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DYNAMIC PANEL ESTIMATION OF THE DEATON PARADOX

Ruschka, A., Janíčko, M., Chytilová, H.

Adam Ruschka / Prague University of Economics and Business Faculty of Economics, Department of Economics, W. Churchill Sq. 4, 130 67, Prague, Czech Republic. Email: adam.ruschka@vse.cz

Martin Janíčko / Charles University, Faculty of Social Sciences, Institute of Economic Studies, Opletalova 26, 110 00, Prague, Czech Republic. Email: janicko@mnd.cz (corresponding author)

Helena Chytilová / Prague University of Economics and Business Faculty of Economics, Department of Economics, W. Churchill Sq. 4, 130 67, Prague, Czech Republic. Email: helena.chytilova@vse.cz

Abstract

This paper estimates the presence of the Deaton paradox in Europe. Using panel data for 24 countries ranging from 2000 to 2021, we estimate the presence of excess smoothness of consumption. We use the generalised method of moments (GMM) estimator. We cluster our dataset, which lowers the data variability, and use both quarterly and monthly data to obtain robust estimates. We broaden our knowledge of the Deaton paradox in a new direction by using a combination of uncommon datasets, GMM and clustering. Our findings indicate that traditional economic theories about consumption may not be applicable. The evident excess smoothness in consumption patterns across Europe provides key insights into consumer behaviour, especially during periods of volatility and instability such as the present. Our research indirectly corroborates newer theories in behavioural economics regarding consumption and places them within a wider macroeconomic context. This has implications for both monetary and fiscal policy.

Business and Corporate Implications for Central European audience: The provided insights into the excess smoothness of European consumption patterns are vital for business strategy, particularly in consumer-focused industries. Companies can use these findings to improve forecasting accuracy, optimize inventory and tailor marketing efforts. The relative stability of consumer behaviour, even in economic shifts, suggests opportunities for enhancing brand loyalty and customer retention. Additionally, these insights are crucial for informed investment decisions and pricing strategies in consumer-dependent sectors. Firms can also use this knowledge in policy advocacy, promoting economic decisions that reflect consumer spending trends. Aligning business strategies with these findings not only boosts operational efficiency but also contributes to their economic stability.

Keywords: Deaton paradox; panel data; clustering; variability of consumption

JEL Classification: B22, C01, C23, E21

Introduction

The main objective of the paper is to verify whether consumption follows the path suggested by the permanent income hypothesis or whether is subject to an excess smoothness tendency, which is a crucial part of an empirical observation called the Deaton paradox.

The permanent income hypothesis is still one of the leading mainstream economic theories of consumption. It is widely acknowledged as a theory which explains how consumers decide about their consumption with respect to their income.

The Deaton paradox challenges traditional economic theories such as the permanent income hypothesis (PIH), as Campbell and Deaton (1989) observed unusual sensitivity and smoothness in consumption patterns. Behavioural economics, as explained by Schmidt & Zank (2005), suggests loss aversion affects reluctance to reduce consumption. Empirical evidence from Foellmi et al. (2019) and Barigozzi et al. (2012) supports this smoother-than-expected consumption trend. Understanding these patterns is crucial for policymaking, particularly in high inflation periods affecting high-consumption individuals.

The theoretical background of how the Deaton paradox has been derived from the permanent income hypothesis is the main body of the first section of this paper. The last part of the first section is devoted to the recent research on the phenomenon of consumption smoothing since it is still a frequently discussed topic (Alcidi et al., 2022; Bairoliya et al., 2021; Baugh et al., 2021; Breitenlechner et al., 2022; Dreger & Reimers (2006); Ganong et al., 2020; Gil-Alana et al., 2009; Luengo-Prado & Sørensen, 2008; Thakral & Tô, 2021). We discuss how the granularity of the data and the method used can change the outcome of the exploration of consumption smoothing, which helps us develop our own model.

In this article, we introduce a novel approach to exploring the Deaton paradox, not by developing new methods, but by applying established dynamic panel estimators in a unique context. We utilize a hitherto unexplored panel dataset encompassing 24 European countries over two decades (from 2000Q1 to 2021Q2), a scope of data not previously examined in this area of research. This application of dynamic panel estimators to such an extensive and specific dataset represents an innovative step in investigating instances of the Deaton paradox in European countries with open market economies. Furthermore, the granularity of the data is a key focus of our study. We compare the implications of using monthly data versus quarterly data, investigating the potential impacts on our estimates. This aspect, coupled with our rigorous preliminary research, forms the basis of our main model. Thus, the novelty of our research lies in the unique combination of our empirical approach and the specific dataset employed, offering new insights into a well-established economic phenomenon.

1 Theoretical Background

The Deaton paradox can be divided into two parts: the excess smoothness of consumption and the excess sensitivity of consumption (as in Flavin, 1981). Excess smoothness marks a situation where consumption reacts too little in response to an unexpected change of income. This paper considers only the excess smoothness[1].

[1] *Even though excess sensitiveness and excess smoothness are somehow related, it is possible to inspect them separately. The mathematical derivation in this section follows the derivation in original paper by Campbell and Deaton (1989).*

A less intuitive but more interesting explanation comes from Campbell and Deaton (1989). In line with Flavin (1981), Campbell and Deaton (1989) used a well-known equation as a representation of the permanent income. The equation is as follows:

$$c_t = \frac{r}{1+r} \times \left[A_t + \sum_{i=0}^{\infty} (1+r)^{-i} \, E_t y_{t+i} \right], \tag{1}$$

where r stands for the real interest rate, which is supposed to be constant. A_t represents the real non-human (capital gains) per capita wealth at the end of the period t[2]. In Equation (1), E_t represents a situation where the consumer has some expectations about the future and those expectations are based on available information at the time t. Furthermore, y_t is the real per capita labour income that is received at the time t and c_t stands for consumption at the time t.

The motion of resources that are available to the consumer through time can be expressed as:

$$A_{t+1} = (1+r) \times (A_t + y_t - c_t), \tag{2}$$

from which it is obvious that current wealth is equal to the discounted value of the wealth in the previous period.

Using (1) and substituting it into (2) yields:

$$c_t = r(A_{t-1} + y_{t-1} - c_{t-1}) + \frac{r}{1+r} \times \sum_{i=0}^{\infty} (1+r)^{-i} \, E_t y_{t+i}. \tag{3}$$

For the time being, we go one period back and multiply the whole Equation (3) by $(1 + r)$ and reshuffle the income terms to get Equation (4).

$$(1+r)c_{t-1} = rA_{t-1} + ry_{t-1} + \frac{r}{1+r} \sum_{i=0}^{\infty} (1+r)^{-i} \, E_{t-1} y_{t-k} \tag{4}$$

Now we can subtract (3) from (4), which yields:

$$\varDelta c_{t+1} = r \sum_{i=1}^{\infty} (1+r)^{-i} (E_{t+1} - E_t) y_{t+i}, \tag{5}$$

which is identical with the results of Hall (1978).

Using the derivation of Campbell (1987), we can define savings as:

$$s_t = \frac{r \times A_t}{1+r} + y_t - c_t = z_t - c_t, \tag{6}$$

[2] *Hence,* $\frac{rA_t}{1+r}$ *is equal to capital income.*

where z_t is equal to $\frac{\mathrm{r} \times \mathrm{A_t}}{1+\mathrm{r}} + \mathrm{y_t}$ and hence z_t represents the discounted momentous wealth. This element comes from the derivation of the "saving for a rainy day" equation[3]. The derivation of this equation is as follows[4]:

$$c_t = \frac{r}{1+r} A_t + \frac{r}{1+r} \sum_{i=0}^{\infty} (1+r)^{-i} E_t y_{t+i}. \tag{7}$$

Savings are defined as follows:

$$s_t = \frac{r \times A_t}{1+r} + y_t - c_t. \tag{8}$$

The first two terms on the right-hand side of (8) can be interpreted as disposable income. This yields a standard definition of savings as the difference between income and consumption.

We can therefore equate Equations (7) and (8) for consumption and rewrite them to get:

$$-s_t = \frac{E_t \Delta y_{t+1}}{1+r} - \frac{E_t y_{t+1}}{(1+r)^2} + \frac{r}{1+r} \times \sum_{2}^{\infty} (1+r)^{-i} \times y_{t+i}. \tag{9}$$

We could do a repetition of this procedure for $E_t y_{t+2}$ and $E_t y_{t+3}$, $E_t y_{t+3}$ and $E_t y_{t+4}$ eventually to infinity to get the equation of "saving for a rainy day", which is described as follows:

$$s_t = -\sum_{i=1}^{\infty} (1+r)^{-i} E_t \Delta y_{t+i} \tag{10}$$

Equation (10) is suitable for expressing the predicted outcome of expected change in income. Since there is a minus sign, the relation is of the opposite direction: if the income is expected to rise, the savings will decrease. If the income is expected to drop, the savings will increase. The equation of "rainy-day" savings is also important for verifying our hypothesis about excess smoothness of consumption. This testing process will be described later.

According to Campbell and Deaton (1989), the golden rule for testing consumption takes the form of the equations shown earlier and utilizes linear time series to estimate the link between consumption and (current) income. Deaton stated, in line with Flavin (1981) and Hansen and Sargent (1981), that if income follows an autoregressive (AR) process (usually AR (1) or AR (2)), the changes in consumption to income after the shock should be approximately 1.76 times larger (with a 10% interest rate and the difference in the interest rate decreasing slowly). This also holds for the standard deviation of consumption. In other words, the consumption should be almost twice more volatile than the income. However, the estimates obtained from such a simple model are not in line with the data.

It was Deaton's idea that although the AR process describes the income nicely, it is not stationary in most cases (including the time series that we use). As a result, Deaton's analysis incorporates the first difference of logarithm (and so does Section 2 of this paper). The most appropriate form seems to be a log-linearized model, which accounts for savings in the form

[3] *Saving for a rainy day describes a situation where rational forward-looking consumers anticipate a possible decline in their income and save some resources to maintain a stable level of consumption in all time periods. Examples and a brief theoretical overview can be found for example in Romer (2012).*
[4] *For clarity, we begin again with Equation (1), hence Equations (7) and (1) are in fact identical.*

related with income (rather than working with consumption). The derivation of the log-linear model of the permanent income hypothesis goes as follows.

We need to start with the following equation[5]:

$$c_t = \frac{r}{1+r}\left[A_t + \sum_{i=0}^{\infty}(1+r)^{-i}E_t y_{t+i}\right]. \tag{11}$$

The next step is to subtract the capital income from both sides of (11) in order to obtain:

$$c_t - \frac{rA_t}{1+r} = \frac{r}{1+r}\left[y_t + \sum_{i=0}^{\infty}(1+r)^{-i}E_t y_{t+i}\right]. \tag{12}$$

The left-hand side of Equation (12) is equal to $y_t - s_t$; therefore, we can rewrite (12) as:

$$y_t - s_t = \frac{r}{1+r}\left[y_t + \sum_{i=0}^{\infty}(1+r)^{-i}E_t y_{t+i}\right]. \tag{13}$$

Having Equation (13), we divide the equation by y_t, which is the current labour income, in order to obtain:

$$1 - \frac{s_t}{y_t} = \frac{r}{1+r}\left[1 + \sum_{i=1}^{\infty}(1+r)^{-i}E_t \times \frac{y_{t+i}}{y_t}\right]. \tag{14}$$

Based on the previous equation, it must hold that for all $j > 0$:

$$\frac{y_{t+j}}{y_t} = \exp\left[j\mu + \sum_{k=1}^{j}(\Delta \log y_{t+k} - \mu)\right]. \tag{15}$$

It is also possible to state that the right-hand side of Equation (15) is approximately equal to $e^{j\mu}\left[1 + \sum_{k=1}^{j}(\Delta \log y_{t+k} - \mu)\right]$; therefore, Equation (15) can be rewritten as follows:

$$\frac{y_{t+j}}{y_t} \approx e^{j\mu}\left[1 + \sum_{k=1}^{j}(\Delta \log y_{t+k} - \mu)\right], \tag{16}$$

where the parameter μ stands for the average first difference of the logarithm of income. Proceeding with the calculation, we can take the right-hand side of Equation (14), which – after a small manipulation – yields:

$$1 - \frac{s_t}{y_t} \approx \frac{r}{(1+r)(1+\rho)} \times \left[1 + \sum_{i=1}^{\infty}\rho^{-i}E_t(\Delta \log y_{t+i} - \mu)\right]. \tag{17}$$

In Equation (17), the parameter ρ is the discount factor. If we assume that the ratio of savings to income is small enough, then it is possible to take logarithms of both sides and do the approximation once more, which will provide us with the final form depicted in Equation (18).

[5] *Equation (11) is identical to Equation (1).*

$$\frac{s_t}{y_t} \approx -\sum_{i=1}^{\infty} \rho^i E_t \Delta \, log \, y_{t+i} - \kappa \tag{18}$$

In Equation (18), κ is equal to:

$$\kappa = \log\left(\frac{r}{1+r}\right) - \log(1-\rho) - \frac{\mu\rho}{1-\rho} \tag{19}$$

Our adjustments clearly illustrate that it is necessary to rewrite Equation (6) into a new form:

$$\frac{s_t}{y_t} \approx -\sum_{i=1}^{\infty} \rho^i E_t \Delta \log(y_{t+i}) - \kappa, \tag{20}$$

where ρ is the discount factor, which is equal to $\frac{1+\mu}{1+r} \approx 1 + \mu - r$. Here, μ is the average difference of income or – In other words – the rate of growth of income, which is given by the log-linearization, and κ is derived in Equation (19). The method requires incorporation of the following assumption: $r > \mu$. This assumption is not very realistic, but a consensus is that the benefits of using logarithmic forms outweigh it.

Equation (5) is rewritten in logarithmic form below:

$$\frac{\Delta c_{t+1}}{y_t} \approx \frac{r}{r-\mu} \sum_{i=1}^{\infty} \rho^i (E_{t+1} - E_t) \Delta \log y_{t+i}. \tag{21}$$

From Equation (21), the fraction on the left-hand side is approximately equal to the change in the present value of the future rates of growth of income. The discount rate is again described as the difference between the real interest rate and the growth rate.

Equations (20) and (21) are not consistent with one another (which is caused by the approximation). To solve this problem, additional assumptions are introduced, namely that both $\frac{\mu}{r}$ and r are sufficiently small, so we can write that $\frac{r}{(r-\mu)} \approx 1$. After dividing the lagged value of income by the discount factor and subtracting it from Equation (20), we obtain:

$$\frac{s_t}{y_t} - \Delta \log(y_t) - \frac{s_{t-1}}{\rho y_{t-1}} \approx -\sum_{i=0}^{\infty} \rho^i (E_t - E_{t-1}) \Delta \log(y_{t+i}) \approx -\frac{\Delta c_t}{y_{t-1}}, \tag{22}$$

The outer expressions describe the change in consumption at the time t relative to the income at the time $t-1$ (with a negative sign). The inner expression describes the discounted value of the change in the present value of the future rates of growth of income. More intuitively, this equation states that the change in consumption of rational consumers mirrors all expected changes in all future incomes based only on the knowledge of their current and past income. Hence, the information set available to the consumer in this case is highly constrained. The main idea of Deaton's research is not whether the outer expressions described by Equation (22) can be considered equal (they can, at least according to the data), but whether either of them can be put equal to the middle expression.

1.1 Deaton's empirical approach

One of the most significant contributions from Campbell and Deaton (1989) was their new empirical approach to an already well-described theory. Hence, it is necessary to describe the procedure for using the vector autoregression (VAR) model in order to understand the generalised method of moments (GMM) model used in this paper (Section 2.3). A description of the VAR model used by Campbell and Deaton (1989) follows.

The calculations provided in the previous stage (namely Equations 20 and 22) are not sufficient because with such a notation the consumers only form their beliefs about the future income based on the current and lagged income. However, this is not the case because we usually incorporate a much broader set of information in our expectations[6] in order to make the best decisions. Hence, as stated by Campbell and Deaton (1989), this information surplus represents innovations in expectations of rational agents about their stream of income before the change occurs.

Having at least some extra information leads to even more (excess) smoothness of consumption (West, 1988). Rational consumers try to estimate permanent income using only the lags described and then adjust their actual permanent income as closely as possible to their estimate[7].

Combining the previous two paragraphs into one statement could lead to a claim that the permanent income hypothesis is correct because consumers have enough information to smooth out their permanent income and consumption. This can be justified by the fact that the analysis described can only incorporate measurable variables, not the information available to the consumer, thus it can never hold. This defence of the permanent income hypothesis can be falsified only with great trouble because it is impossible to be certain about the perfect specification of the econometric model with all the important variables.

Hence, in line with Campbell (1987) and Campbell and Deaton (1989), we embrace a new hypothesis: consumers will reveal their expectations (estimations) about permanent income using the channel of consumption and savings if the permanent income hypothesis holds.

To do so, we need to rewrite Equation (20) once again to obtain the savings in a form that is more suitable for our model, which will give us Equation (23).

$$\frac{s_t}{y_t} \approx -\sum_{i=1}^{\infty} \rho^i \, E[\Delta \log(y_{t+i}) \,|I_t] - \kappa \tag{23}$$

In Equation (23), the parameter I_t is set to be the amount of information available to the consumer, and it is unknown. Next, we define another information set, which is denoted by H_t, which contains all the current and lagged values of $\Delta \log(y_t)$ and $\frac{s_t}{y_t}$. It is, by definition, true

[6] *Such as information about fiscal policy, elections, inflation, monetary policy, unemployment, vaccination speed or even contextual information (Valle et al., 2017).*
[7] *In theory, a perfectly estimating consumer would have both constant permanent income and constant consumption.*

that $I_t > H_t$, but it is also true that H_t is bigger than the information set which we were working with in our calculations in Section 1[8]. Hence, we use H_t instead of I_t in (23) to get Equation (24).

$$\frac{s_t}{y_t} \approx -\sum_{i=1}^{\infty} \rho^i \, E[\Delta \log(y_{t+i}) \,|H_t] - \kappa \tag{24}$$

As stated before, H_t includes $\frac{s_t}{y_t}$, hence the left-hand side of Equation (24) must be equal to the left-hand side of Equation (23). As also declared before, since $I_t > H_t$ and also $H_t \subset I_t$, the right-hand sides only differ in the information above the H_t information set (thus, we get closer to the perfect foresight).

In order to adjust Equation (22) to the new and enlarged set of information, we subtract $\Delta \log(y_t)$ and $\frac{s_{t-1}}{\rho_{t-1}}$ from it. We can make this step since all of the elements used are incorporated in H_t. This yields the following:

$$\frac{s_t}{y_t} - \Delta \log(y_t) - \frac{s_{t-1}}{\rho y_{t-1}} \approx -\sum_{i=0}^{\infty} \rho^i [E(\Delta \log y_{t+i} \,|H_t) - E(\Delta \log y_{t+i} \,|H_{t+1})]. \tag{25}$$

The difference between Equations (25) and (22) is of the same fashion as before.

When using this theoretical background and these assumptions, Campbell and Deaton (1989) could use quite a simple econometric model to test for the predictions of the permanent income hypothesis. They compared standard deviations of the left-hand side of Equation (25) to the right-hand side of the same equation. If the standard deviation of the left-hand side is smaller than the standard deviation of the right-hand side, it would imply that the consumption exhibits excess smoothness even for cases when the information set is sub-perfect.

Thus, Campbell and Deaton (1989) used a vector autoregressive model, henceforth referred to as VAR, with two equations for estimation and comparison of standard deviations: the first equation is for $\Delta \log y_t$ and the second is for $\frac{s_t}{y_t}$. The VAR model is constructed as:

$$\begin{pmatrix} \Delta \log y_t - \mu \\ \frac{s_t}{y_t} - \sigma \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} \Delta \log y_{t-1} - \mu \\ \frac{s_{t-1}}{y_{t-1}} - \sigma \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix} \tag{26}$$

The parameter σ in Equation (26) is equal to the mean saving ratio. We also use a matrix notation of this model later, which is as follows:

$$x_t = Ax_{t-1} + u_t. \tag{27}$$

Campbell and Deaton (1989) put an emphasis on the analysis with only first-order lag, which is also the case of our analysis in Section 2, but it is possible to use more lags[9]. Campbell and Deaton (1989) used quarterly data running from the first quarter of 1953 to the last quarter

[8] *The new information set contains all that was contained in the old one, and in addition contains information of all $\frac{s_t}{y_t}$, which is basically information about future incomes.*

[9] *This possibility is used in the empirical stages of this paper.*

of 1985. They used labour income per capita and different series for consumption of different types of goods[10] and the mean real interest rate of the period in question was $r = 6\%$.

In order to link the estimated VAR and the theory mentioned before (Section 1), we define two vectors: $e_1' = \binom{1}{0}$ and $e_2' = \binom{0}{1}$. Equation (25) is then rewritten using the VAR notation as follows:

$$\frac{s_t}{y_t} - \Delta \log y_t - \frac{s_{t-1}}{\rho y_{t-1}} = (e_2' - e_1')x_t - \rho^{-1} e_2' x_{t-1}, \tag{28}$$

which yields after substitution from (27):

$$\frac{s_t}{y_t} - \Delta \log y_t - \frac{s_{t-1}}{\rho y_{t-1}} = [(e_2' - e_1')A - \rho^{-1} e_2']x_{t-1} + (e_2' - e_1')u_1. \tag{29}$$

Once substituting expectations into (27), we get:

$$(E_t - E_{t-1})x_{t+i} = A^i u_t. \tag{30}$$

Since we also know that $e_1' x_t = \Delta \log y_t$, it is easy to derive Equation (31).

$$\sum_{i=0}^{\infty} \rho^i (E_t - E_{t-1}) \Delta \log y_{t+1} = \sum_{i=0}^{\infty} e_1' \rho^i A^i u_t. \tag{31}$$

According to the permanent income hypothesis, the left-hand side of Equation (29) should be equal to the left-hand side of Equation (31) with a negative sign. To be able to equalize those two expressions, we need to introduce two following constraints.

$$(e_2' - e_1')A - \rho^{-1} e_2' = 0 \tag{32}$$

$$-\sum_{i=0}^{\infty} e_1' \rho^i A^i = e_2' - e_1' \tag{33}$$

Equation (32) states that the left-hand side of Equation (29) is not dependent on the lagged income growth or on the lagged saving ratio. In a nutshell, such an independence enables us to verify whether the consumption is unpredictable and not "too sensitive". Equation (33) states basically the opposite – if it holds, the changes in consumption are derived from the changes of income and there is no excess smoothness.

Consequently, we need to rewrite our matrix *A* in the manner of the conditions introduced, to get[11,12]:

$$A = \begin{pmatrix} \alpha & \beta \\ \alpha & \beta + \rho^{-1} \end{pmatrix} \tag{34}$$

[10] *The series that best follows the AR(1) process is for total consumption, which we also use in Section 2.*
[11] *Note that we can write that: $a_{11}, a_{21} = \alpha$, $a_{12} = \beta$ and $a_{22} = \beta + \rho^{-1}$.*
[12] *We need to have $\beta \neq 0$ to be able to compute the determinant of $(I - \rho A)$ which holds (Campbell, 1986).*

Now, we can rewrite Equation (32) to be identical with Equation (33), which yields the following Equation (35).

$$-e_1'(I - \rho A)^{-1} = e_2' - e_1' \quad (35)$$

Having the conditions and the VAR set up, Campbell and Deaton (1989) made their estimates and used the Wald test (Ward and Ahlquist, 2018) to examine whether the restriction holds, in order to find out that the consumption is too smooth.

Campbell and Deaton (1989) also provided several explanations as to why consumption appears to be too smooth (and why our models fail when facing real data), e.g., the following ones: measurable consumption and income are time averages of continuous processes (imperfect aggregate information) (Goodfriend, 1992; Pischke, 1995; Demery and Duck, 2000), the marginal utility of consumption depends on more variables, real interest rates differ (Michener, 1984; Hall, 1988), consumers face liquidity constraints (Hall & Mishkin, 1982), consumer adjustment is a slow and costly process (Attfield et al., 1992) or habits and preferences might play some role. Other reasons may be precautionary savings (Zeldes, 1989) or finite planning horizons (Gali, 1990). Following Campbell and Deaton (1989), others have tried to use innovative econometric approaches to work with the data differently and some of those stances are introduced in the following chapter. Later, in Section 2, our own model is constructed.

1.2 Literature review

There is a significant amount of literature dealing with the Deaton paradox. The theory used is often similar or identical to the theory used in this paper (and in Campbell and Deaton, 1989). The econometric apparatus used is often unique and represents a novelty in academic literature[13]. The most influential articles recently, which served as an inspiration for shaping our research hypothesis, are Gil-Alana et al. (2009) and Luengo-Prado and Sørensen (2008).

The article written by Gil-Alana et al. (2009) rests heavily on the research carried out by Diebold and Rudebusch (1991). The main idea of Diebold and Rudebusch (1991) is that the assumption of income and consumption following an ARIMA[14] (auto-regressive integrated moving average) process may be too strong. When testing this assumption by employing different parameters and then computing confidence intervals instead of point estimations, they found a source of possible explanation for excess smoothness. Just the fact that the authors used a different and more sophisticated method gave them much better results.

Gil-Alana et al. (2009) continued this work by deploying monthly data because they believed that one of the sources of excess smoothness of consumption in our models may be too big an aggregation of the data when using quarterly aggregates. Another argument for using monthly data is its sensitivity to the order of integration (Caporale & Gil-Alana, 2010). More observations lead to a smaller bias, hence more accurate estimations. Another contribution to the analysis of the excess smoothness of consumption is the incorporation of structural breaks into the model.

The most fundamental finding considering our hypothesis is that when using monthly data, the excess smoothness of consumption becomes smaller or vanishes completely (Gil-Alana

[13] *As was in the case of Campbell and Deaton (1989).*
[14] *Autoregressive integrated moving average.*

et al., 2009). The effect of a reduction in excess smoothness of consumption is strengthened even more when incorporating structural breaks into the model. Henceforth, when using monthly data, the permanent income hypothesis holds (for US time-series data running from 1947 to 2008 when using quarterly data and from 1951 to 2008 when using monthly granularity). What makes the distinction in the observation of excess smoothness of consumption is the different order of integration estimated under the two frequencies. It is also a well-observed fact that less-than-three-month cyclical variations disappear when using quarterly data (Rossana & Seater, 1995).

We examine this conclusion in the next stage of this paper when comparing results of our panel-data analysis while using both quarterly and monthly frequencies.

Using panel data to investigate excess smoothness is an approach that is not very widespread. According to the authors, the only research that has been done is the study of Luengo-Prado and Sørensen (2008)[15].

Their analysis was based on an estimation of the marginal propensity to consume when using the state-level annual panel dataset for the USA. In the period running from 1964 to 1998, Luengo-Prado and Sørensen (2008) used the current and lagged incomes as explanatory variables. The method deployed was panel-data regression that controls for time-specific and state-level fixed effects because a marginal propensity to consume is different across the US states. This approach does not use pure aggregate data as Campbell and Deaton (1989) used, or as we will in Section 2, but it is somehow similar to our own approach (with regard to the intuition) because we use country-level data for all of our estimations of excess smoothness of consumption within Europe.

The above-mentioned findings are not very persuasive. The excess smoothness of consumption is not mitigated on a macro level, even though there are big differences between estimates for separate countries. When using buffer-stock saving in the model, the authors were able to calibrate the model to fit the data used, but such an approach is not applicable to different datasets.

The main reason for the failure of their model in explaining the excess smoothness of consumption is to be seen in the granularity of the data: annual data are not suitable and it is believed that it is necessary to use the highest available frequency to explain the Deaton paradox (as discussed in the previous section). We would also argue that using simple fixed-effects panel estimations is not sufficient when using lagged values as explanatory variables because of the autocorrelation and resulting estimation bias.

The purpose of our investigation is to illustrate that the utilization of panel data to examine the Deaton paradox is not common. Moreover, analysis other than with US data is a rare option. As a result, our research aims to fill this gap and we intend to do so while using an uncommon econometric method.

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[15]*At least one other paper exists on United Kingdom (UK) micro data. However, since we are interested in using well-defined macro data, it is out of our interest, even though it is interesting that when using micro data, the excess smoothness vanishes, at least according to Attanasio and Pavoni (2011).*

Other recent studies that deal with the topic of excess smoothness of consumption may be for example Bairoliya et al. (2021). The authors found that Indian households display a pronounced life-cycle savings rate, peaking due to the necessity of financing significant purchases such as housing and vehicles, highlighting distinct saving drivers compared to Western patterns. Meanwhile, in the paper from Baugh et al. (2021), households exhibit rather complex behaviour by increasing consumption with expected tax refunds and smoothing out consumption during other times through internal transfers, indicating a nuanced approach to managing finances that goes beyond simple liquidity constraints or impulsive spending. Similar or at least directionally similar results can be found in Breitenlechner et al. (2022); Liu et al. (2021); and Thakral and Tô (2021).

Still, we refrain from delving into detailed descriptions of these studies, as they do not explicitly tackle the Deaton paradox, but rather explore its implications and potential explanations through various avenues. Nonetheless, the phenomenon of excess smoothness of consumption remains a vibrant and enduring theme within the scholarly discourse.

2 Data and Model

2.1 Data

No extensive macroeconomic research has been done regarding the Deaton paradox in Europe so far and data availability may be one of the reasons behind this. We have gathered panel data for 24[16] European countries running from the first quarter of 2000 to the second quarter of 2021[17]. We use gross domestic product (GDP) per capita as *income* and aggregate household consumption (from national accounts of respective countries) as *consumption*. All the data have been deflated, so we have real variables at 2010 prices[18]. Savings are then computed as the difference between income and consumption[19]. Basic descriptive statistics for income and savings are depicted in Table 1.

Table 1 | Descriptive statistics (in 2010 prices)

Variable	*n*	Min	Max	Median	Mean	Std. dev.
Income	2064	656.8	20160.4	4926.3	5799.3	3641.5
Savings	2064	47.98	9490.7	1491.6	1921.6	1486.5

Source: Own calculations

Table 1 together with the previous statement suggests that the data are noisy (absolutely speaking and even more when compared to Campbell and Deaton, 1989). We will try to deal with the noise later.

It might be illustrative to see the distribution of values. Figures 1 and 2 can be used for this purpose. Based on the histograms and Table 2, it is observable that the variables are not

[16] Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Hungary, Austria, Portugal, Slovenia, Slovakia, Finland, Sweden, Norway, and Serbia.
[17] Note that the inclusion of the pandemic period makes the analysis even more complicated, since it comes with extra noise to the dataset.
[18] All data and deflators are provided by the Eurostat.
[19] This does not mean that the savings cannot be negative at an individual level. From the perspective of macroeconomics, however, the savings must be non-negative.

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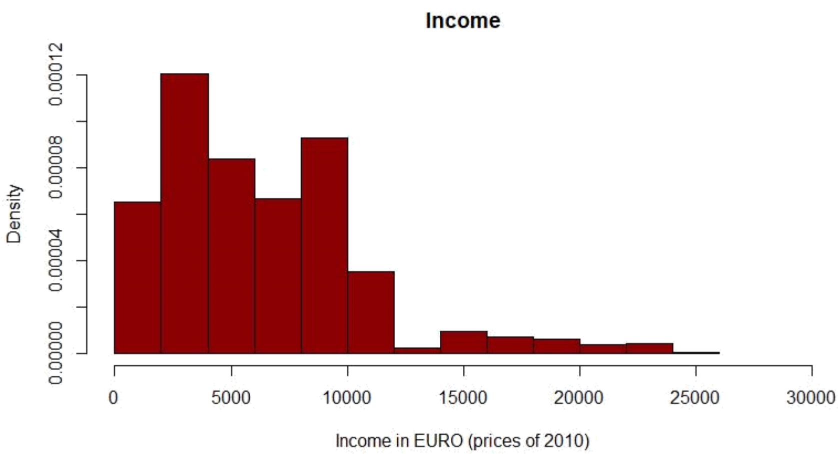
normally distributed. For both variables, there is an apparent logarithmic distribution, which is a typical distribution of income[20].

Table 2 | Skewness and kurtosis

Variable	Skewness	Kurtosis
Income	0.8160	3.5038
Savings	1.5782	6.6500

Source: Own calculations

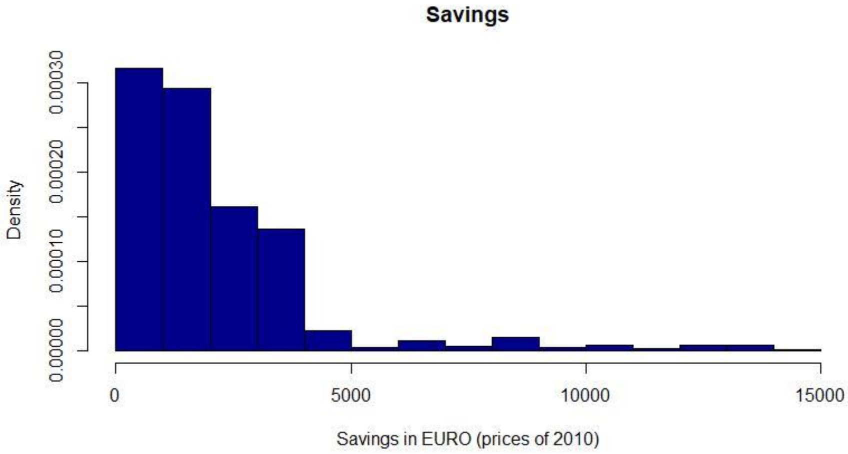
Figure 1 | Distribution of income



Source: Own calculation based on Eurostat

[20] Histograms after transformation of variables are available from the authors upon request. The nature of aggregated macroeconomic data is behind the reported low densities in Figures 1 and 2.

Figure 2 | Distribution of savings



Source: Own calculation based on Eurostat

It is practical to transform the data in the same manner as Campbell and Deaton (1989) did. Hence, income is used in the form $\Delta \log y_t - \mu$, where μ is the average first difference of $\Delta \log y_t$, and savings are transformed as $\frac{s_t}{y_t} - \sigma$, where σ is an average of $\frac{s_t}{y_t}$**.** The series were tested for unit roots (Dickey and Fuller, 1979), and the null hypothesis was rejected on all reasonable levels of significance.

2.2 Pre-research

Before deploying the main model, we conducted some preliminary analysis to gain better knowledge of the character of the data. The nature of the dataset (dynamic panel) suggests that the standard panel estimators are not applicable in our case because the estimates are always at risk of being autocorrelated.

We conducted VAR estimates (identical to Campbell and Deaton, 1989) to discover that most of the countries have insignificant coefficients for their equations. This gives us yet more evidence of the vast amount of noise in the dataset. There is the possibility to perform a separate test of the permanent income hypothesis for each country in our dataset using the VAR estimates, but this would not bring any novelty into our investigation of the Deaton paradox.

As far as we know, there has only been limited research on this topic. Most research has been done on separate time series (using sophisticated VAR models). To the best of our knowledge, the only paper which considers the Deaton paradox and deploys macro panel data is Luengo-Prado and Sørensen (2008) mentioned in 1.2 above. Hence, the usage of dynamic panel estimators might be considered a new contribution to the discussion of the Deaton paradox.

In what follows, we describe the structure of the model used. Subsequently, we define smaller groups of countries to make the dataset less volatile and more suitable for the estimation. In the final stage of the next section, we use three different methods of interpolation to enable construction of monthly panels. These panels are used afterwards to verify whether the granularity of the data plays any role in the outcome of the permanent income hypothesis tests.

2.3 Model

In the next part, we describe and then use the first difference of the GMM estimator introduced by Arellano and Bond (1991)[21,22].

2.3.1 Dynamic panels

The idea starts with the basic fixed-effects formula:

$$y_{i,t} = \rho y_{i,t-1} + x'_{i,t}\beta + \alpha + \varepsilon_{i,t}, \quad (36)$$

where ρ and β are parameters, α is an unobserved fixed effect and $\varepsilon_{i,t}$ is the error term. We work with the same set of assumptions[23] and conventions as in the fixed-effects model because we also make the first differences.

$$y_{i,t} - y_{i,t-1} = \rho\left(y_{i,t-1} - y_{i,t-2}\right) + \left(x'_{i,t} - x'_{i,t-1}\right)\beta + \varepsilon_{i,t} - \varepsilon_{i,t-1} \quad (37)$$

Such a procedure deprives us of the unobserved cross-sectional specific fixed effect α. The main advantage of this method lies in the number of instruments available for the estimation. The analysis of the level instruments available for instrumenting the differenced lagged dependent variable $y_{i,2} - y_{i,1}$ at different time periods is as follows:

- The equation that is subject to our estimation in the period *t = 3* is as follows:

$$y_{i,3} - y_{i,2} = \rho\left(y_{i,2} - y_{i,1}\right) + \left(x'_{i,3} - x'_{i,2}\right)\beta + \varepsilon_{i,3} - \varepsilon_{i,2} \quad (38)$$

and the instrument that can be used for the estimation of $y_{i,2} - y_{i,1}$is just $y_{i,1}$.

- Doing the same for the period *t = 4* yields:

$$\mathrm{y}_{\mathrm{i},4} - \mathrm{y}_{\mathrm{i},3} = \rho\left(\mathrm{y}_{\mathrm{i},3} - \mathrm{y}_{\mathrm{i},2}\right) + \left(\mathrm{x}'_{\mathrm{i},4} - \mathrm{x}'_{\mathrm{i},3}\right)\beta + \varepsilon_{\mathrm{i},4} - \varepsilon_{\mathrm{i},3} \quad (39)$$

In Equation (39), the instruments available for the estimation of $y_{i,3} - y_{i,2}$ are $y_{i,1}$ and $y_{i,2}$. Now it is obvious that when we extend the period of our data, we get more instruments that might be used for the estimation, up to the point where $t = T$. At the point of $t = T$, we can

[21] *The estimator is similar to the one in Anderson and Hsiao (1982).*
[22] *In the explanation, we follow Mertens (2017).*
[23] *See, e.g., Greene (2001).*

use the instruments $y_{i,1}, y_{i,2}, \dots, y_{i,T-2}$. With more instruments available, the set of moment conditions expands, too[24].

We can depict the instruments in the matrix form as follows.

$$Z = \begin{pmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_N \end{pmatrix} with \begin{pmatrix} y_{i,1} & 0 & 0 & \dots & 0 & \dots & 0 & x'_{i,3} - x'_{i,2} \\ 0 & y_{i,1} & y_{i,2} & \dots & 0 & \dots & 0 & x'_{i,4} - x'_{i,3} \\ \vdots & \vdots & \vdots & \dots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & y_{i,1} & \dots & y_{i,T-2} & x'_{i,T} - x'_{i,T-1} \end{pmatrix} \tag{40}$$

The matrix *Z* is conventionally denoted as the "GMM-style" instrument matrix. It is possible to add other endogenous variables (other than the differenced lagged variable $y_{i,t} - y_{i,t-1}$) to the model and then extend the matrix *Z* with another set of instrumental variables. To estimate the parameters of the model, we impose the following set of moment conditions on the data:

$$E(Z_i \Delta\varepsilon_i) = 0 \text{ for } i = 1, \dots, N \tag{41}$$

where:

$$\Delta\varepsilon_i \begin{pmatrix} \Delta\varepsilon_{i,3} \\ \Delta\varepsilon_{i,4} \\ \vdots \\ \Delta\varepsilon_{i,T} \end{pmatrix} \tag{42}$$

The result is then $\frac{(T-1)(T-2)}{2} + K$ moment conditions per individual, which yields $N\left(\frac{(T-1)(T-2)}{2} + K\right)$ moment conditions. The last expression is usually significantly bigger than the number of parameters which are to be estimated within the model; thus, the estimator works. Knowing this, the asymptotically efficient GMM estimator is derived as a minimization of the following equation:

$$Q_N = \left(\frac{1}{N}\sum_{t=1}^{N} Z'_i \Delta\varepsilon_i\right)' W_N \left(\frac{1}{N}\sum_{t=i}^{N} Z'_i \Delta\varepsilon_i\right) \tag{43}$$

If we calculate the first difference of Equation (43) with respect to the model parameters, and then solve for them (denoted as γ), we obtain Equation (44).

$$\hat{\gamma} = (X'ZW_N Z'X)^{-1} X'ZW_N Z'X_y \tag{44}$$

In Equation (44), W_N is the matrix of weights, which is included to deal with the heteroscedasticity in the error term, and X is equal to the following expression:

$$X = \begin{pmatrix} X_1 \\ X_2 \\ \vdots \\ X_N \end{pmatrix} with\ X_i = \begin{pmatrix} y_{i,2} - y_{i,1} & x'_{i,3} - x'_{i,2} \\ y_{i,3} - y_{i,2} & x'_{i,4} - x'_{i,3} \\ \vdots & \vdots \\ y_{i,T-1} - y_{i,T-2} & x'_{i,T} - x'_{i,T-1} \end{pmatrix} \tag{45}$$

[24] *In comparison with Anderson and Hsiao (1982).*

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For the estimator to work properly, we need to estimate the optimal matrix of weights, which is denoted as W_N^{OPT}. With the intention of doing so, we use a so-called two-step procedure.

In the first step the first-differenced GMM estimator is constrained only to the case where there is no autocorrelation in the error term $\varepsilon_{i,t}$. Another assumption is that the error term is homoscedastic. With such assumptions, the first step weighting matrix W_N^{s1} is computed as:

$$W_N^{s1} = (Z'GZ)^{-1} \tag{46}$$

where:

$$G = I_n \times G_T \text{ and } G_T = F_T' F_T = \begin{pmatrix} 2 & -1 & 0 & \dots \\ -1 & 2 & \ddots & 0 \\ 0 & \ddots & \ddots & -1 \\ \vdots & 0 & -1 & 2 \end{pmatrix} \tag{47}$$

We can consequently use the matrix W_N^{s1} from Equation (44), by plugging in the matrix in question, which yields:

$$\widehat{\gamma^{s1}} = (X'ZW_N^{s1}Z'X)^{-1}X'ZW_N^{s1}Z'X_y \tag{48}$$

Based on the above estimate, we can compute residuals as described in Equation (48).

$$\hat{\varepsilon} = Y - X\widehat{\gamma^{s1}} \tag{49}$$

Now we use these residuals to perform the second step of calculating the optimal weighting matrix W_N^{OPT}. This can be done as follows:

$$W_N^{OPT} = \left(Z'\Delta\widehat{\varepsilon\varepsilon' Z}\right)^{-1} \tag{50}$$

After substituting Equation (50) into Equation (44), we obtain the final form of the GMM estimator. This form is described in Equation (51).

$$\widehat{\gamma^{s2}} = \left(X'ZW_N^{OPT}Z'X\right)^{-1}X'ZW_N^{OPT}Z'X_y \tag{51}$$

The estimator is used for all the estimates of parameters in the following sections. These parameters will be subject to our attention once we test for excess smoothness of consumption.

2.3.2 Model specification

Since we want to introduce the novelty of using the panel data when investigating the excess smoothness of consumption, we need to divide the original VAR model into two separate equations. Combining the notation from previous sections, our equations will have the following form:

$$\Delta \log y_{i,t} - \mu_i = a_{11}(\Delta \log y_{i,t-k} - \mu_i) + a_{12}\left(\frac{s_{i,t-k}}{y_{i,t-k}} - \sigma_i\right) + \alpha + \varepsilon_{i,t} \tag{52}$$

$$\frac{s_{i,t}}{y_{i,t}} - \sigma_i = a_{21}(\Delta \log y_{i,t-k} - \mu_i) + a_{22}\left(\frac{s_{i,t-k}}{y_{i,t-k}} - \sigma_i\right) + \alpha + \varepsilon_{i,t} \quad (53)$$

In Equations (52) and (53), the index *i* denotes the cross-sectional element, $t - k$ signals the number of lags[25] and α is the unobservable fixed effect (which will drop out during the procedure).

The coefficients a_{11}, a_{12}, a_{21} and a_{22} will be subject to testing to verify whether the permanent income hypothesis holds. If the permanent income hypothesis should be the true description of reality, the following conditions must hold (Campbell and Deaton, 1989):

$$a_{11} = a_{21} \quad (54)$$

$$a_{12} = a_{22} + \rho^{-1} \quad (55)$$

where ρ is the discount factor[26].

In order to test whether the conditions given in Equations (54) and (55) hold, we use the test for comparing regression coefficients between models, introduced by Clogg et al. (1995)[27]. Under the null hypothesis, we assume that the conditions hold. Rejecting the null hypothesis would mean that the prediction of the permanent income hypothesis about future consumption does not hold, thus we have proven the existence of the Deaton paradox in Europe.

It is important to emphasize that we cannot test for the excess smoothness of consumption per se within our procedure because dividing the model into two equations disables interactions between coefficients of Equation (52) and Equation (53) (and their variance-covariance matrices). However, we can test whether the prediction of the permanent income hypothesis holds or not. It is also very unlikely that rejecting the null hypothesis would mean that the consumption is not too smooth but quite jumpy. Such behaviour is, however, not observed in reality. Hence, rejecting the null hypothesis of equality for both conditions given by the permanent income hypothesis can be taken as valid proof of excess smoothness of consumption. If we failed to reject the null hypothesis, it would imply that the permanent income hypothesis is valid, and the Deaton paradox could be addressed effectively using dynamic panel-data estimators.

2.3.3 Quarterly data estimates

In this part we use the quarterly granularity in the same vein as Campbell and Deaton (1989) to examine the validity of predictions given by the PIH in Europe. First, the whole dataset is used in the estimation, followed by using statistical methods to divide the large dataset into smaller datasets, to ensure more homogeneous groups and test those groups individually. We aim to check whether the frequency of observations in the dataset matters for the afore-

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[25] The number of lags for each estimate was chosen to get the highest statistical significance. It was not possible to use first lags in all estimates as Campbell and Deaton (1989) did because our dataset is much more heterogeneous.

[26] The discount factor is computed in continuous time as $\rho = e^{-rt}$, where r is the average euro money-market interest rate over the examined period, which is equal to 1.6% p. a. It is possible to use such approximation because, as argued by Flavin (1981) or Campbell and Deaton (1989), the permanent income hypothesis prediction about consumption varies only little with large differences in interest rate.

[27] Later described by Paternoster et al. (1998).

mentioned permanent income hypothesis. For that purpose, the quarterly data estimates in this section will be compared with the monthly data in Section 2.3.4.

First, we proceed with the entire dataset and then we will perform segmentation into groups.

Table 3 | Coefficients for entire dataset – quarterly data

Coefficient	Number of lags	Estimate	*p-value*
a_{11}	1	-0.1543	0.0009
a_{12}	1	0.0936	0.0050
a_{21}	1	0.0037	0.9598
a_{22}	1	0.0255	0.2777

Source: Own calculation

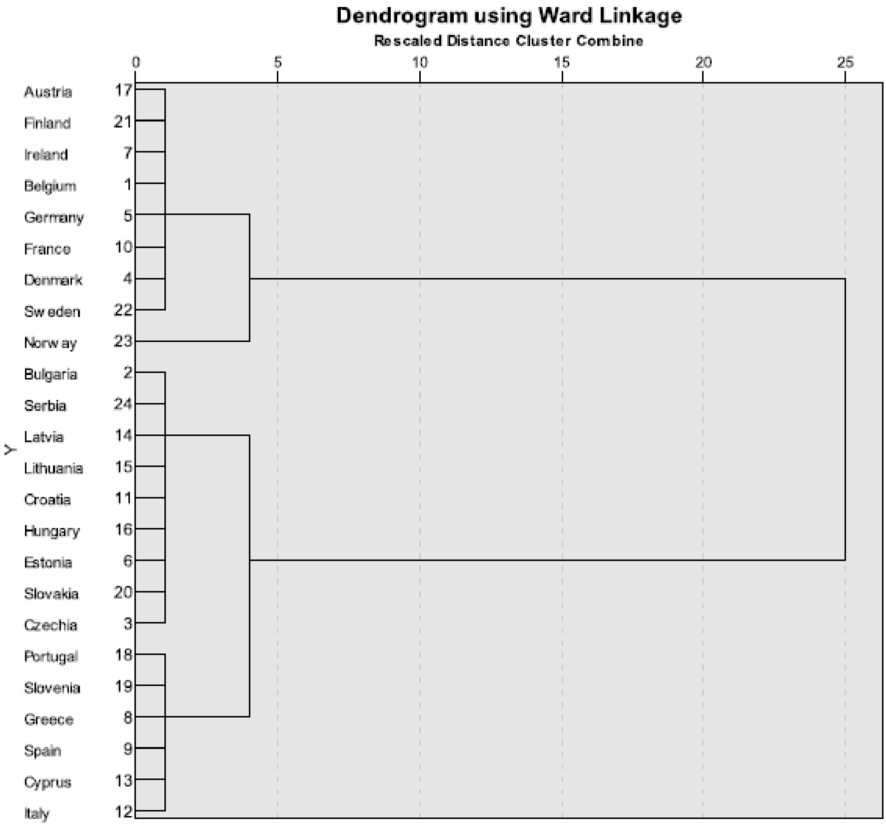
As Table 3 illustrates, two of the estimated coefficients are statistically insignificant. This insignificance persists even with various combinations of lags. This, again, is caused by the severe variability of the data used. The main reason behind dividing the dataset into smaller parts is to maintain some information about a bigger geographical space but also homogenise the data enough to make them applicable in our analysis.

To segment our dataset for 24 countries into smaller subgroups, we use two methods[28]. Firstly, we use the hierarchical clustering approach (Ward Jr's (1963) method) to reveal the number of possible subgroups. Secondly, we use the *k*-nearest neighbours algorithm to specify those groups more rigorously and to see how far from one another the groups are. By deploying this method, we aim to achieve the smallest variability among group members and the biggest possible variability between groups. Hierarchical clustering allows an intuitive, exploratory analysis of our dataset by revealing natural groupings without pre-specifying cluster numbers, while the application of the *k*-nearest neighbours algorithm refines these clusters and ensures minimal intra-group variability and maximal inter-group distinctiveness. These methods combined offer a robust, contextually relevant approach for analysing complex datasets, providing clear insights and practical implications in our study of the 24 countries.

Figure 3 shows the four main groups (clusters) of countries in our dataset. One cluster, which consists of just one member – Norway, is subject to further consideration, as it might represent a potential outlier. No other country has similar characteristics.

[28] *The division is based on the average of our two main variables over the time period for each country.*

Figure 3 | Hierarchical clustering of dataset



Source: Own calculation

Our dataset will be subject to more thorough scrutiny by using the *k*-nearest neighbours algorithm (Fix & Hodges, 1951) to perform the cluster analysis (Driver & Kroeber, 1932).

The *k*-nearest neighbours algorithm is a method of clustering based on the procedure of computing centroids. This method suffers from the basic disadvantage of giving priority to the number of clusters within the analysis. Nevertheless, we can use the results of the hierarchical analysis, which alleviates this drawback.

When we have specified the number of clusters, the units are (randomly or based on some additional information) assigned to groups. The algorithm then moves the units from one group to another to optimise the distance between centroids. This method is much more effective, and it is also useful for showing the distance between groups easily.

Figure 4 documents that the four groups represent groups of extremely rich countries, followed by rich, middle-income and lower-income countries ("poor"). Figure 4 also provides an argument for excluding Norway as an outlier, since Norway has unique characteristics within our dataset. To homogenize our dataset even more, we also decided to remove two

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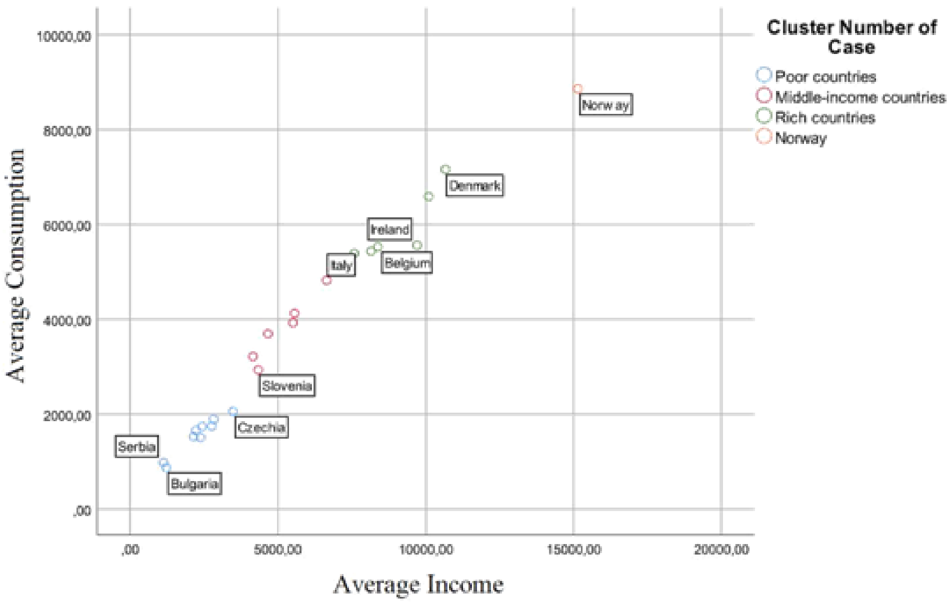
countries from the poor country group (Bulgaria and Serbia). Henceforth, our new dataset consists of 21 European countries[29].

Figure 4 | *K*-nearest neighbours clustering of dataset



Source: Own calculation

The first estimate is conducted for the dataset of 21 countries. The results of the parameter estimations as well as the subsequent permanent income hypothesis test can be found in the table below.

Table 4 | Estimates and PIH tests for 21-country dataset

Coefficient	Number of lags	Estimate	p-value	PIH test	p-value
a_{11}	3	0.1853	0.0013	$a_{11} = a_{21}$	0.1425
a_{12}	1	0.0968	0.0020		
a_{21}	1	-0.0635	0.0231	$a_{12} = a_{22} + \rho^{-1}$	0.0000
a_{22}	1	-0.1871	0.0000		

Source: Authors' own calculation

Using Table 4, we can conclude that the permanent income hypothesis about consumption does not hold for our dataset when using dynamic panel estimation of parameters and – as

[29] *Austria, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Portugal, Slovakia, Slovenia, Spain and Sweden.*

argued before (Section 2.3) – this can be considered evidence of the Deaton paradox in Europe.

Despite this finding, it is worth analysing the behaviour of separate sub-groups in more detail. First, we will repeat the same procedure for the subset of countries marked earlier as rich[30].

Table 5 | Estimates and PIH tests for "rich" countries

Coefficient	Number of lags	Estimate	p-value	PIH test	p-value
a_{11}	3	-0.6088	0.0006	$a_{11} = a_{21}$	0.0112
a_{12}	1	-0.0094	0.9012		
a_{21}	1	0.0159	0.8213	$a_{12} = a_{22} + \rho^{-1}$	0.0000
a_{22}	1	-0.6379	0.0000		

Source: Authors' own calculation

Table 5 shows that the results for the "rich" countries do not yield statistically significant coefficients. Thus, the permanent income hypothesis tests are not robust. The following table illustrates the results for the middle-income countries[31].

Table 6 | Estimates and PIH tests for "middle-income" countries

Coefficient	Number of lags	Estimate	p-value	PIH test	p-value
a_{11}	1	0.9472	0.0000	$a_{11} = a_{21}$	0.0001
a_{12}	1	0.6712	0.0308		
a_{21}	1	0.1489	0.0009	$a_{12} = a_{22} + \rho^{-1}$	0.0015
a_{22}	1	0.9163	0.0004		

Source: Authors' own calculation

Table 6 also does not speak in favour of the PIH in the case of middle-income countries.

The last subset to investigate is that of the lower-income countries[32]. As might be seen in Table 7, we can conclusively reject the permanent income hypothesis.

Based on the summary in Tables 4 to 7, we conclude that the usage of dynamic panels with quarterly data for estimation of consumption behaviour could not help with the Deaton paradox, which is now also present in Europe. The prediction of the permanent income hypothesis is not supported by the data.

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[30] This subset consists of Belgium, Denmark, Ireland, France, Austria, Finland and Sweden.
[31] Greece, Spain, Italy, Cyprus, Portugal and Slovenia.
[32] Czech Republic, Estonia, Croatia, Latvia, Lithuania, Hungary and Slovakia.

Table 7 | Estimates and PIH tests for “low-income” countries

Coefficient	Number of lags	Estimate	p-value	PIH test	p-value
a_{11}	2	0.4903	0.0000	$a_{11} = a_{21}$	0.0001
a_{12}	1	0.4145	0.0020		
a_{21}	1	0.1703	0.0019	$a_{12} = a_{22} + \rho^{-1}$	0.0000
a_{22}	3	0.6723	0.0000		

Source: Authors’ own calculation

2.3.4 Monthly data estimates

Gil-Alana et al. (2009) argued that data granularity may play a significant role in the estimation of consumption behaviour. In this section, we use the same procedure as before (Section 2.3.3), but use a monthly panel dataset. Unfortunately, it is impossible to use the original data because the statistical offices in many European countries do not collect or publish monthly data. Also, using retail sales or a similar proxy would not encompass the entire consumption behaviour, especially with the weight of services having increased over time. Therefore, we interpolate quarterly panel data. We are aware of the problems connected with interpolation (such as restrained variability), but we believe this is justifiable in our case. The interpolation will be done three times (linear, quadratic and cubic) to check whether the interpolation method has any effect. This approach was chosen to achieve as robust estimations as possible.

The linear interpolation is described by a standard formula which reads as follows:

$$y_{t-j} = y_{t-k} + (y_t - y_{t-k}) \times \frac{x_{t-j} - x_{t-k}}{x_t - x_{t-k}} \tag{56}$$

where $k > j$. In our case, x is the time indicator and y is the variable, which is subject to interpolation (income or consumption). The polynomial interpolation is mathematically more complicated[33] but the main idea can be summarized as follows. Let $x_0, x_1, \dots, x_n$ be distinct numbers and let $y_0, y_1, \dots, y_n$ be related function values. It is necessary to find such a polynomial $p(x)$ that interpolates the given data:

$$p(x_i) = y_i, \qquad i = 0,1, \dots, n \tag{57}$$

The polynomial we want to find can be generally written as:

$$p(x) = a_0 + a_1 x + \dots + a_m x^m \tag{58}$$

Again, this is a general case. In our model, *m* is equal to 2 and 3, respectively. It is clear from the last expression that for a general polynomial of the degree m, there are $m + 1$ independent parameters a_0, a_1, …, a_m. From (57) we also know that there are $n + 1$

[33] *For the whole procedure and proofs, see Atkinson (1988).*

conditions on $p(x)$. We consider the case of $m = n$. The objective is to find the parameters a_0, a_1, …, a_n such that:

$$\begin{gathered} a_0 + a_1 x_0 + a_2 x_0^2 + \cdots + a_n x_0^n = y_0 \\ \vdots \\ a_0 + a_1 x_n + a_2 x_n^2 + \cdots + a_n x_n^n = y_n \end{gathered} \tag{59}$$

The system of Equations (59) is a system of $n + 1$ linear equations and $n + 1$ unknown variables, which makes our model solvable.

We rewrite the same situation, but in matrix formulation, as follows:

$$Xa = y$$

where:

$$\begin{gathered} X = \left[x_i^j\right] \qquad i, j = 0,1, \dots, n \\ a = [a_0, a_1, \dots, a_n]^T \\ y = [y_0, y_1, \dots, y_n]^T. \end{gathered} \tag{60}$$

The aggregate Table 8 indicates that using data with a higher frequency (monthly instead of quarterly) does not significantly alter our findings regarding the excess smoothness of consumption. Most of our estimates lack statistical significance. The sole exception is the significant result from linear interpolation, which aligns with our findings from quarterly data. Therefore, we conclude that increasing the data frequency to monthly does not solve the Deaton paradox.

Table 8 | Monthly data estimates

Linear interpolation

Coefficient	Number of lags	Estimate	p-value	PIH test	p-value
a_{11}	1	-0.3454	0.0000	$a_{11} = a_{21}$	0.1283
a_{12}	4	0.0244	0.0087		
a_{21}	1	-0.1678	0.0581	$a_{12} = a_{22} + \rho^{-1}$	0.0000
a_{22}	3	-0.1291	0.0000		

Quadratic interpolation

Coefficient	Number of lags	Estimate	p-value	PIH test	p-value
a_{11}	1	-0.1892	0.0000	$a_{11} = a_{21}$	0.1252
a_{12}	1	0.0054	0.4812		
a_{21}	1	-0.0241	0.8003	$a_{12} = a_{22} + \rho^{-1}$	0.0000
a_{22}	1	0.0238	0.0546		

Cubic interpolation

Coefficient	Number of lags	Estimate	p-value	PIH test	p-value
a_{11}	1	-0.1522	0.0000	$a_{11} = a_{21}$	0.8502
a_{12}	1	0.0026	0.7536		
a_{21}	1	-0.1315	0.2102	$a_{12} = a_{22} + \rho^{-1}$	0.0000
a_{22}	1	0.0277	0.0189		

Source: Own calculation

Conclusion

The overall findings are not very persuasive. The excess smoothness of consumption is not mitigated on a macro level, even though there are big differences between estimates for separate countries. When using buffer-stock saving in the model, they were able to calibrate the model to fit the data used, but such an approach is not applicable for different datasets.

The Deaton paradox is a frequently discussed phenomenon (or perhaps "empirical observation") which has an important position in the field of economics. Its investigation is crucial to broaden our understanding of consumer behaviour and to increase our ability to make better predictions.

The objective of this paper was to follow up on the Deaton paradox and test two hypotheses about consumption behaviour based on income. Firstly, we aimed to test for excess smoothness of consumption, which is a crucial part of the Deaton paradox. Secondly, we tested the hypothesis that higher granularity of the data used may affect the results of excess smoothness of consumption tests.

We conducted the analysis with quarterly data from over twenty European countries, covering the period from 2000Q1 to 2021Q2. As far as we know, no similar research has been done so far on this topic. Luengo-Prado and Sørensen (2008) also used panel data (for the United States) but their method did not make it possible to enhance the full dynamics of the time series used.

Likewise, our method also represents a novel approach. It enables us to test the Deaton paradox over a greater geographical area while sustaining the time dimensionality of the dataset. One of the main contributions of Campbell and Deaton (1989) was the usage of new econometric approaches. In this sense, this paper is the first, to the best of our knowledge, to account for the Deaton paradox in panel data using a dynamic panel estimator, combining the dynamics of the approach of Campbell and Deaton (1989) and later approaches using static panels.

The results are as follows: we rejected the null hypothesis of validity of the permanent income hypothesis in all the tests that we performed. The consumption appears too smooth in the data. We tested separately for the whole dataset and for subsets derived by hierarchical clustering and the *k*-nearest neighbours method. The approach provided us with groups of countries that are similar with respect to the characteristics analysed.

In the later stage, we also rejected the hypothesis of the importance of granularity of the data used. For this purpose, we constructed a monthly panel dataset, when using three types of interpolation to rule out the possibility that the interpolation method may have any effect. Conclusively, we rejected the permanent income hypothesis for both quarterly and monthly datasets.

The reasoning behind the observed empirical anomaly is still yet to be fully uncovered but there are some possible explanations. It is the nature of aggregate data that it befogs some information about reality; unfortunately, use of micro datasets is not possible for large comparisons between several countries. Another explanation could come from behavioural economics. Since people in general fear losses more than they value gains (loss aversion), they are strongly motivated to hedge from sudden income decreases. Another reason behind the smooth consumption path may be that the focus on consumption of individuals increases in high inflation or recession periods. People restrict their other expenditures in favour of maintaining a solid consumption level. It may also play an important role that there are physical boundaries to consumption preventing it from falling under a certain level that are not present for other expenditures. This argument is also supported by the fact that consumption expenditure shares vary only a little over time, which supports the stability of the consumption path. In some cases, the share of autonomous consumption expenditures may consume some households' entire income and even land them in debt.

The implications of our findings are now getting even more important in the current unstable environment. It is vital for governments to know, in order to effectively target their aid, that consumption can behave rather steadily even with upcoming recession. On the other hand, the monetary policy should not rely on a fast decline of domestic inflationary pressures when fighting high inflation, since consumption seems to be rather persistent in its development.

It is very much in the spirit of Campbell and Deaton (1989) to use a more advanced econometric approach to test the validity of the theory. There are various suggestions for future research such as enlargement of datasets or working with original monthly data in the model.

It is also important to recognise that in the recent context of high inflation and declining real wages affecting Czech households (among others in Europe), the adjustments in consumption might have been more significant than theoretical predictions would suggest. That might be due to one practical aspect through which the paradox becomes observable: the availability of credit. In scenarios where high inflation is met with quite stringent monetary policies, borrowing becomes restricted, making it harder to smooth out consumption completely. Nevertheless, even among Czech families, and particularly for essentials such as food, we observed that consumption patterns remained remarkably stable, which partly ties back to the behavioural underpinnings of consumption patterns.

In conclusion, despite our limitations in accurately forecasting consumption behaviour from income data, there remains significant value in using even imperfect forecasts. Recognising the influence of consumption patterns on economic analysis and policy formulation is crucial. The principal benefit of such research lies in its ability to yield substantial insights from minimal input, facilitated by the standardisation and increasingly straightforward measurement of income and consumption, thanks to statistical and econometric advancements.

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