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Testing the validity of the Galor-Weil model for Portugal

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Abstract

This research econometrically analyzes Portugal's escape from the Malthusian trap with the Galor-Weil (2000) model. The study employs vector autoregression (VAR) methodology, Granger causality tests, and variance decomposition analysis for the period 1976-2023. The empirical findings indicate that educational attainment contributes to reduced fertility and mortality rates, while tertiary education emerges as a necessary catalyst for technological advancement. Through strategic education policies, Portuguese society has transitioned from quantity to quality preferences, thereby facilitating escape from the Malthusian trap.

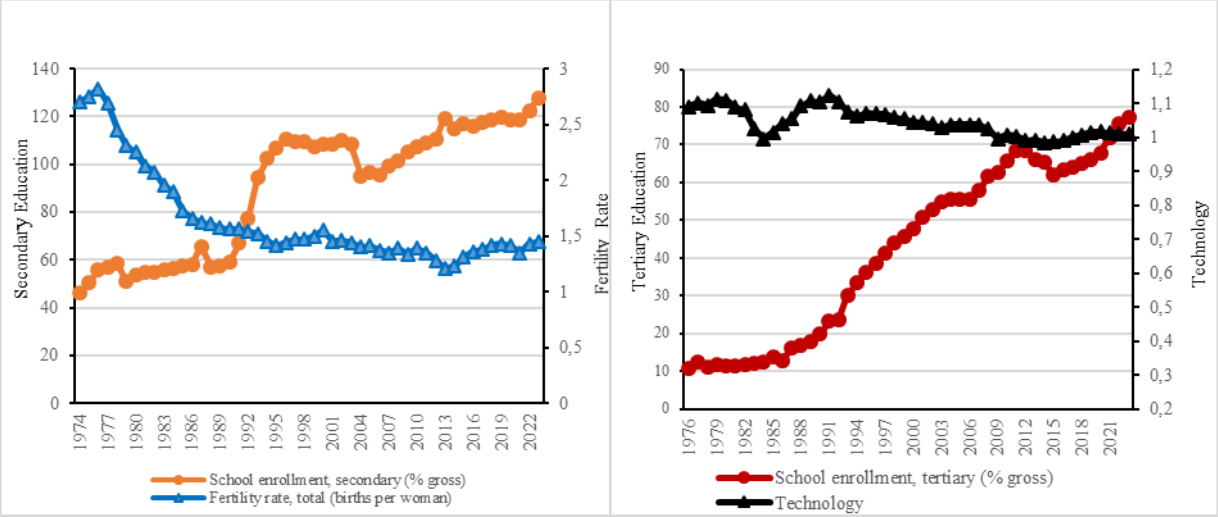
Keywords: Malthusian Trap, Quantity-quality tradeoff, Economic Growth
Jel codes: I25, O10

1. Introduction

According to Malthus (1798), population growth is higher than production growth. Production growth must outpace population growth in order for development to take place and for nations to escape from the Malthusian trap. According to Galor and Weil (2000), escape from this trap is achievable through a quantity-quality transition of the population. They argue that this transition accelerates technological development, which in turn positively impacts production. However, if increased prosperity leads to higher fertility rates, this makes it more difficult to escape from the trap. Therefore, parents should continue to prioritize quality over quantity in their choice of children. The societal transition toward quality-oriented preferences enhances human capital development through improved educational attainment, subsequently increasing technological efficiency. When this quantity-quality transition is achieved and technological progress is sustained, economic growth exhibits both quantitative and qualitative enhancement. However, this process may exhibit substantial variation across countries, as exemplified by Portugal.

The monarchy in Portugal, which began in 1926, ended in 1974 with the transition to democracy. During the monarchy period, Portugal significantly succeeded in the transformation from an agricultural society to an

industrial society and achieved high growth rates between 1950-1973.This economically successful period ended with the 1973 Oil Crisis and the subsequent change of political regime in Portugal. While this situation negatively affected Portugal economically, it was a necessary step for the structural reform process. During this transformation, Portugal prioritized education and directed its investments toward this field. It implemented educational policies to increase the literacy rate in the country and to create a qualified workforce (Stoer and Dale, 1987; Nunes, Mata and Valério, 1989; Nunes, 2003; Lains, 2004; Pereira and Lains, 2011; Crato, 2020; Ferraz, 2022). Thus, a transformation from quantity to quality in the population began to be achieved. Figures



1.a and 1.b illustrate this situation.

Graph 1a-1b. Secondary Education and Fertility Rate - Tertiary Education and Technology

Source. Based on World Bank 2024 data

As demonstrated in Figure 1.a, a negative correlation exists between secondary education and fertility. In Figure 1.b, technology has maintained its current level while tertiary education has increased. It is evident from the available data that a demographic transition has occurred in Portugal over time. Considering all these factors, the applicability of the Galor-Weil model to Portugal's escape from the Malthusian trap represents the fundamental motivation of study. Based on this motivation, the study aims to empirically test whether Porketiz has escaped from the Malthusian trap in accordance with the Galor-Weil (2000) model.

This research is divided into five chapters. In the second section, the theoretical background is explained, and the empirical literature of the model is presented. In the third section, data and methodology are explained. In the four sections, the empirical results and discussions existed. In the fifth section, conclusions and policy implications are included.

2. Theoretical Background and Empirical Literature

Galor and Weil (2000) improved the Malthusian model by including educational factors in order to explain how countries can escape the Malthusian trap. Their model is based on the fundamental assumption that households must choose between the number of children they have and how much they spend on their education. Their production function is expressed as follows:

$$Y = H_t^{\alpha}(A_t X)^{1-\alpha} \qquad 0 < \alpha < 1$$

(1)

In this equation, Y represents total output, H_t represents the productivity level of labor employed at time t, X indicates the total amount of land, while $A_t > 0$ indicates the endogenously determined technological level at time t.

The Galor and Weil (2000) model is based on the fundamental assumption that households face a trade-off between the number of children they have and how much they spend on their education. The time allocated to each child comprises two components: basic childcare (τ) and educational investment (τ^e). Given that e_{t+1} represents the time devoted to a child's education in the subsequent period and that n_t denotes the total number of offspring in period t, the total time allocated to children is normalized to 1. Consequently, the household's time constraint can be expressed as follows:

$$n_t(\tau + \tau^e e_{t+1}) = 1 \quad (2)$$

Equation (2) demonstrates the trade-off between quantity of children and their educational attainment.

The mechanism for escape from the Malthusian trap depends on this trade-off between quantity and quality.

In the Galor and Weil model, the optimal level of e_{t+1} is expressed as a function of technological progress ($e_t = (g_t)$). The fundamental assumption is that higher educational attainment in a society leads to accelerated technological advancement. The growth rate of technological knowledge is represented in equation (5):

$$\frac{A_{t+1}-A_t}{A_t} = g_{t+1} = g(e_t L_t) \quad (3)$$

As educational attainment increases in the economy, the rate of technological advancement accelerates. Consequently, when the economy reaches equilibrium at high levels of educational attainment and technological progress, escape from the Malthusian trap becomes possible.[1]

Table 1 presents a comprehensive review of empirical literature examining the escape from the Malthusian trap through the Galor-Weil (2000) model.

Table 1. Literature Table

Author(s)	Data Set	Method	Empirical Findings
Mejía, D., Ramírez, M. T. & Tamayo, J. (2008)	Colombia (1905-2005)	VAR Analysis	Galor-Weil (2000) model is valid.
Elgin, C. (2010)	England (1750-2000)	Simulation	Galor-Weil (2000) model is valid.
Ashraf, Q., & Galor, O. (2011)	21 OECD Countries (1-1500)	OLS	Galor-Weil (2000) model is not valid.
Si-Tou, W. K. (2011)	China (1960-2008)	Simulation	Galor-Weil (2000) model is not valid.
Xue, J., & Yip, C. K. (2017)	China (1979-2016)	Simulation	Galor-Weil (2000) model is not valid.
Madsen J., & Strulik H. (2023)	21 OECD Countries (1750-2000)	2SLS Regression Analysis	Galor-Weil (2000) model is valid.
Bakırtaş İ., & Yardımcı E. (2024)	Turkiye (1974-2021)	Granger Causality and VAR Analysis	Galor-Weil (2000) model is not valid.
Bakırtaş İ., & Yardımcı E. (2024)	South Korea (1974-2021)	Granger Causality, VAR Analysis and ARDL Bounds Test	Galor-Weil (2000) model is valid.

The methodological approaches employed in the limited empirical literature include vector autoregressive (VAR) models, simulation techniques, ordinary least squares (OLS) estimation, two-stage least squares (2SLS)

1 For the derivation equation, see Galor and Weil, 2000.

regression, and autoregressive distributed lag bounds test analysis. The primary focus of these studies is long-term dynamics. The investigations examine whether societies achieve escape from the Malthusian trap through technological advancement driven by demographic transition. The empirical findings regarding the model's validity demonstrate heterogeneous results.

3. Data & Methodology

This section presents the dataset and provides descriptive statistics of the variables employed in the empirical analysis.

Table 2. Data and Methodology Table

Symbol	Variable	Definition	Year	Source
pcig	GDP per capita growth	Annual growth rate of real income per capita	1976-2023	World Bank
tfp	Technology	Output per hour worked	1976-2023	FRED (2020-2023 data derived from ARIMA method)
fr	Fertility rate	Birth rate per woman	1976-2023	World Bank (2023 data derived from ARIMA method)
mr	Mortality rate	Under-5 mortality rate (per 1,000 live births)	1976-2023	World Bank (2023 data derived from ARIMA method)
sc(2)	School enrollment, secondary	Gross enrollment ratio for secondary school is calculated by dividing the number of students enrolled in secondary education regardless of age by the population of the age group which officially corresponds to secondary education, and multiplying by 100.	1976-2023	World Bank (1981-1985,2022, 2023 data derived from ARIMA method)
sc(3)	School enrollment, tertiary	Gross enrollment ratio for tertiary school is calculated by dividing the number of students enrolled in tertiary education regardless of age by the population of the age group which officially corresponds to tertiary education, and multiplying by 100.	1976-2023	World Bank (2023 data derived from ARIMA method)

The analysis encompasses the period 1976-2023, corresponding to Portugal's post-democratization era when education emerged as a strategic priority.

Variance decomposition analysis is a suitable method for examining the relationships between variables in the Galor-Weil (2000) model; therefore, Vector Autoregressive (VAR) methodology is employed to test the research hypothesis.

4. Analysis Results

In time series analyses, the stationarity of the data is first checked by unit root tests. Extended Dickey-Fuller (ADF) and Phillips-Peron (PP) tests are used for stationarity checks. The results of the unit root tests are shown in Table 1. According to the unit root test results shown in Table 1, all variables are stationary at I(0) level.

Table 3. Unit Root Tests

Level				
Constant			Constant and Trend	
	ADF	PP	ADF	PP
pcig	-5,17***	-5,03***	-5,29***	-5,08***
tfp	-5,53***	-5, 48***	-5,61***	-5, 49***
fr	-4,38***	-3,90***	-3,82**	-5,38***
mr	-3,24***	-20,52***	-3,73**	-11,59***
sc(2)	-5,25***	-5,20***	-5,20***	-5,16***
sc(3)	-4,94***	-5,04***	-4,93***	-5,04***

Note: *, ** and *** denote stationary data at 10%, 5% and 1% statistical significance levels, respectively.

Subsequent to the stationarity test, a Vector Autoregressive (VAR) model was constructed for the analysis. Prior to the analysis, three critical conditions for the validity of the VAR model were evaluated. The results of the test indicated the following: firstly, the modular values of the characteristic equation remained within the unit root circle, thereby indicating unit root stationarity. Secondly, the models do not contain heteroscedasticity and confirm constant variance at the 5% significance level. Thirdly, no autocorrelation was detected at the 5% significance level. Subsequent to the satisfaction of these fundamental conditions for VAR analysis, the block exogeneity Wald test was applied in order to conduct Granger causality analysis.

Table 4. Granger Causality Test (Block Exogeneity Wald Test) Results

fr	⇄	pcig	6.735504** 8.611204**	There is mutual Granger causality	This observed mutual Granger causality is consistent with the theoretical framework of escape from the Malthusian trap.
mr	→	pcig	9.716945**	There is one-way Granger causality	This observed Granger causality is consistent with the theoretical framework of escape from the Malthusian trap.
tfp	⇄	fr	9.420619** 22.62248***	There is one-way Granger causality	This observed Granger causality is consistent with the Galor-Weil (2000) model.
fr	→	mr	15.13259***	There is one-way Granger causality	This observed Granger causality is consistent with the theoretical framework of escape from the Malthusian trap.
pcig	→	tfp	12.53297***	There is one-way Granger causality	This observed Granger causality it is consistent with the Galor-Weil (2000) model.

mr	⟶	tfp	38.88346***	There is one-way Granger causality	The Granger causality of mortality rates for technology has no connection with the theory.
sc3	⟶	tfp	7.104262*	There is one-way Granger causality	This observed Granger causality it is consistent with the Galor-Weil (2000) model.

Note: *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

In this analytical phase, variance decomposition analysis was conducted to assess the explanatory powers of variables in both short and long-term contexts. This methodological approach enables a comprehensive examination of variable interactions during Portugal's demographic transformation process. Consequently, Portugal's alignment with the Galor-Weil (2000) model is more clearly examined.

Table 5. Variance Decomposition Test Results - Model 1

	Yıl	PCI	FR	MR	SC2	SC3	TFP
Per Capita Income Growth	1	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
	2	94.46280	2.040261	0.192598	1.677113	1.616904	0.010319
	3	89.59537	5.443278	0.792080	1.546887	2.612916	0.009468
	4	88.07793	6.348551	0.777925	1.745434	2.840069	0.210096
	5	86.11895	6.308230	1.246664	2.245257	3.576295	0.504606
	6	85.28430	6.216316	1.860617	2.415736	3.686205	0.536826
	7	84.07957	6.097314	2.965555	2.661728	3.647976	0.547858
	8	82.31715	5.964955	4.318645	2.832953	3.926195	0.640098
	9	81.11184	5.879265	5.218263	2.859597	4.150005	0.781030
	10	80.53587	5.842565	5.484026	2.838608	4.387628	0.911301
	Yıl	PCI	FR	MR	SC2	SC3	TFP
Fertility Rate	1	5.931616	94.06838	0.000000	0.000000	0.000000	0.000000
	2	20.10855	73.00785	0.221055	1.137333	1.064475	4.460745
	3	18.94447	64.80016	2.532572	4.393748	2.817968	6.511076
	4	17.90594	58.79145	4.128790	7.245015	5.915321	6.013482
	5	16.97767	55.40192	4.605556	8.504339	8.729544	5.780967
	6	16.45170	53.85128	5.031682	9.094417	9.746938	5.823986
	7	16.22500	53.06231	5.449267	9.369514	10.06690	5.827017
	8	16.37197	52.61974	5.596674	9.408217	10.19880	5.804591

	9	16.58624	52.41603	5.592881	9.383363	10.22871	5.792775
	10	16.70934	52.33464	5.587687	9.364285	10.22223	5.781818
	Yıl	PCI	FR	MR	SC2	SC3	TFP
Mortality Rate	1	0.168135	4.047223	95.78464	0.000000	0.000000	0.000000
	2	1.592051	8.331454	87.19161	0.882659	1.817445	0.184777
	3	0.734003	11.61980	84.22540	0.528353	2.625646	0.266796
	4	0.428760	10.81582	82.47459	0.342406	5.024022	0.914401
	5	0.280300	8.981801	82.04163	0.577679	6.878934	1.239657
	6	0.220554	7.232201	81.70246	0.715832	8.783490	1.345462
	7	0.202152	5.912864	80.75821	0.664008	11.09286	1.369902
	8	0.215970	5.040836	78.91087	0.565895	13.96431	1.302116
	9	0.292287	4.643171	76.31680	0.540004	17.02761	1.180125
	10	0.394324	4.681625	73.14140	0.653795	20.06328	1.065575
	Yıl	PCI	FR	MR	SC2	SC3	TFP
Secondary Education	1	4.561671	0.852175	0.098603	94.48755	0.000000	0.000000
	2	5.233144	1.176364	0.224930	93.05426	0.005922	0.305376
	3	6.203131	2.873879	0.238860	87.95029	1.181826	1.552016
	4	7.939335	4.721245	0.351409	82.25131	1.737497	2.999208
	5	7.723945	7.173654	0.484823	78.53005	2.597275	3.490251
	6	8.338803	7.465256	0.550790	77.02863	3.141194	3.475332
	7	8.134782	7.782133	0.542158	74.78894	5.380535	3.371452
	8	8.063618	7.771407	0.571151	74.20410	6.008532	3.381192
	9	7.990774	7.747611	0.641028	73.66586	6.558045	3.396685
	10	7.960782	7.724161	0.780510	73.48439	6.652799	3.397358
	Yıl	PCI	FR	MR	SC2	SC3	TFP
Tertiary Education	1	6.354310	1.299914	1.387411	4.691849	86.26652	0.000000
	2	5.197320	8.026024	4.990524	11.90361	69.87298	0.009543
	3	5.597341	7.618155	5.131468	11.82332	69.80320	0.026517

4	12.50727	7.114663	4.910652	11.08547	64.33026	0.051678
5	12.88368	7.855891	4.782734	11.28717	62.83833	0.352185
6	12.65094	8.963373	4.779160	11.02932	62.08621	0.491006
7	12.63341	9.655869	4.696022	10.81839	61.71082	0.485490
8	12.44839	9.910242	4.599287	10.76159	61.79186	0.488634
9	12.35483	10.04083	4.576537	10.75413	61.77977	0.493918
10	12.33345	10.10343	4.762484	10.86811	61.44266	0.489864

Technology

Yıl	PCI	FR	MR	SC2	SC3	TFP
1	31.29222	0.422125	0.440504	3.828715	3.032845	60.98359
2	33.06395	10.69434	0.225310	2.454622	5.926161	47.63562
3	29.49450	16.69559	2.630706	1.988635	15.17605	34.01451
4	27.72445	16.35480	4.814501	1.355836	26.48735	23.26307
5	23.73872	16.39758	5.479204	1.266587	33.90819	19.20972
6	21.25507	16.78355	4.997554	1.433093	37.99436	17.53638
7	19.84072	16.91581	5.016135	2.147660	39.52575	16.55392
8	19.00998	16.88465	6.583268	2.985956	38.85221	15.68393
9	18.24510	16.62173	9.472894	3.879405	36.88693	14.89395
10	17.38180	16.21326	12.48465	4.507942	34.96227	14.45008

The findings of the variance decomposition analysis results indicate that the entire variation in per capita income growth is self-explanatory in the short run. This pattern is also evident in the long-term horizon.

The results of the variance decomposition analysis demonstrate that fertility's self-explanatory power is 94% in the initial period, but this ratio decreases to 73% in the subsequent period. In contrast, the explanatory power of per capita income growth increases to 20%. These findings are consistent with the Malthusian trap hypothesis. According to Malthus (1798), the enhancement of prosperity has been demonstrated to increase fertility rates in societies that have not yet achieved educational and technological advancement. This pattern is evident in Portugal's short-term dynamics. However, when the long-term horizon is considered, the explanatory power of fertility variation shifts towards secondary and tertiary education. While the explanatory contribution of per capita income growth diminishes, the combined explanatory power of secondary and tertiary education reaches 20%. In the case of Portugal, which demonstrates endeavours to escape from the Malthusian trap, parents' transitioning preferences from quantity to quality over time enhances education's explanatory power regarding fertility. This outcome aligns with the theoretical framework proposed by Galor and Weil (2000).

In the initial period, 95 percent of the variation in the under-five mortality rate is self-explanatory, with fertility accounting for 5 percent. During the second and third periods, fertility's explanatory power regarding under-five mortality increases. This pattern demonstrates that the fertility-mortality cycle characteristic of the Malthusian trap manifests in Portugal's case. However, this relationship undergoes transformation in the long-term horizon. The explanatory contribution of tertiary education reaches 20 percent. Consequently, as the proportion of the educated population increases, mortality rates decline.

In the short term, 94 percent of variation in secondary education is self-explanatory, whereas this rate decreases to 73 percent in the long term. In the long-term context, the remaining explanatory contributions are distributed as follows: 7 percent to fertility, 7 percent to per capita income growth, 6 percent to tertiary education, and 3 percent to technological advancement. According to the theoretical framework, initial variation in educational attainment is considered exogenous. Consequently, the variance decomposition results for secondary education in Portugal demonstrate consistency with the Galor-Weil (2000) model.

In the short term, 86 percent of variation in tertiary education is self-explanatory, whereas this proportion decreases to 61 percent in the long term. The explanatory contribution of secondary education increases from 4 percent to 10 percent in the long-term context. The enhancement of educational prioritization through policy interventions has resulted in a substantial expansion of the secondary education graduate population, with subsequent positive impacts on tertiary education.

In the short term, approximately 61% of the variation in technology is self-explanatory, while 31% is accounted for by growth in per capita income. However, in the long term, the self-explanatory power of technology declines to 14%, and the explanatory power of per capita income growth decreases to 17%. By the tenth period, the contribution of tertiary education to explaining technological change rises to 34%. The total long-term effect of education on technology reaches approximately 40%. These findings support the theory proposed by Galor and Weil (2000), which suggests that technological progress—initially slow and insufficient—is eventually driven by a more educated population. To adapt to the accelerating pace of technological advancement and ensure its sustainability, the level of educational attainment must also rise. As the analysis shows, while technology in Portugal is initially driven by growth in per capita income, tertiary education emerges as the key driver in the long term.

5. Conclusion

Galor-Weil (2000) argues that escape from the Malthusian trap can occur as a result of quantity-quality transfer through technological development. In this study, the Galor-Weil (2000) model was tested on Portugal, a country that struggled with democratization in the 1970s and experienced economic distress during this process. With the transition to democracy, the Portuguese government prioritized education and began developing policies in this direction. These policies targeted demographic transition and the acquisition of qualified human capital. Portugal's main objective in this process was to increase the share of qualified labor in the production process.

According to the variance decomposition analysis results for Portugal during the 1976-2023 period, secondary and tertiary education maintain high explanatory power regarding the decline in fertility. Similarly, tertiary education demonstrates high explanatory power concerning the reduction in mortality rates. Additionally, participation rates in secondary and tertiary education have been progressively increasing over the years. Based on these results, the quantity-quality transfer, which represents the first stage of escape from the Malthusian trap, has been realized for Portugal. The subsequent phase concerns the relationship between an educated workforce and technological advancement. While Portugal achieved a certain technological threshold in the 1970s, the sustainability of this progress necessitates that educated labor serve as the locomotive for technological development. Variance decomposition results indicate that tertiary education functions as the primary driver of technological advancement in the long-term horizon. Through this process, Portugal has successfully completed the secondary phase required for escape from the Malthusian trap.

Between 1950-1973, Portugal achieved substantial growth and elevated technology to a significant level. However, this development took place under the oppressive regime of the monarchy and the ongoing practice of colonialism, failing to produce any significant societal transformation. With democratization, Portugal aimed to accomplish both demographic transition and the development of a conscious society. Additionally, it abandoned colonial policies and targeted an increase in the educated workforce. Consequently, through its democratization process, Portugal underwent a transformation within the framework of the Galor-Weil model and established the educated workforce as the locomotive production factor.

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