Wage Convergence in the Heckscher-Ohlin Model: Evidence from Puerto Rico

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ABSTRACT. This paper aims to empirically confirm the wage convergence conjecture within neoclassical economics' Hecksher-Ohlin model in the Puerto Rican manufacturing industry over the period 1950-1987. Using time series econometrics, I isolate the effects of increased trade liberalization on Puerto Rican manufacturing wages. Log-first-differencing technique is applied due to nonstationarity in the data. Results indicate that wage convergence is observed, but shows little correlation with movements in U.S. gross national product after differencing. These results indicate that wage convergence is observed but not due to increased trade liberalization or shock effects, and highlights the limitations of real-world applications of neoclassical economic theory.

Introduction

In neoclassical economics, the Heckscher-Ohlin (H-O) model suggests that trade patterns arise because nations specialize in producing and exporting goods that align with their factor abundance, while they import goods tied to their factor scarcity, and conjectures that a country may begin trading a good if its factors in production are naturally endowed and produced intensively. Factor-price equalization may result from the increased trade liberalization, leading to wage convergence in the industry which produces that good intensively (Feenstra and Taylor 2021). In this paper, I will empirically answer if wage convergence is observed in Puerto Rico during the U.S.-Puerto Rico rapprochement, as predicted by the H-O model. This will be accomplished by testing if Puerto Rican manufacturing wages converge in response to increased trade openness in the period 1950-1987. An empirical analysis of the H-O model in a *developing* country has important implications; the Global South's developing regions may utilize empirically confirmed cases of the H-O model to advocate for trade liberalization, and *developed* countries may express greater willingness for international trade if substantial evidence suggests that there is economic benefit for the developing country (Panagariya, 2004). A few notable examples related to my work are Mitra and Hossain (2018) and O'Rourke and Williamson (1994). Mitra and Hossain (2018) empirically confirm the H-O model's prediction of increased income inequality in developed countries resulting from increased trade openness, and found a long-term significantly positive relationship between income inequality and trade openness in developed nations, consistent with the propositions of the H-O model. O'Rourke and Williamson (1994) analyzed dynamic causality in wage convergence between Britain and America in the period from 1870-1913, and found that real Anglo-American wages converged over this period and over half of the noted convergence was, in fact, due to commodity price equalization. This

paper builds on the findings of O'Rourke and Williamson (1994), while discussing a more recent and *developing* country-focused analysis of the H-O model. As opposed to their findings, the research in this paper does not find that the observed wage convergence is isolatedly due to increased trade liberalization.

Empirical Model

To justify the use of Puerto Rico over this time period as a vector of analysis for the H-O model, I present a few unique and notable characteristics which arise from the U.S.-Puerto Rican rapprochement's positioning in history, all of which draw clear parallels to the underlying context of the H-O model.

First, the inception of Puerto Rico as a Commonwealth of the U.S. in 1952 stands as a divisive moment in which barriers to trade are dropped and trade liberalization can develop, as it occurs alongside the U.S. federal government's almost immediate investment in Puerto Rican infrastructure (Puerto Rico Report 2024). Seeing as Puerto Rico's infrastructure development received direct oversight from the U.S. federal government, a parallel can be drawn to the "identical technology" and "free movement of labor and capital" assumptions within the H-O model; improvements in technology facilitated by the U.S. tend to reflect the U.S. technological development, design standards, and implementation strategies (U.S. Agency for International Development, "Environment, Energy, and Infrastructure"). The most central characteristic of the rapprochement period, however, is that of Operation Bootstrap, which saw the U.S. federal government heavily prioritizing Puerto Rico's manufacturing development and export prowess (Ayala and Bernabe 2007). This form of developmental incentivization works particularly nicely when drawing parallels between the rapprochement period and the H-O model; we can treat manufacturing as Puerto Rico's intensively-produced-good and proceed with interpretation of the

model. Consequently, by controlling for the influences of Operation Bootstrap, it can be seen that the historical positioning of the Puerto Rico-U.S. rapprochement replicates the conditions in H-O model which presuppose wage convergence, painting a causal picture from increased trade liberalization to wage convergence. An intuitive empirical analysis of the wage convergence conjecture within the H-O model follows naturally from the context surrounding the two nations' rapprochement.

To make an empirical analysis of the H-O model's wage convergence prediction in Puerto Rico, I will isolate how Puerto Rican manufacturing wages respond to movements in U.S. gross national product (GNP) and a *wage proportion,* defined as the ratio of manufacturing wage growth rates to average wage growth rates. The use of U.S. GNP as a signifier for U.S.-Puerto Rico trade volume is admittedly due to limitations in the dataset, but remains theoretically tractable; the robust, correlative link between GNP and trade volume has been thoroughly confirmed in the literature (Frankel and Romer 1999). In similar fashion, the idea of the wage proportion hints towards a predicted feedback loop, where manufacturing wage growth rates outpacing average wages lead to further investment, bargaining power, and movement towards that sector, consistent with the factor-price equalization presupposition within the H-O framework (Katz & Krueger 1991). Using these as the focal point to build the analysis, the following population estimation model is proposed:

$$(Puerto\ Rico\ Manufacturing\ Wages)_t = \beta_0 + \beta_1(U.S.\ GNP)_t +$$

$$\beta_2\ (Wage\ Proportion)_t + \beta_3(Operation\ Bootstrap)_t + \beta_4(Stagflation)_t + u_t$$

Where t = 1,2,3, … , 38, *Wage Proportion* is defined as $\boldsymbol{\Delta} ln(PRMW)/\boldsymbol{\Delta} ln(PR\ Average\ Wages)$, *Operation Bootstrap* and *Stagflation* are dummy variables to control for shock economic influences, and $\{u_t\}$ is i.i.d. with zero mean and constant variance. This model is testing the null

hypothesis $H0$: $\beta_1 = \beta_2 = 0$ against the alternative $H1$: $\beta_1 \vee \beta_2 \neq 0$; essentially, the model is testing whether U.S. GNP, *Wage Proportion*, or both have predictive effects on Puerto Rican manufacturing wages at the 95% significance level. To confirm my hypothesis, it requires a positive coefficient slope for both U.S. GNP and *Wage Proportion*: positive trends in U.S. GNP can be related to increased trade volume, which would warrant wage convergence in Puerto Rico. Similarly, positive slopes in the proportion of growth rates would indicate an increase in the difference between manufacturing wages and average wages, showing an increasingly concentrated movement towards the manufacturing industry. The expected sign for *Operation Bootstrap* is positive, as direct federal investment in an industry can be linked to wage increases in that industry (Office for National Statistics 2020). The expected sign for *Stagflation* is negative; economic logic dictates that a national recession and productive deceleration would lead to decreases in wages.

Data and Estimation

The dataset I used for my research comes from Castillo-Freeman and Freeman (1992), which includes time-series data on a variety of Puerto Rican and American macroeconomic indicators, like gross national product, Puerto Rican minimum wages, and Puerto Rican employment-population ratio from 1950-1987. The dataset was accessed through Canvas. The following **Table 1.1** gives a description of the variables.

Table 1.1. Variables and their descriptions.

VARIABLE NAME	DESCRIPTION	VARIABLE NAME	DESCRIPTION
year	Year 1950-1987	*prepop*	Puerto-Rican employment-population ratio
avgmin	Weighted average min. wage across 44 industries	*prepopf*	Puerto-Rican employment-population ratio, alter.
kaitz	Kaitz minimum wage index	*prgnp*	Puerto Rican GNP
avgcov	Weighted average coverage, 8 industries	*prunemp*	Puerto Rican unemployment rate
covt	Economy-wide coverage of minimum wage	*usgnp*	US GNP
mfgwage	Average manufacturing wage	*t*	Time trend, 1-38
prdef	Puerto-Rican Price Deflator	*post74*	Time trend starts in 1974

Log-first-difference transformations were applied to *U.S. GNP* and *Puerto Rican Manufacturing Wages* due to non-cointegrated highly dependent, unit root behavior in the data. In dealing with two non-cointegrated I(1) processes, two attempts were made for estimation: one with ordinary least squares (OLS) regression with Newey-West heteroskedasticity-autocorrelation (HAC) robust standard errors (to account for non-constant residual variance), and one with Prais-Winsten feasible generalized least squares (FGLS) regression with the same HAC standard errors; if slope estimates remain the same between the two, FGLS regression does a better job of

increasing the efficiency of our estimator by correcting highly autocorrelative residuals, although vast differences in slope estimates rendered this inviable. The following **Table 1.2** and **Table 1.3** give the summary statistics and Pearson correlation coefficients, with *glmfg.pw* being the log-first-difference of *Puerto Rican Manufacturing Wages*, *glusgnp.pw* as the log-first-difference of *US GNP*, and *glwp.pw* as the ratio between *glmfg.pw* and the log-first-difference of *Puerto Rican Average Wages.*

Table 1.2. Summary statistics of model parameters.

VARIABLE NAME	MEAN	MEDIAN	MAX	MIN	STD. DEV.
glmfg.pw	0.0680357	0.0645385	0.17185027	0.0037694	0.0307453
glusgnp.pw	0.0312093	0.0298522	0.0984245	0.02581675	0.0257395
glwp.pw	1.207972	1.112964	4.1127561	0.1172146	0.738962

Table 1.3. Pearson Coefficients of the dependent variable and its regressors.

VARIABLE NAME	GLMFG.PW	GLUSGNP.PW	GLWP.PW
glmfg.pw	1	-0.2202603	0.1447898
glusgnp.pw	0.2202603	1	-0.005316395
glwp.pw	0.1447898	-0.005316395	1

Estimation Results

The following **Table 1.4** gives the results from OLS estimation with Newey-West errors to account for serial correlation.

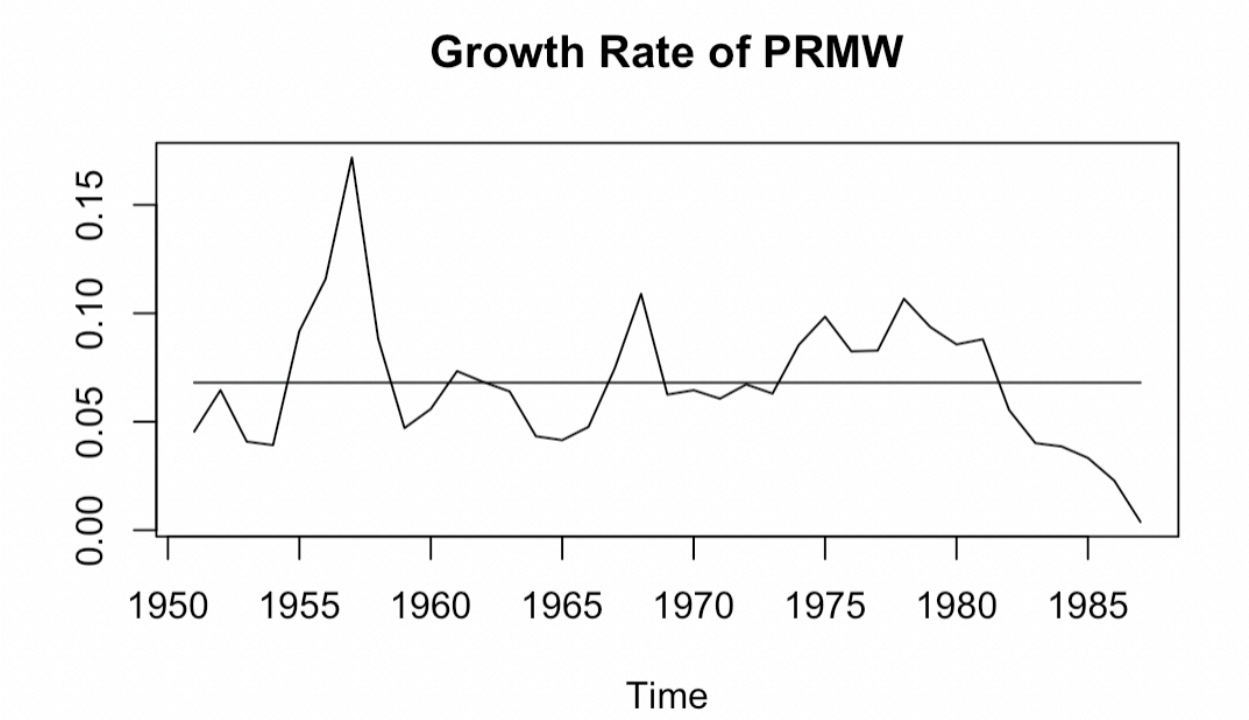
Table 1.4. Estimation results from regression fitted with N-W covariance matrix.

VARIABLE	ESTIMATE	STANDARD ERROR	T-STATISTIC	P-VALUE
Intercept	0.0581872	0.0115641	5.0317	1.812e-05 ***
glusgnp.pw	-0.2984775	0.1580718	-1.8882	0.06809 .
operation_bootstrap.ts.pw	0.0165872	0.0147141	1.1269	0.26817
stagflation.ts.pw	0.0305766	0.0112869	2.7090	0.01075 *
glwp.pw	0.0055345	0.0057279	0.9662	0.34117

Note that "***" refers to significance at the 1% level, "*" refers to significance at the 5% level, and "." refers to significance at the 10% level. In this model, the *Intercept*'s valur can be interpreted as the Expected Value of *Puerto Rican Manufacturing Wages* conditional on the reference group (i.e., $E(Y_t|X_{1,t=0}, X_{2,t=0},..., X_{n,t=0})$.) This says that the time average of *Puerto Rican Manufacturing Wage* growth rates, controlling for the shock effects of Operation

Bootstrap and Stagflatoin is 0.0581872, intuitively but reasonably lower than the time mean with no controlling of 0.068, seen in **Figure 1.1**:

Figure 1.1. Puerto Rican Manufacturing Wage growth rates + time mean.



This implies that the model does a good job of capturing shock effects in the time frame. Next, *glusgnp.pw*'s negative coefficient and statistical significance imply that the growth rates of *Puerto Rican Manufacturing Wages* react negatively to increases in U.S. GNP growth. While the 10% significance of the variable is notable, the negative coefficient strictly denies the theoretical justification underlying my hypothesis. The positive slopes and coefficients on the two dummy variables, *operation_bootstrap.ts.pw* and *stagflation.ts.pw*, imply a positive shock effect on the growth rate of *PRMW* (the combined effects of β_3 and β_4 + the β_0 intercept), consistent with the propositions of my hypothesis, and carrying no major implications for the validity of the H-O model's application into this timeframe.. Finally, *glwp.pw*'s positive slope is highly indicative of

the positive feedback loop discussed earlier, largely due to its time mean of 1.20729 (implying that on average, manufacturing wage growth rates are outpacing average wages from its >1 slope,) but its effect is minimized by the lack of statistical significance. This segues to goodness-of-fit measures, where an adjusted R-square of 0.113 is returned. The overall F-test on coefficients under the null hypothesis $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$ also fails to reject at any significance level, meaning there is insufficient evidence to conclude that the regressors are jointly significant in the regression model. The conclusion from these results is that the model effectively captured shock effects and the idea of a feedback loop in the *PRMW* growth rates; however, the low R-squared and unexpected negative slope on *glusgnp.pw* points to the inefficacy of using U.S. GNP as a signifier for trade closeness, or simply revealing spuriousness between two highly persistent, I(1) stochastic processes. There is therefore largely insufficient evidence to conclude that the wage convergence observed in manufacturing wage growth rates over 1950-1987 can be isolatedly due to trade liberalization.

Conclusion

This study sought to explore the wage convergence hypothesis within the context of Puerto Rican manufacturing from 1950-1987, aligned with the Heckscher-Ohlin model. The analysis aimed to assess whether trade liberalization led to wage convergence between Puerto Rico and the U.S., but the findings did not confirm this hypothesis. Although strong correlations were initially observed, they were ultimately deemed spurious after differencing. The study's limitations include its narrow focus on Puerto Rican trade liberalization and a limited timeframe; future research could explore additional variables, such as global trade policies or demographic shifts, to better understand the causality of wage convergence within the H-O framework. Results suggest that while trade liberalization may stimulate growth, the use of U.S. GNP growth rates

and wage proportion growth rates did not prove to be statistically significant predictors of Puerto Rican manufacturing wage growth rates. Overall, while the H-O model provides a useful framework, more expansive datasets and methods are needed to address the complexities of wage dynamics in developing countries.

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