
| 1981.5 | 28854.08 | 0.59 | 181.2577 | 7445.236 | 1.45\% | -4.50\% | 3.24\% | 0.49\% |


| 1981.583 | 28931 | 0.591 | 181.4202 | 7410.376 | 1.39\% | -4.67\% | 3.37\% | 0.73\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1981.666 | 28883.77 | 0.591 | 181.5802 | 7376.43 | 1.33\% | -4.83\% | 2.85\% | 0.72\% |
| 1981.75 | 28731.61 | 0.587 | 181.7392 | 7343.862 | 1.28\% | -4.96\% | 1.78\% | 0.07\% |
| 1981.833 | 28519 | 0.588 | 181.8987 | 7313.138 | 1.23\% | -5.05\% | 0.32\% | 0.18\% |
| 1981.916 | 28291.14 | 0.586 | 182.0601 | 7284.722 | 1.19\% | -5.10\% | -1.29\% | -0.21\% |
| 1982 | 28095.94 | 0.582 | 182.2249 | 7259.079 | 1.15\% | -5.08\% | -2.66\% | -0.73\% |
| 1982.083 | 27982 | 0.582 | 182.3946 | 7236.594 | 1.13\% | -4.99\% | -3.37\% | -0.86\% |
| 1982.166 | 27977.89 | 0.582 | 182.5701 | 7217.335 | 1.12\% | -4.84\% | -3.17\% | -0.99\% |
| 1982.25 | 28032.08 | 0.581 | 182.7523 | 7201.286 | 1.11\% | -4.63\% | -2.54\% | -1.36\% |
| 1982.333 | 28073 | 0.579 | 182.942 | 7188.435 | 1.12\% | -4.36\% | -2.12\% | -1.86\% |
| 1982.416 | 28047.58 | 0.582 | 183.1401 | 7178.768 | 1.13\% | -4.03\% | -2.39\% | -1.36\% |
| 1982.5 | 27976.77 | 0.578 | 183.3475 | 7172.272 | 1.15\% | -3.67\% | -3.04\% | -1.24\% |
| 1982.583 | 27900 | 0.577 | 183.5651 | 7168.933 | 1.18\% | -3.26\% | -3.56\% | -1.48\% |
| 1982.666 | 27850.45 | 0.578 | 183.7937 | 7168.737 | 1.22\% | -2.82\% | -3.58\% | -1.34\% |
| 1982.75 | 27836.18 | 0.576 | 184.0342 | 7171.671 | 1.26\% | -2.34\% | -3.12\% | -1.09\% |
| 1982.833 | 27859 | 0.574 | 184.2874 | 7177.722 | 1.31\% | -1.85\% | -2.31\% | -1.46\% |
| 1982.916 | 27920.67 | 0.573 | 184.5541 | 7186.876 | 1.37\% | -1.34\% | -1.31\% | -1.32\% |
| 1983 | 28022.81 | 0.572 | 184.8354 | 7199.119 | 1.43\% | -0.83\% | -0.26\% | -0.93\% |
| 1983.083 | 28167 | 0.572 | 185.1315 | 7214.357 | 1.50\% | -0.31\% | 0.66\% | -0.91\% |
| 1983.166 | 28350.48 | 0.571 | 185.4418 | 7232.176 | 1.57\% | 0.21\% | 1.33\% | -1.02\% |
| 1983.25 | 28553.01 | 0.571 | 185.765 | 7252.08 | 1.65\% | 0.71\% | 1.86\% | -0.88\% |
| 1983.333 | 28750 | 0.573 | 186.0999 | 7273.574 | 1.73\% | 1.18\% | 2.41\% | -0.35\% |
| 1983.416 | 28923.5 | 0.573 | 186.4454 | 7296.163 | 1.80\% | 1.64\% | 3.12\% | -0.71\% |
| 1983.5 | 29082.1 | 0.578 | 186.8001 | 7319.35 | 1.88\% | 2.05\% | 3.95\% | 0.47\% |
| 1983.583 | 29241 | 0.581 | 187.1631 | 7342.642 | 1.96\% | 2.42\% | 4.81\% | 1.01\% |
| 1983.666 | 29411.8 | 0.582 | 187.5331 | 7365.542 | 2.03\% | 2.75\% | 5.61\% | 1.03\% |
| 1983.75 | 29591.63 | 0.584 | 187.9088 | 7387.555 | 2.11\% | 3.01\% | 6.31\% | 1.57\% |
| 1983.833 | 29774 | 0.584 | 188.2892 | 7408.186 | 2.17\% | 3.21\% | 6.87\% | 1.85\% |
| 1983.916 | 29953.74 | 0.587 | 188.6731 | 7426.939 | 2.23\% | 3.34\% | 7.28\% | 2.39\% |
| 1984 | 30130.93 | 0.588 | 189.0593 | 7443.32 | 2.29\% | 3.39\% | 7.52\% | 2.67\% |
| 1984.083 | 30307 | 0.588 | 189.4468 | 7456.938 | 2.33\% | 3.36\% | 7.60\% | 2.68\% |
| 1984.166 | 30480.93 | 0.591 | 189.8351 | 7467.823 | 2.37\% | 3.26\% | 7.51\% | 3.22\% |
| 1984.25 | 30641.98 | 0.591 | 190.224 | 7476.111 | 2.40\% | 3.09\% | 7.32\% | 3.23\% |
| 1984.333 | 30777 | 0.593 | 190.6132 | 7481.939 | 2.43\% | 2.86\% | 7.05\% | 3.22\% |
| 1984.416 | 30876.93 | 0.597 | 191.0023 | 7485.442 | 2.44\% | 2.59\% | 6.75\% | 3.75\% |
| 1984.5 | 30949.12 | 0.599 | 191.3912 | 7486.755 | 2.46\% | 2.29\% | 6.42\% | 3.34\% |
| 1984.583 | 31005 | 0.598 | 191.7796 | 7486.015 | 2.47\% | 1.95\% | 6.03\% | 2.81\% |
| 1984.666 | 31055.53 | 0.596 | 192.167 | 7483.357 | 2.47\% | 1.60\% | 5.59\% | 2.42\% |
| 1984.75 | 31109.69 | 0.597 | 192.5534 | 7478.917 | 2.47\% | 1.24\% | 5.13\% | 2.29\% |
| 1984.833 | 31176 | 0.597 | 192.9383 | 7472.831 | 2.47\% | 0.87\% | 4.71\% | 2.29\% |
| 1984.916 | 31259.07 | 0.598 | 193.3216 | 7465.234 | 2.46\% | 0.52\% | 4.36\% | 2.02\% |
| 1985 | 31348 | 0.599 | 193.7028 | 7456.263 | 2.46\% | 0.17\% | 4.04\% | 2.02\% |
| 1985.083 | 31428 | 0.599 | 194.0819 | 7446.102 | 2.45\% | -0.15\% | 3.70\% | 2.01\% |
| 1985.166 | 31491.04 | 0.6 | 194.4589 | 7435.134 | 2.44\% | -0.44\% | 3.31\% | 1.75\% |
| 1985.25 | 31556.13 | 0.602 | 194.8338 | 7423.791 | 2.42\% | -0.70\% | 2.98\% | 2.00\% |
| 1985.333 | 31649 | 0.601 | 195.2068 | 7412.506 | 2.41\% | -0.93\% | 2.83\% | 1.61\% |
| 1985.416 | 31784.53 | 0.601 | 195.5781 | 7401.708 | 2.40\% | -1.12\% | 2.94\% | 1.10\% |
| 1985.5 | 31934.05 | 0.598 | 195.9477 | 7391.832 | 2.38\% | -1.27\% | 3.18\% | 0.47\% |
| 1985.583 | 32058 | 0.599 | 196.3157 | 7383.308 | 2.37\% | -1.37\% | 3.40\% | 0.72\% |
| 1985.666 | 32129.31 | 0.6 | 196.6824 | 7376.569 | 2.35\% | -1.43\% | 3.46\% | 1.09\% |
| 1985.75 | 32170.86 | 0.603 | 197.0477 | 7372.046 | 2.33\% | -1.43\% | 3.41\% | 1.34\% |
| 1985.833 | 32218 | 0.603 | 197.4119 | 7370.172 | 2.32\% | -1.37\% | 3.34\% | 1.33\% |


| 1985.916 | 32295.22 | 0.604 | 197.775 | 7371.378 | 2.30\% | -1.26\% | 3.31\% | 1.33\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1986 | 32383.51 | 0.604 | 198.1372 | 7376.096 | 2.29\% | -1.08\% | 3.30\% | 1.20\% |
| 1986.083 | 32453 | 0.606 | 198.4986 | 7384.619 | 2.28\% | -0.83\% | 3.26\% | 1.45\% |
| 1986.166 | 32484.29 | 0.603 | 198.859 | 7396.678 | 2.26\% | -0.52\% | 3.15\% | 0.94\% |
| 1986.25 | 32499.94 | 0.605 | 199.2185 | 7411.867 | 2.25\% | -0.16\% | 2.99\% | 0.94\% |
| 1986.333 | 32533 | 0.605 | 199.5769 | 7429.778 | 2.24\% | 0.23\% | 2.79\% | 1.06\% |
| 1986.416 | 32605.84 | 0.605 | 199.934 | 7450.004 | 2.23\% | 0.65\% | 2.58\% | 1.06\% |
| 1986.5 | 32698.17 | 0.607 | 200.2898 | 7472.136 | 2.22\% | 1.09\% | 2.39\% | 1.68\% |
| 1986.583 | 32779 | 0.608 | 200.6442 | 7495.769 | 2.20\% | 1.52\% | 2.25\% | 1.68\% |
| 1986.666 | 32825.78 | 0.608 | 200.997 | 7520.494 | 2.19\% | 1.95\% | 2.17\% | 1.55\% |
| 1986.75 | 32849.61 | 0.608 | 201.3483 | 7545.905 | 2.18\% | 2.36\% | 2.11\% | 1.17\% |
| 1986.833 | 32870 | 0.609 | 201.6977 | 7571.593 | 2.17\% | 2.73\% | 2.02\% | 1.29\% |
| 1986.916 | 32903.89 | 0.609 | 202.0453 | 7597.151 | 2.16\% | 3.06\% | 1.88\% | 1.16\% |
| 1987 | 32957.88 | 0.61 | 202.3909 | 7622.173 | 2.15\% | 3.34\% | 1.77\% | 1.28\% |
| 1987.083 | 33036 | 0.61 | 202.7345 | 7646.318 | 2.13\% | 3.54\% | 1.80\% | 1.03\% |
| 1987.166 | 33137.86 | 0.611 | 203.0763 | 7669.52 | 2.12\% | 3.69\% | 2.01\% | 1.53\% |
| 1987.25 | 33245.37 | 0.612 | 203.4166 | 7691.778 | 2.11\% | 3.78\% | 2.29\% | 1.39\% |
| 1987.333 | 33336 | 0.613 | 203.7556 | 7713.093 | 2.09\% | 3.81\% | 2.47\% | 1.52\% |
| 1987.416 | 33397.41 | 0.616 | 204.0937 | 7733.467 | 2.08\% | 3.80\% | 2.43\% | 1.88\% |
| 1987.5 | 33457.91 | 0.614 | 204.4311 | 7752.899 | 2.07\% | 3.76\% | 2.32\% | 1.38\% |
| 1987.583 | 33556 | 0.616 | 204.7681 | 7771.39 | 2.06\% | 3.68\% | 2.37\% | 1.50\% |
| 1987.666 | 33714.03 | 0.618 | 205.1049 | 7788.941 | 2.04\% | 3.57\% | 2.71\% | 1.74\% |
| 1987.75 | 33889.81 | 0.616 | 205.442 | 7805.552 | 2.03\% | 3.44\% | 3.17\% | 1.50\% |
| 1987.833 | 34025 | 0.618 | 205.7795 | 7821.224 | 2.02\% | 3.30\% | 3.51\% | 1.61\% |
| 1987.916 | 34081.42 | 0.619 | 206.1177 | 7835.958 | 2.02\% | 3.14\% | 3.58\% | 1.74\% |
| 1988 | 34101.55 | 0.62 | 206.4569 | 7849.754 | 2.01\% | 2.99\% | 3.47\% | 1.73\% |
| 1988.083 | 34148 | 0.62 | 206.7972 | 7862.582 | 2.00\% | 2.83\% | 3.37\% | 1.73\% |
| 1988.166 | 34263.28 | 0.621 | 207.1382 | 7874.293 | 2.00\% | 2.67\% | 3.40\% | 1.73\% |
| 1988.25 | 34409.34 | 0.619 | 207.4794 | 7884.706 | 2.00\% | 2.51\% | 3.50\% | 1.36\% |
| 1988.333 | 34528 | 0.622 | 207.8202 | 7893.641 | 1.99\% | 2.34\% | 3.58\% | 1.60\% |
| 1988.416 | 34579.57 | 0.62 | 208.16 | 7900.918 | 1.99\% | 2.17\% | 3.54\% | 0.99\% |
| 1988.5 | 34598.32 | 0.623 | 208.4983 | 7906.357 | 1.99\% | 1.98\% | 3.41\% | 1.60\% |
| 1988.583 | 34637 | 0.623 | 208.8345 | 7909.776 | 1.99\% | 1.78\% | 3.22\% | 1.35\% |
| 1988.666 | 34733.83 | 0.624 | 209.1681 | 7910.997 | 1.98\% | 1.57\% | 3.02\% | 1.22\% |
| 1988.75 | 34868.96 | 0.624 | 209.4984 | 7909.839 | 1.97\% | 1.34\% | 2.89\% | 1.47\% |
| 1988.833 | 35008 | 0.625 | 209.825 | 7906.121 | 1.97\% | 1.09\% | 2.89\% | 1.34\% |
| 1988.916 | 35123.47 | 0.627 | 210.1472 | 7899.664 | 1.95\% | 0.81\% | 3.06\% | 1.46\% |
| 1989 | 35215.48 | 0.626 | 210.4646 | 7890.287 | 1.94\% | 0.52\% | 3.27\% | 1.21\% |
| 1989.083 | 35291 | 0.629 | 210.7764 | 7877.919 | 1.92\% | 0.20\% | 3.35\% | 1.57\% |
| 1989.166 | 35357.01 | 0.629 | 211.0818 | 7862.92 | 1.90\% | -0.14\% | 3.19\% | 1.44\% |
| 1989.25 | 35420.39 | 0.629 | 211.3798 | 7845.763 | 1.88\% | -0.49\% | 2.94\% | 1.68\% |
| 1989.333 | 35488 | 0.629 | 211.6695 | 7826.916 | 1.85\% | -0.85\% | 2.78\% | 1.31\% |
| 1989.416 | 35561.85 | 0.629 | 211.9499 | 7806.85 | 1.82\% | -1.19\% | 2.84\% | 1.54\% |
| 1989.5 | 35624.59 | 0.63 | 212.2201 | 7786.037 | 1.79\% | -1.52\% | 2.97\% | 1.29\% |
| 1989.583 | 35654 | 0.63 | 212.4791 | 7764.944 | 1.75\% | -1.83\% | 2.94\% | 1.28\% |
| 1989.666 | 35639.47 | 0.631 | 212.7259 | 7744.045 | 1.70\% | -2.11\% | 2.61\% | 1.27\% |
| 1989.75 | 35616.71 | 0.628 | 212.9598 | 7723.807 | 1.65\% | -2.35\% | 2.14\% | 0.89\% |
| 1989.833 | 35633 | 0.629 | 213.1796 | 7704.703 | 1.60\% | -2.55\% | 1.79\% | 0.88\% |
| 1989.916 | 35719.04 | 0.63 | 213.3845 | 7687.201 | 1.54\% | -2.69\% | 1.70\% | 0.74\% |
| 1990 | 35839.14 | 0.63 | 213.5735 | 7671.773 | 1.48\% | -2.77\% | 1.77\% | 0.85\% |
| 1990.083 | 35941 | 0.632 | 213.7463 | 7658.78 | 1.41\% | -2.78\% | 1.84\% | 0.71\% |
| 1990.166 | 35985.44 | 0.632 | 213.9042 | 7648.148 | 1.34\% | -2.73\% | 1.78\% | 0.69\% |


| 1990.25 | 35985.67 | 0.632 | 214.0489 | 7639.694 | 1.26\% | -2.63\% | 1.60\% | 0.67\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1990.333 | 35968 | 0.63 | 214.1824 | 7633.235 | 1.19\% | -2.47\% | 1.35\% | 0.42\% |
| 1990.416 | 35950.57 | 0.631 | 214.3063 | 7628.589 | 1.11\% | -2.28\% | 1.09\% | 0.52\% |
| 1990.5 | 35918.81 | 0.629 | 214.4226 | 7625.573 | 1.04\% | -2.06\% | 0.83\% | 0.14\% |
| 1990.583 | 35850 | 0.628 | 214.5331 | 7624.004 | 0.97\% | -1.82\% | 0.55\% | 0.00\% |
| 1990.666 | 35729.73 | 0.627 | 214.6394 | 7623.699 | 0.90\% | -1.55\% | 0.25\% | -0.25\% |
| 1990.75 | 35576.97 | 0.625 | 214.7435 | 7624.476 | 0.84\% | -1.29\% | -0.11\% | -0.15\% |
| 1990.833 | 35419 | 0.625 | 214.847 | 7626.152 | 0.78\% | -1.02\% | -0.60\% | -0.28\% |
| 1990.916 | 35281.57 | 0.623 | 214.9517 | 7628.543 | 0.73\% | -0.76\% | -1.22\% | -0.65\% |
| 1991 | 35184.24 | 0.622 | 215.0594 | 7631.468 | 0.70\% | -0.53\% | -1.83\% | -0.78\% |
| 1991.083 | 35145 | 0.62 | 215.1716 | 7634.763 | 0.67\% | -0.31\% | -2.21\% | -1.26\% |
| 1991.166 | 35172.57 | 0.619 | 215.2882 | 7638.351 | 0.65\% | -0.13\% | -2.26\% | -1.38\% |
| 1991.25 | 35238.49 | 0.618 | 215.4092 | 7642.172 | 0.64\% | 0.03\% | -2.08\% | -1.50\% |
| 1991.333 | 35305 | 0.62 | 215.5341 | 7646.168 | 0.63\% | 0.17\% | -1.84\% | -1.03\% |
| 1991.416 | 35342.4 | 0.616 | 215.6629 | 7650.279 | 0.63\% | 0.28\% | -1.69\% | -1.62\% |
| 1991.5 | 35353.2 | 0.617 | 215.7952 | 7654.449 | 0.64\% | 0.38\% | -1.57\% | -1.27\% |
| 1991.583 | 35348 | 0.616 | 215.9309 | 7658.618 | 0.65\% | 0.45\% | -1.40\% | -1.27\% |
| 1991.666 | 35338.81 | 0.615 | 216.0697 | 7662.727 | 0.67\% | 0.51\% | -1.09\% | -1.27\% |
| 1991.75 | 35343.4 | 0.616 | 216.2114 | 7666.719 | 0.68\% | 0.55\% | -0.66\% | -0.91\% |
| 1991.833 | 35381 | 0.615 | 216.3557 | 7670.534 | 0.70\% | 0.58\% | -0.11\% | -1.02\% |
| 1991.916 | 35463.79 | 0.614 | 216.5024 | 7674.115 | 0.72\% | 0.60\% | 0.52\% | -0.90\% |
| 1992 | 35575.8 | 0.612 | 216.6513 | 7677.401 | 0.74\% | 0.60\% | 1.11\% | -1.02\% |
| 1992.083 | 35694 | 0.615 | 216.8023 | 7680.358 | 0.76\% | 0.60\% | 1.56\% | -0.42\% |
| 1992.166 | 35799.55 | 0.613 | 216.9557 | 7683.031 | 0.77\% | 0.58\% | 1.78\% | -0.53\% |
| 1992.25 | 35890.24 | 0.615 | 217.1117 | 7685.492 | 0.79\% | 0.57\% | 1.85\% | -0.17\% |
| 1992.333 | 35968 | 0.616 | 217.2707 | 7687.808 | 0.81\% | 0.54\% | 1.88\% | -0.28\% |
| 1992.416 | 36036.3 | 0.615 | 217.4331 | 7690.051 | 0.82\% | 0.52\% | 1.96\% | 0.08\% |
| 1992.5 | 36104.63 | 0.615 | 217.5993 | 7692.288 | 0.84\% | 0.49\% | 2.13\% | -0.03\% |
| 1992.583 | 36184 | 0.616 | 217.7695 | 7694.59 | 0.85\% | 0.47\% | 2.37\% | 0.21\% |
| 1992.666 | 36278.8 | 0.616 | 217.9442 | 7697.026 | 0.87\% | 0.45\% | 2.66\% | 0.34\% |
| 1992.75 | 36367 | 0.614 | 218.1236 | 7699.665 | 0.88\% | 0.43\% | 2.90\% | -0.02\% |
| 1992.833 | 36420 | 0.613 | 218.3082 | 7702.577 | 0.90\% | 0.42\% | 2.94\% | -0.02\% |
| 1992.916 | 36420.25 | 0.614 | 218.4981 | 7705.831 | 0.92\% | 0.41\% | 2.70\% | 0.23\% |
| 1993 | 36394.61 | 0.614 | 218.6939 | 7709.497 | 0.94\% | 0.42\% | 2.30\% | 0.48\% |
| 1993.083 | 36381 | 0.614 | 218.8957 | 7713.613 | 0.97\% | 0.43\% | 1.92\% | 0.12\% |
| 1993.166 | 36406.04 | 0.614 | 219.1031 | 7718.095 | 0.99\% | 0.46\% | 1.69\% | 0.37\% |
| 1993.25 | 36451.04 | 0.615 | 219.3157 | 7722.829 | 1.02\% | 0.49\% | 1.56\% | 0.25\% |
| 1993.333 | 36486 | 0.615 | 219.533 | 7727.699 | 1.04\% | 0.52\% | 1.44\% | 0.14\% |
| 1993.416 | 36492.34 | 0.617 | 219.7545 | 7732.592 | 1.07\% | 0.55\% | 1.27\% | 0.51\% |
| 1993.5 | 36497.16 | 0.618 | 219.9798 | 7737.393 | 1.09\% | 0.59\% | 1.09\% | 0.64\% |
| 1993.583 | 36539 | 0.618 | 220.2082 | 7741.986 | 1.12\% | 0.62\% | 0.98\% | 0.52\% |
| 1993.666 | 36642.95 | 0.62 | 220.4395 | 7746.257 | 1.14\% | 0.64\% | 1.00\% | 0.77\% |
| 1993.75 | 36780.33 | 0.617 | 220.6731 | 7750.092 | 1.17\% | 0.65\% | 1.14\% | 0.66\% |
| 1993.833 | 36909 | 0.618 | 220.9085 | 7753.376 | 1.19\% | 0.66\% | 1.34\% | 0.91\% |
| 1993.916 | 36999.77 | 0.619 | 221.1452 | 7755.994 | 1.21\% | 0.65\% | 1.59\% | 0.91\% |
| 1994 | 37075.26 | 0.62 | 221.3829 | 7757.831 | 1.23\% | 0.63\% | 1.87\% | 1.04\% |
| 1994.083 | 37171 | 0.622 | 221.6212 | 7758.823 | 1.25\% | 0.59\% | 2.17\% | 1.29\% |
| 1994.166 | 37308.99 | 0.623 | 221.8604 | 7759.105 | 1.26\% | 0.53\% | 2.48\% | 1.41\% |
| 1994.25 | 37456.94 | 0.621 | 222.1011 | 7758.863 | 1.27\% | 0.47\% | 2.76\% | 1.05\% |
| 1994.333 | 37569 | 0.623 | 222.3438 | 7758.284 | 1.28\% | 0.40\% | 2.97\% | 1.30\% |
| 1994.416 | 37615.53 | 0.625 | 222.589 | 7757.551 | 1.29\% | 0.32\% | 3.08\% | 1.29\% |
| 1994.5 | 37631.73 | 0.623 | 222.8372 | 7756.852 | 1.30\% | 0.25\% | 3.11\% | 0.93\% |


| 1994.583 | 37669 | 0.623 | 223.0891 | 7756.372 | 1.31\% | 0.19\% | 3.09\% | 0.93\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1994.666 | 37762.41 | 0.626 | 223.345 | 7756.297 | 1.32\% | 0.13\% | 3.06\% | 1.06\% |
| 1994.75 | 37881.63 | 0.627 | 223.6055 | 7756.811 | 1.33\% | 0.09\% | 2.99\% | 1.55\% |
| 1994.833 | 37980 | 0.629 | 223.8711 | 7758.102 | 1.34\% | 0.06\% | 2.90\% | 1.67\% |
| 1994.916 | 38022.88 | 0.63 | 224.1423 | 7760.355 | 1.36\% | 0.06\% | 2.77\% | 1.67\% |
| 1995 | 38023.72 | 0.631 | 224.4197 | 7763.755 | 1.37\% | 0.08\% | 2.56\% | 1.67\% |
| 1995.083 | 38008 | 0.63 | 224.7035 | 7768.421 | 1.39\% | 0.12\% | 2.25\% | 1.31\% |
| 1995.166 | 37998.12 | 0.631 | 224.9935 | 7774.198 | 1.41\% | 0.19\% | 1.85\% | 1.32\% |
| 1995.25 | 38004.14 | 0.631 | 225.2891 | 7780.866 | 1.44\% | 0.28\% | 1.46\% | 1.57\% |
| 1995.333 | 38033 | 0.631 | 225.5899 | 7788.204 | 1.46\% | 0.39\% | 1.24\% | 1.33\% |
| 1995.416 | 38088.29 | 0.627 | 225.8955 | 7795.99 | 1.49\% | 0.50\% | 1.26\% | 0.61\% |
| 1995.5 | 38160.07 | 0.627 | 226.2052 | 7804.004 | 1.51\% | 0.61\% | 1.40\% | 0.86\% |
| 1995.583 | 38235 | 0.628 | 226.5187 | 7812.023 | 1.54\% | 0.72\% | 1.50\% | 0.99\% |
| 1995.666 | 38301.38 | 0.628 | 226.8354 | 7819.827 | 1.56\% | 0.82\% | 1.43\% | 0.63\% |
| 1995.75 | 38353.93 | 0.629 | 227.1549 | 7827.195 | 1.59\% | 0.91\% | 1.25\% | 0.64\% |
| 1995.833 | 38389 | 0.629 | 227.4767 | 7833.905 | 1.61\% | 0.98\% | 1.08\% | 0.40\% |
| 1995.916 | 38410.02 | 0.628 | 227.8003 | 7839.737 | 1.63\% | 1.02\% | 1.02\% | 0.17\% |
| 1996 | 38448.74 | 0.627 | 228.1253 | 7844.468 | 1.65\% | 1.04\% | 1.12\% | -0.06\% |
| 1996.083 | 38544 | 0.627 | 228.4512 | 7847.933 | 1.67\% | 1.02\% | 1.41\% | 0.06\% |
| 1996.166 | 38717.91 | 0.629 | 228.7787 | 7850.18 | 1.68\% | 0.98\% | 1.89\% | 0.18\% |
| 1996.25 | 38925.73 | 0.63 | 229.1081 | 7851.314 | 1.70\% | 0.91\% | 2.42\% | 0.30\% |
| 1996.333 | 39106 | 0.63 | 229.4401 | 7851.439 | 1.71\% | 0.81\% | 2.82\% | 0.31\% |
| 1996.416 | 39214.78 | 0.63 | 229.7752 | 7850.659 | 1.72\% | 0.70\% | 2.96\% | 0.79\% |
| 1996.5 | 39278.22 | 0.632 | 230.1141 | 7849.077 | 1.73\% | 0.58\% | 2.93\% | 1.03\% |
| 1996.583 | 39340 | 0.633 | 230.4573 | 7846.798 | 1.74\% | 0.45\% | 2.89\% | 1.03\% |
| 1996.666 | 39431.83 | 0.633 | 230.8053 | 7843.925 | 1.75\% | 0.31\% | 2.95\% | 1.03\% |
| 1996.75 | 39537.53 | 0.634 | 231.1588 | 7840.564 | 1.76\% | 0.17\% | 3.09\% | 1.04\% |
| 1996.833 | 39629 | 0.635 | 231.5183 | 7836.816 | 1.78\% | 0.04\% | 3.23\% | 1.16\% |
| 1996.916 | 39688.77 | 0.634 | 231.8844 | 7832.787 | 1.79\% | -0.09\% | 3.33\% | 1.16\% |
| 1997 | 39742.12 | 0.634 | 232.2576 | 7828.581 | 1.81\% | -0.20\% | 3.36\% | 1.29\% |
| 1997.083 | 39825 | 0.634 | 232.6384 | 7824.302 | 1.83\% | -0.30\% | 3.32\% | 1.30\% |
| 1997.166 | 39962.27 | 0.634 | 233.0266 | 7820.059 | 1.86\% | -0.38\% | 3.21\% | 1.06\% |
| 1997.25 | 40134.46 | 0.636 | 233.4217 | 7815.962 | 1.88\% | -0.45\% | 3.11\% | 1.18\% |
| 1997.333 | 40311 | 0.637 | 233.8236 | 7812.119 | 1.91\% | -0.50\% | 3.08\% | 1.31\% |
| 1997.416 | 40466.06 | 0.638 | 234.2318 | 7808.641 | 1.94\% | -0.54\% | 3.19\% | 1.44\% |
| 1997.5 | 40592.78 | 0.637 | 234.6459 | 7805.637 | 1.97\% | -0.55\% | 3.35\% | 1.09\% |
| 1997.583 | 40689 | 0.639 | 235.0657 | 7803.216 | 2.00\% | -0.56\% | 3.43\% | 1.21\% |
| 1997.666 | 40756.43 | 0.639 | 235.4908 | 7801.489 | 2.03\% | -0.54\% | 3.36\% | 1.22\% |
| 1997.75 | 40812.13 | 0.639 | 235.9209 | 7800.563 | 2.06\% | -0.51\% | 3.22\% | 1.11\% |
| 1997.833 | 40877 | 0.639 | 236.3556 | 7800.55 | 2.09\% | -0.46\% | 3.15\% | 0.99\% |
| 1997.916 | 40966.02 | 0.641 | 236.7946 | 7801.558 | 2.12\% | -0.40\% | 3.22\% | 1.36\% |
| 1998 | 41070.54 | 0.64 | 237.2375 | 7803.698 | 2.14\% | -0.32\% | 3.34\% | 1.25\% |
| 1998.083 | 41176 | 0.64 | 237.6841 | 7807.057 | 2.17\% | -0.22\% | 3.39\% | 1.25\% |
| 1998.166 | 41271.85 | 0.64 | 238.1342 | 7811.648 | 2.19\% | -0.11\% | 3.28\% | 1.26\% |
| 1998.25 | 41363.65 | 0.64 | 238.5878 | 7817.461 | 2.21\% | 0.02\% | 3.06\% | 1.02\% |
| 1998.333 | 41461 | 0.641 | 239.045 | 7824.487 | 2.23\% | 0.16\% | 2.85\% | 1.03\% |
| 1998.416 | 41573.14 | 0.641 | 239.5055 | 7832.715 | 2.25\% | 0.31\% | 2.74\% | 0.92\% |
| 1998.5 | 41707.95 | 0.64 | 239.9695 | 7842.138 | 2.27\% | 0.47\% | 2.75\% | 0.92\% |
| 1998.583 | 41873 | 0.64 | 240.4368 | 7852.745 | 2.28\% | 0.63\% | 2.91\% | 0.69\% |
| 1998.666 | 42068.67 | 0.639 | 240.9075 | 7864.527 | 2.30\% | 0.81\% | 3.22\% | 0.58\% |
| 1998.75 | 42266.79 | 0.642 | 241.3814 | 7877.476 | 2.31\% | 0.99\% | 3.56\% | 0.93\% |
| 1998.833 | 42432 | 0.641 | 241.8586 | 7891.581 | 2.33\% | 1.17\% | 3.80\% | 0.82\% |


| 1998.916 | 42539.57 | 0.642 | 242.339 | 7906.833 | 2.34\% | 1.35\% | 3.84\% | 0.70\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1999 | 42607.15 | 0.643 | 242.8225 | 7923.224 | 2.35\% | 1.53\% | 3.74\% | 0.94\% |
| 1999.083 | 42663 | 0.644 | 243.309 | 7940.657 | 2.37\% | 1.71\% | 3.61\% | 1.06\% |
| 1999.166 | 42729.97 | 0.642 | 243.7979 | 7958.695 | 2.38\% | 1.88\% | 3.53\% | 0.83\% |
| 1999.25 | 42809.34 | 0.642 | 244.2885 | 7976.811 | 2.39\% | 2.04\% | 3.50\% | 0.83\% |
| 1999.333 | 42897 | 0.642 | 244.7799 | 7994.483 | 2.40\% | 2.17\% | 3.46\% | 0.72\% |
| 1999.416 | 42993.67 | 0.643 | 245.2715 | 8011.185 | 2.41\% | 2.28\% | 3.42\% | 0.84\% |
| 1999.5 | 43119.39 | 0.642 | 245.7625 | 8026.391 | 2.41\% | 2.35\% | 3.38\% | 0.84\% |
| 1999.583 | 43299 | 0.642 | 246.2522 | 8039.579 | 2.42\% | 2.38\% | 3.41\% | 0.84\% |
| 1999.666 | 43539.2 | 0.642 | 246.7399 | 8050.223 | 2.42\% | 2.36\% | 3.50\% | 0.96\% |
| 1999.75 | 43773.93 | 0.642 | 247.2249 | 8057.798 | 2.42\% | 2.29\% | 3.57\% | 0.61\% |
| 1999.833 | 43919 | 0.643 | 247.7065 | 8061.779 | 2.42\% | 2.16\% | 3.50\% | 0.84\% |
| 1999.916 | 43925.77 | 0.644 | 248.1839 | 8061.643 | 2.41\% | 1.96\% | 3.26\% | 0.84\% |
| 2000 | 43887.99 | 0.644 | 248.6564 | 8056.864 | 2.40\% | 1.69\% | 3.01\% | 0.72\% |
| 2000.083 | 43935 | 0.646 | 249.1235 | 8047.138 | 2.39\% | 1.34\% | 2.98\% | 0.83\% |
| 2000.166 | 44150.81 | 0.646 | 249.5848 | 8033.045 | 2.37\% | 0.93\% | 3.33\% | 1.06\% |
| 2000.25 | 44438.04 | 0.646 | 250.0399 | 8015.384 | 2.35\% | 0.48\% | 3.80\% | 1.06\% |
| 2000.333 | 44654 | 0.647 | 250.4887 | 7994.956 | 2.33\% | 0.01\% | 4.10\% | 1.17\% |
| 2000.416 | 44698.15 | 0.644 | 250.9308 | 7972.56 | 2.31\% | -0.48\% | 3.96\% | 0.69\% |
| 2000.5 | 44638.7 | 0.645 | 251.3661 | 7948.997 | 2.28\% | -0.96\% | 3.52\% | 0.92\% |
| 2000.583 | 44586 | 0.642 | 251.7941 | 7925.065 | 2.25\% | -1.42\% | 2.97\% | 0.56\% |
| 2000.666 | 44618.91 | 0.642 | 252.2146 | 7901.565 | 2.22\% | -1.85\% | 2.48\% | 0.55\% |
| 2000.75 | 44690.17 | 0.642 | 252.6273 | 7879.298 | 2.19\% | -2.22\% | 2.09\% | 0.55\% |
| 2000.833 | 44721 | 0.642 | 253.032 | 7859.062 | 2.15\% | -2.51\% | 1.83\% | 0.42\% |
| 2000.916 | 44658.87 | 0.643 | 253.4284 | 7841.658 | 2.11\% | -2.73\% | 1.67\% | 0.41\% |
| 2001 | 44556.29 | 0.644 | 253.8161 | 7827.886 | 2.08\% | -2.84\% | 1.52\% | 0.52\% |
| 2001.083 | 44492 | 0.644 | 254.1953 | 7818.318 | 2.04\% | -2.84\% | 1.27\% | 0.28\% |
| 2001.166 | 44519.08 | 0.643 | 254.5668 | 7812.614 | 2.00\% | -2.74\% | 0.83\% | 0.15\% |
| 2001.25 | 44587.87 | 0.643 | 254.932 | 7810.208 | 1.96\% | -2.56\% | 0.34\% | 0.14\% |
| 2001.333 | 44623 | 0.64 | 255.2922 | 7810.531 | 1.92\% | -2.31\% | -0.07\% | -0.33\% |
| 2001.416 | 44571.09 | 0.638 | 255.6488 | 7813.018 | 1.88\% | -2.00\% | -0.28\% | -0.23\% |
| 2001.5 | 44466.6 | 0.637 | 256.003 | 7817.1 | 1.84\% | -1.66\% | -0.39\% | -0.47\% |
| 2001.583 | 44366 | 0.637 | 256.3561 | 7822.211 | 1.81\% | -1.30\% | -0.49\% | -0.13\% |
| 2001.666 | 44315.5 | 0.632 | 256.7093 | 7827.784 | 1.78\% | -0.93\% | -0.68\% | -0.72\% |
| 2001.75 | 44320.46 | 0.635 | 257.0641 | 7833.251 | 1.76\% | -0.58\% | -0.83\% | -0.38\% |
| 2001.833 | 44376 | 0.632 | 257.4216 | 7838.044 | 1.73\% | -0.27\% | -0.77\% | -0.73\% |
| 2001.916 | 44473.17 | 0.63 | 257.7832 | 7841.598 | 1.72\% | 0.00\% | -0.42\% | -1.09\% |
| 2002 | 44586.65 | 0.629 | 258.1501 | 7843.345 | 1.71\% | 0.20\% | 0.07\% | -1.32\% |
| 2002.083 | 44687 | 0.627 | 258.5234 | 7842.878 | 1.70\% | 0.31\% | 0.44\% | -1.55\% |
| 2002.166 | 44752.91 | 0.63 | 258.9028 | 7840.432 | 1.70\% | 0.36\% | 0.53\% | -1.09\% |
| 2002.25 | 44795.51 | 0.628 | 259.288 | 7836.403 | 1.71\% | 0.34\% | 0.47\% | -1.32\% |
| 2002.333 | 44834 | 0.627 | 259.6786 | 7831.187 | 1.72\% | 0.26\% | 0.47\% | -1.09\% |
| 2002.416 | 44880.99 | 0.629 | 260.0741 | 7825.181 | 1.73\% | 0.16\% | 0.70\% | -0.63\% |
| 2002.5 | 44922.51 | 0.627 | 260.4741 | 7818.779 | 1.75\% | 0.02\% | 1.03\% | -0.74\% |
| 2002.583 | 44938 | 0.627 | 260.8782 | 7812.378 | 1.76\% | -0.13\% | 1.29\% | -0.74\% |
| 2002.666 | 44915.55 | 0.627 | 261.286 | 7806.373 | 1.78\% | -0.27\% | 1.35\% | -0.15\% |
| 2002.75 | 44878.03 | 0.63 | 261.697 | 7801.161 | 1.80\% | -0.41\% | 1.26\% | -0.14\% |
| 2002.833 | 44857 | 0.627 | 262.1109 | 7797.136 | 1.82\% | -0.52\% | 1.08\% | -0.14\% |
| 2002.916 | 44876.15 | 0.625 | 262.5271 | 7794.696 | 1.84\% | -0.60\% | 0.91\% | -0.14\% |
| 2003 | 44927.7 | 0.624 | 262.9453 | 7794.236 | 1.86\% | -0.63\% | 0.76\% | -0.13\% |
| 2003.083 | 44996 | 0.625 | 263.3652 | 7796.032 | 1.87\% | -0.60\% | 0.69\% | 0.23\% |
| 2003.166 | 45071.59 | 0.625 | 263.787 | 7799.885 | 1.89\% | -0.52\% | 0.71\% | -0.12\% |


| 2003.25 | 45169.76 | 0.624 | 264.2111 | 7805.478 | 1.90\% | -0.39\% | 0.84\% | 0.00\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2003.333 | 45312 | 0.624 | 264.6379 | 7812.492 | 1.91\% | -0.24\% | 1.07\% | 0.12\% |
| 2003.416 | 45510.13 | 0.623 | 265.0677 | 7820.608 | 1.92\% | -0.06\% | 1.40\% | -0.24\% |
| 2003.5 | 45737.3 | 0.623 | 265.5011 | 7829.51 | 1.93\% | 0.14\% | 1.81\% | 0.00\% |
| 2003.583 | 45957 | 0.621 | 265.9383 | 7838.878 | 1.94\% | 0.34\% | 2.27\% | -0.23\% |
| 2003.666 | 46139.3 | 0.621 | 266.3798 | 7848.394 | 1.95\% | 0.54\% | 2.72\% | -0.23\% |
| 2003.75 | 46280.62 | 0.62 | 266.8259 | 7857.74 | 1.96\% | 0.73\% | 3.13\% | -0.70\% |
| 2003.833 | 46384 | 0.621 | 267.2771 | 7866.599 | 1.97\% | 0.89\% | 3.40\% | -0.22\% |
| 2003.916 | 46454.79 | 0.623 | 267.7338 | 7874.651 | 1.98\% | 1.03\% | 3.52\% | 0.26\% |
| 2004 | 46507.76 | 0.622 | 268.1963 | 7881.579 | 2.00\% | 1.12\% | 3.52\% | 0.26\% |
| 2004.083 | 46560 | 0.623 | 268.6648 | 7887.113 | 2.01\% | 1.17\% | 3.48\% | 0.26\% |
| 2004.166 | 46625.5 | 0.623 | 269.1387 | 7891.183 | 2.03\% | 1.17\% | 3.45\% | 0.27\% |
| 2004.25 | 46705.73 | 0.622 | 269.6172 | 7893.766 | 2.05\% | 1.13\% | 3.40\% | 0.27\% |
| 2004.333 | 46799 | 0.623 | 270.0993 | 7894.841 | 2.06\% | 1.05\% | 3.28\% | 0.40\% |
| 2004.416 | 46902.42 | 0.623 | 270.5843 | 7894.386 | 2.08\% | 0.94\% | 3.06\% | 0.52\% |
| 2004.5 | 47008.12 | 0.624 | 271.0713 | 7892.378 | 2.10\% | 0.80\% | 2.78\% | 0.64\% |
| 2004.583 | 47107 | 0.625 | 271.5595 | 7888.796 | 2.11\% | 0.64\% | 2.50\% | 1.01\% |
| 2004.666 | 47194.56 | 0.624 | 272.048 | 7883.617 | 2.13\% | 0.45\% | 2.29\% | 0.89\% |
| 2004.75 | 47284.71 | 0.623 | 272.5359 | 7876.82 | 2.14\% | 0.24\% | 2.17\% | 0.90\% |
| 2004.833 | 47396 | 0.623 | 273.0224 | 7868.383 | 2.15\% | 0.02\% | 2.18\% | 0.78\% |
| 2004.916 | 47537.99 | 0.625 | 273.5067 | 7858.283 | 2.16\% | -0.21\% | 2.33\% | 0.78\% |
| 2005 | 47684.4 | 0.624 | 273.988 | 7846.5 | 2.16\% | -0.45\% | 2.53\% | 0.78\% |
| 2005.083 | 47800 | 0.624 | 274.4654 | 7833.086 | 2.16\% | -0.69\% | 2.66\% | 0.66\% |
| 2005.166 | 47862.05 | 0.624 | 274.9387 | 7818.403 | 2.16\% | -0.92\% | 2.65\% | 0.66\% |
| 2005.25 | 47897.81 | 0.624 | 275.4075 | 7802.885 | 2.15\% | -1.15\% | 2.55\% | 0.78\% |
| 2005.333 | 47947 | 0.627 | 275.8716 | 7786.97 | 2.14\% | -1.37\% | 2.45\% | 1.02\% |
| 2005.416 | 48036.61 | 0.628 | 276.3307 | 7771.093 | 2.12\% | -1.56\% | 2.42\% | 1.13\% |
| 2005.5 | 48142.56 | 0.627 | 276.7845 | 7755.69 | 2.11\% | -1.73\% | 2.41\% | 0.89\% |
| 2005.583 | 48228 | 0.628 | 277.2329 | 7741.197 | 2.09\% | -1.87\% | 2.38\% | 0.88\% |
| 2005.666 | 48270.47 | 0.629 | 277.6755 | 7728.051 | 2.07\% | -1.97\% | 2.28\% | 1.12\% |
| 2005.75 | 48305 | 0.628 | 278.112 | 7716.688 | 2.05\% | -2.03\% | 2.16\% | 1.11\% |
| 2005.833 | 48381 | 0.628 | 278.5423 | 7707.543 | 2.02\% | -2.04\% | 2.08\% | 1.11\% |
| 2005.916 | 48529.52 | 0.627 | 278.9661 | 7701.052 | 2.00\% | -2.00\% | 2.09\% | 0.74\% |
| 2006 | 48708.13 | 0.628 | 279.3831 | 7697.653 | 1.97\% | -1.90\% | 2.15\% | 0.97\% |
| 2006.083 | 48856 | 0.629 | 279.7932 | 7697.607 | 1.94\% | -1.73\% | 2.21\% | 1.09\% |
| 2006.166 | 48926.55 | 0.63 | 280.1962 | 7700.488 | 1.91\% | -1.51\% | 2.22\% | 1.20\% |
| 2006.25 | 48930.06 | 0.631 | 280.5923 | 7705.695 | 1.88\% | -1.25\% | 2.16\% | 1.31\% |
| 2006.333 | 48891 | 0.63 | 280.9813 | 7712.627 | 1.85\% | -0.95\% | 1.97\% | 0.82\% |
| 2006.416 | 48835.56 | 0.631 | 281.3633 | 7720.685 | 1.82\% | -0.65\% | 1.66\% | 0.81\% |
| 2006.5 | 48796.69 | 0.631 | 281.7384 | 7729.268 | 1.79\% | -0.34\% | 1.36\% | 0.93\% |
| 2006.583 | 48809 | 0.63 | 282.1065 | 7737.775 | 1.76\% | -0.04\% | 1.20\% | 0.68\% |
| 2006.666 | 48891.05 | 0.631 | 282.4676 | 7745.607 | 1.73\% | 0.23\% | 1.29\% | 0.67\% |
| 2006.75 | 48997.02 | 0.631 | 282.8217 | 7752.162 | 1.69\% | 0.46\% | 1.43\% | 0.78\% |
| 2006.833 | 49065 | 0.633 | 283.1689 | 7756.84 | 1.66\% | 0.64\% | 1.41\% | 1.01\% |
| 2006.916 | 49054.02 | 0.633 | 283.509 | 7759.042 | 1.63\% | 0.75\% | 1.08\% | 1.12\% |
| 2007 | 49006.8 | 0.634 | 283.8422 | 7758.166 | 1.60\% | 0.79\% | 0.61\% | 1.12\% |
| 2007.083 | 48987 | 0.633 | 284.1681 | 7753.727 | 1.56\% | 0.73\% | 0.27\% | 0.87\% |
| 2007.166 | 49040.59 | 0.633 | 284.4852 | 7745.702 | 1.53\% | 0.59\% | 0.23\% | 0.74\% |
| 2007.25 | 49142.75 | 0.633 | 284.7918 | 7734.179 | 1.50\% | 0.37\% | 0.43\% | 0.61\% |
| 2007.333 | 49251 | 0.63 | 285.086 | 7719.251 | 1.46\% | 0.09\% | 0.74\% | 0.37\% |
| 2007.416 | 49332.75 | 0.63 | 285.3661 | 7701.007 | 1.42\% | -0.25\% | 1.02\% | 0.24\% |
| 2007.5 | 49395.08 | 0.63 | 285.6303 | 7679.539 | 1.38\% | -0.64\% | 1.23\% | 0.23\% |


| 2007.583 | 49455 | 0.629 | 285.8768 | 7654.936 | 1.34\% | -1.07\% | 1.32\% | 0.22\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2007.666 | 49518.97 | 0.627 | 286.1039 | 7627.29 | 1.29\% | -1.53\% | 1.28\% | -0.15\% |
| 2007.75 | 49551.36 | 0.629 | 286.3098 | 7596.691 | 1.23\% | -2.01\% | 1.13\% | 0.07\% |
| 2007.833 | 49506 | 0.627 | 286.4927 | 7563.229 | 1.17\% | -2.50\% | 0.90\% | -0.42\% |
| 2007.916 | 49359.62 | 0.629 | 286.6511 | 7526.996 | 1.11\% | -2.99\% | 0.62\% | -0.20\% |
| 2008 | 49180.55 | 0.627 | 286.783 | 7488.082 | 1.04\% | -3.48\% | 0.35\% | -0.57\% |
| 2008.083 | 49060 | 0.629 | 286.8876 | 7446.7 | 0.96\% | -3.96\% | 0.15\% | -0.23\% |
| 2008.166 | 49060.83 | 0.628 | 286.9671 | 7403.553 | 0.87\% | -4.42\% | 0.04\% | -0.37\% |
| 2008.25 | 49132.47 | 0.627 | 287.0246 | 7359.468 | 0.78\% | -4.84\% | -0.02\% | -0.51\% |
| 2008.333 | 49196 | 0.627 | 287.0632 | 7315.271 | 0.69\% | -5.23\% | -0.11\% | -0.18\% |
| 2008.416 | 49183.31 | 0.625 | 287.0859 | 7271.787 | 0.60\% | -5.57\% | -0.30\% | -0.44\% |
| 2008.5 | 49069.63 | 0.624 | 287.0958 | 7229.844 | 0.51\% | -5.86\% | -0.66\% | -0.59\% |
| 2008.583 | 48841 | 0.622 | 287.0958 | 7190.266 | 0.43\% | -6.07\% | -1.24\% | -0.73\% |
| 2008.666 | 48497.22 | 0.62 | 287.089 | 7153.881 | 0.34\% | -6.21\% | -2.06\% | -0.75\% |
| 2008.75 | 48093.05 | 0.619 | 287.0784 | 7121.514 | 0.27\% | -6.26\% | -2.94\% | -1.13\% |
| 2008.833 | 47697 | 0.617 | 287.0671 | 7093.991 | 0.20\% | -6.20\% | -3.65\% | -1.15\% |
| 2008.916 | 47366.41 | 0.614 | 287.0579 | 7072.139 | 0.14\% | -6.04\% | -4.04\% | -1.75\% |
| 2009 | 47113.92 | 0.61 | 287.054 | 7056.784 | 0.09\% | -5.76\% | -4.20\% | -2.01\% |
| 2009.083 | 46941 | 0.606 | 287.0576 | 7048.45 | 0.06\% | -5.35\% | -4.32\% | -2.73\% |
| 2009.166 | 46844.18 | 0.603 | 287.0689 | 7046.464 | 0.04\% | -4.82\% | -4.52\% | -2.98\% |
| 2009.25 | 46800.24 | 0.599 | 287.0875 | 7049.848 | 0.02\% | -4.21\% | -4.75\% | -3.34\% |
| 2009.333 | 46781 | 0.598 | 287.1129 | 7057.626 | 0.02\% | -3.52\% | -4.91\% | -3.46\% |
| 2009.416 | 46767.04 | 0.596 | 287.1448 | 7068.823 | 0.02\% | -2.79\% | -4.91\% | -3.47\% |
| 2009.5 | 46773.93 | 0.594 | 287.1825 | 7082.463 | 0.03\% | -2.04\% | -4.68\% | -3.60\% |
| 2009.583 | 46826 | 0.593 | 287.2258 | 7097.57 | 0.05\% | -1.29\% | -4.13\% | -3.49\% |
| 2009.666 | 46935.48 | 0.591 | 287.2741 | 7113.166 | 0.06\% | -0.57\% | -3.22\% | -3.49\% |
| 2009.75 | 47066.22 | 0.587 | 287.3271 | 7128.278 | 0.09\% | 0.09\% | -2.14\% | -3.86\% |
| 2009.833 | 47170 | 0.585 | 287.3843 | 7141.928 | 0.11\% | 0.68\% | -1.10\% | -3.86\% |
| 2009.916 | 47214.98 | 0.586 | 287.4453 | 7153.14 | 0.13\% | 1.15\% | -0.32\% | -3.39\% |
| 2010 | 47234.92 | 0.583 | 287.5096 | 7160.939 | 0.16\% | 1.48\% | 0.26\% | -3.28\% |
| 2010.083 | 47280 | 0.585 | 287.577 | 7164.577 | 0.18\% | 1.65\% | 0.72\% | -2.55\% |
| 2010.166 | 47384.87 | 0.585 | 287.6475 | 7164.222 | 0.20\% | 1.67\% | 1.15\% | -2.19\% |
| 2010.25 | 47522.17 | 0.585 | 287.7217 | 7160.269 | 0.22\% | 1.57\% | 1.54\% | -1.70\% |
| 2010.333 | 47649 | 0.587 | 287.7997 | 7153.115 | 0.24\% | 1.35\% | 1.86\% | -1.32\% |
| 2010.416 | 47734.9 | 0.586 | 287.8818 | 7143.155 | 0.26\% | 1.05\% | 2.07\% | -1.19\% |
| 2010.5 | 47799.05 | 0.585 | 287.9685 | 7130.786 | 0.27\% | 0.68\% | 2.19\% | -1.07\% |
| 2010.583 | 47873 | 0.585 | 288.0599 | 7116.404 | 0.29\% | 0.27\% | 2.24\% | -0.94\% |
| 2010.666 | 47973.81 | 0.586 | 288.1565 | 7100.404 | 0.31\% | -0.18\% | 2.21\% | -0.56\% |
| 2010.75 | 48060.36 | 0.585 | 288.2585 | 7083.183 | 0.32\% | -0.63\% | 2.11\% | -0.17\% |
| 2010.833 | 48077 | 0.583 | 288.3662 | 7065.137 | 0.34\% | -1.08\% | 1.92\% | -0.17\% |
| 2010.916 | 47992.54 | 0.582 | 288.48 | 7046.661 | 0.36\% | -1.49\% | 1.65\% | -0.42\% |
| 2011 | 47873.53 | 0.583 | 288.6001 | 7028.153 | 0.38\% | -1.85\% | 1.35\% | 0.09\% |
| 2011.083 | 47811 | 0.583 | 288.7267 | 7009.962 | 0.40\% | -2.16\% | 1.12\% | -0.16\% |
| 2011.166 | 47866.5 | 0.584 | 288.8595 | 6992.258 | 0.42\% | -2.40\% | 1.02\% | -0.02\% |
| 2011.25 | 47983.74 | 0.584 | 288.9979 | 6975.166 | 0.44\% | -2.59\% | 0.97\% | -0.02\% |
| 2011.333 | 48077 | 0.584 | 289.1415 | 6958.81 | 0.47\% | -2.72\% | 0.90\% | -0.27\% |
| 2011.416 | 48087.44 | 0.583 | 289.2897 | 6943.314 | 0.49\% | -2.80\% | 0.74\% | -0.26\% |
| 2011.5 | 48063.87 | 0.582 | 289.4421 | 6928.804 | 0.51\% | -2.83\% | 0.55\% | -0.26\% |
| 2011.583 | 48082 | 0.582 | 289.5981 | 6915.402 | 0.53\% | -2.82\% | 0.44\% | -0.25\% |
| 2011.666 | 48194.77 | 0.583 | 289.7573 | 6903.234 | 0.56\% | -2.78\% | 0.46\% | -0.25\% |
| 2011.75 | 48364.07 | 0.584 | 289.9192 | 6892.424 | 0.58\% | -2.69\% | 0.63\% | 0.02\% |
| 2011.833 | 48529 | 0.584 | 290.0832 | 6883.096 | 0.60\% | -2.58\% | 0.94\% | 0.28\% |


| 2011.916 | 48642.83 | 0.586 | 290.2489 | 6875.375 | $0.61 \%$ | $-2.43 \%$ | $1.35 \%$ | $0.67 \%$ |
| ---: | ---: | ---: | ---: | ---: | :--- | :--- | :--- | :--- |
| 2012 | 48715.48 | 0.586 | 290.4159 | 6869.385 | $0.63 \%$ | $-2.26 \%$ | $1.76 \%$ | $0.54 \%$ |
| 2012.083 | 48771 | 0.584 | 290.5835 | 6865.207 | $0.64 \%$ | $-2.06 \%$ | $2.01 \%$ | $0.29 \%$ |
| 2012.166 | 48827.59 | 0.585 | 290.7512 | 6862.748 | $0.65 \%$ | $-1.85 \%$ | $2.01 \%$ | $0.29 \%$ |
| 2012.25 | 48879.98 | 0.586 | 290.9182 | 6861.869 | $0.66 \%$ | $-1.62 \%$ | $1.87 \%$ | $0.42 \%$ |
| 2012.333 | 48917 | 0.585 | 291.0838 | 6862.433 | $0.67 \%$ | $-1.38 \%$ | $1.75 \%$ | $0.30 \%$ |
| 2012.416 | 48929.6 | 0.585 | 291.2474 | 6864.304 | $0.68 \%$ | $-1.14 \%$ | $1.75 \%$ | $0.43 \%$ |
| 2012.5 | 48917.12 | 0.586 | 291.4081 | 6867.343 | $0.68 \%$ | $-0.89 \%$ | $1.78 \%$ | $0.69 \%$ |
| 2012.583 | 48881 | 0.585 | 291.5654 | 6871.414 | $0.68 \%$ | $-0.64 \%$ | $1.66 \%$ | $0.56 \%$ |
| 2012.666 | 48828.29 | 0.584 | 291.7185 | 6876.379 | $0.68 \%$ | $-0.39 \%$ | $1.31 \%$ | $0.30 \%$ |
| 2012.75 | 48788.56 | 0.587 | 291.8667 | 6882.101 | $0.67 \%$ | $-0.15 \%$ | $0.88 \%$ | $0.55 \%$ |
| 2012.833 | 48797 | 0.588 | 292.0094 | 6888.442 | $0.66 \%$ | $0.08 \%$ | $0.55 \%$ | $0.68 \%$ |
| 2012.916 | 48874.08 | 0.587 | 292.1458 | 6895.265 | $0.65 \%$ | $0.29 \%$ | $0.48 \%$ | $0.29 \%$ |
| 2013 | 48981.44 | 0.586 | 292.2752 | 6902.433 | $0.64 \%$ | $0.48 \%$ | $0.55 \%$ | $0.16 \%$ |
| 2013.083 | 49066 | 0.585 | 292.3971 | 6909.803 | $0.62 \%$ | $0.65 \%$ | $0.60 \%$ | $0.28 \%$ |
| 2013.166 | 49090.69 | 0.586 | 292.5116 | 6917.214 | $0.61 \%$ | $0.79 \%$ | $0.54 \%$ | $0.28 \%$ |
| 2013.25 | 49082.39 | 0.585 | 292.6189 | 6924.498 | $0.58 \%$ | $0.91 \%$ | $0.41 \%$ | $0.02 \%$ |
| 2013.333 | 49084 | 0.586 | 292.7193 | 6931.488 | $0.56 \%$ | $1.01 \%$ | $0.34 \%$ | $0.27 \%$ |
| 2013.416 | 49130.58 | 0.586 | 292.813 | 6938.018 | $0.54 \%$ | $1.07 \%$ | $0.41 \%$ | $0.26 \%$ |
| 2013.5 | 49225.92 | 0.586 | 292.9002 | 6943.921 | $0.51 \%$ | $1.12 \%$ | $0.63 \%$ | $0.13 \%$ |
| 2013.583 | 49366 | 0.587 | 292.9813 | 6949.029 | $0.49 \%$ | $1.13 \%$ | $0.99 \%$ | $0.38 \%$ |
| 2013.666 | 49536.96 | 0.587 | 293.0564 | 6953.177 | $0.46 \%$ | $1.12 \%$ | $1.45 \%$ | $0.50 \%$ |
| 2013.75 | 49685.63 | 0.587 | 293.1257 | 6956.196 | $0.43 \%$ | $1.08 \%$ | $1.84 \%$ | $0.11 \%$ |
| 2013.833 | 49749 | 0.583 | 293.1896 | 6957.919 | $0.40 \%$ | $1.01 \%$ | $1.95 \%$ | $-0.54 \%$ |
| 2013.916 | 49690.77 | 0.586 | 293.2482 | 6958.181 | $0.38 \%$ | $0.91 \%$ | $1.67 \%$ | $-0.03 \%$ |
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[^0]:    ${ }^{1}$ Whenever Marx considered the relationship between the wage and the value of labor-power, the term he used was not "average", but "minimum". In a section of the Grundrisse entitled "The minimum of wages", Marx made it clear that in his complete analysis, the wage would normally exceed the value of labor-power: "For the time being, necessary labor supposed as such; i.e. that the worker always obtains only the minimum of wages. This supposition is necessary, of course, so as to establish the laws of profit insofar as they are not determined by the rise and fall of wages or by the influence of landed property. All these fixed suppositions themselves become fluid in the further course of development." (Marx 1857, p. 817.)

[^1]:    ${ }^{2}$ In Roegen's notation $Q$ is real output, $K$ capital, H labor and R is natural resources.

[^2]:    ${ }^{3}$ And raw materials, as noted in our conclusion.
    ${ }^{4}$ We could collapse these two terms into one, but feel that it is preferable to separate them. In the case of an automobile for example, the former term would indicate the maximum efficiency with which a car converts energy into movement (including its cost of maintenance); the latter reflects how much of this efficiency can be exploited, given traffic and road conditions, compared to an (impossible but reference) ideal of completely frictionless transport of the car's cargo from origin to destination.

[^3]:    ${ }^{5}$ Alternately, there are some limited time series for exergy, in which case $Y=\left(\mathrm{E} x_{K} \cdot e_{K}\right)^{\alpha} \cdot\left(L \cdot E_{L} \cdot x_{L} \cdot e_{L}\right)^{1-\alpha}$ can also be used.
    ${ }^{6}$ The function of labor engaged directly in manufacturing today is predominantly to control machinery, rather than to directly impart its energy to the product.

[^4]:    ${ }^{7}$ The highest correlation coefficient for both equations was found with $\alpha=0.25$, as was the case with the original research by Cobb and Douglas.

