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An Intervention Time Series Analysis: Specialization and Competitiveness in Sports"

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Abstract

We utilize a time-series intervention model in the spirit of Enders (1995) and ask to what extent – if any – institutional specialization improves competitiveness in sports. Specifically, we analyze the impact on the competitiveness of Polish swimmers internationally due to the establishment of high-school sport centers in late 1980's specializing in swimming. This allows us to measure the quantitative and qualitative effects of a standardized system on competitiveness. Our analysis shows that the public policy that allowed for institutional specialization had a significant short-term as well as a long-term effect. In particular, we find that implementing the policy had a long run effect of five additional Polish swimmers in the Top 25 international ranking.

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1. Introduction

In this paper, we use an intervention time series model in the spirit of Enders, Sandle and Canley (1990), Mehanna and Shamsub (2002) and Sridharan, Vujic and Koopman (2012) to evaluate the impact of an institutional policy intervention on performance.[1] Specifically, we look at the international competitiveness of swimmers following the establishment of centralized sport centers in Poland. While these centers where designed to yield better international outcomes, there is no reason to believe that this was a necessary outcome. Hence, our objective is to evaluate the impact these specialized centers had on aggregate swimmer achievements over time, looking at both immediate and long run impacts. We use our findings to argue that institutional specialization led to positive outcomes in Poland, as measured by achievements.

Our analysis can be seen in light of the education literature of Dobbie and Fryer (2011), Damon (2007) and Pop-Elecher and Urquiola (2011), who consider the effect of attending higher-achievement high schools or "magnet" schools on achievement. This literature shows that attending specialized institutions need not yield higher achievement.[2] Hence, the education literature provides a basis for our analysis. Although higher performance is the desired outcome, specialized high-school sports centers (HSCs) are not necessary to achieve it.[3] Our attempt in this paper is to qualify and quantify the actual effects.

Recognizing a link between the HSC policy intervention and athlete outcome can be argued to be equivalent in establishing a link between training and achievement. The HSCs were designed in effect to improve efficiency by allocating time more appropriately to allow for a rise in training, thus contributing to a rise in overall international performance.[4] In this paper, we provide an argument based on an econometric investigation of the data.

We use an intervention time series model that allows for the assessment of any intervention by first estimating an autoregressive moving-average (ARMA) with-intervention model and then using the model's estimates to obtain the pre-intervention mean, the immediate impact effect and the long run effect.[5] In our paper, we analyze the impact of establishing the sport centers on swimmer's international ranking competitiveness (performance). Our analysis is limited due to data availability, as not sufficient data is available prior to the first two HSCs that were established in 1978/1979.[6] Consequently, we analyze the impact of the policy intervention, by looking at swimmers' performance prior and post the establishment of four HSCs in 1989, most of which were fully functional by 1989. We evaluate the immediate impact of opening these four additional sport centers and the long run effect of these centers.

As part of our analysis, we control for the regime switch from communism to a market economy. In the fall of 1989 the first non-communist government came to power in Poland (also

[1] Enders et al. use this methodology to evaluate the impact of changes in security on terrorism, while Sridharan et al. consider the impact of a specific legislature on crime rates in Virginia.

[2] Alternatively, one can look into the education literature that studies the link between amount of instruction and academic achievement, as in Daniels and Haller (1981) and Harnischer and Whiley (1974), where the link between instruction time and student performance is not always clear.

[3] Alternatively, swimmers are part of after school private clubs, as is the case in many developed economies today.

[4] A small survey conducted by the authors (in Poland) found that swimmers in HSC spend on average 6-10 hours per week more in the pool compared to non-HSC swimmers (club swimmers), participated in 11 training sessions per week as compared to 9 sessions for non-HSC, yet still had on average 6 more hours of sleep per week.

[5] The order of the ARMA components are determined using the model selection method of Box and Jenkins (1970).

[6] Note that prior to the establishment of high-school swim centers the performance of Polish swimmers in international competitions was consistently poor. For example, in the 1976 Olympic Games, the Polish national swim team did not achieve a single advancement out of preliminaries (16 swimmers advance) in all events.

the first in Eastern Europe), which began the transition to a market economy with the Balcerowicz Plan.[7] The following year, the inauguration of the first non-communist president occurred on Dec. 21st 1990, and the first parliamentary elections took place in 1991.[8] Hence, as with other eastern bloc countries, Poland did not become a fully democratic country with a market economy immediately in 1989; it was a transition that took a few years. Consequently, we consider the use of 1990 and 1991 as the date of the regimes switch in our analysis and we report results under a regime switch in 1991.[9] Considering the average monthly income we find that it spiked sharply during 1991, while it was fairly stagnant from 1980 to 1990. Thus we believe that the impact of the regime switch on swimmer competitiveness is more likely to have been felt – if at all – in 1991, as compared to 1990 or even 1989.[10] Other controls that we consider include education expenditure, real income and health.

Our results suggest that HSCs had a significant impact on the overall competitiveness of Polish swimmers internationally. More specifically, we find that prior to 1989 the mean number of Polish swimmers who ranked in the Top 25 internationally equaled approximately 3 per year. The increase of high-school sport centers in Poland led to a long-run mean of approximately 8 per year, thus the long-run (permanent) impact of the intervention was close to five additional swimmers in the Top 25 international ranking.

2. Data Description

The data on the international ranking of Polish swimmers was collected primarily from three sources: the Swim News magazine, Glowny Urzad Statystyczny (GUS), and Polski Zwiazek Plywacki (PZP). In addition, some of the data was collected from various issues of the Swimming World magazine and the Fédération Internationale de Natation Amateur (FINA). To obtain our achievement measure we use the number of Polish swimmers who rank in the Top 25 on the Swimming World Rankings in any event as of December 31st between 1980 and 2003.[11]

We use education expenditure as a proxy to expenditure specifically allocated to the sport of swimming (in real domestic currency). It was obtained from Glowny Urzad Statystyczny (GUS), a Polish government statistic agency. We also control for rising income levels using average real monthly earnings (at annual frequencies) obtained from GUS.

Furthermore, since the measurement of outcomes is a ranking among 194 nations, we use the ratio of the population growth in Poland and the average population growth of 12 countries dominating the Top 25 world rankings as a proxy to control for fluctuations in the population. This data is obtained from OECD. To determine the role of health on performance we use the infant mortality rate (per 1000) as a proxy, due to the lack of health expenditure data availability for the whole sample period; obtained from GUS. The use of the infant mortality rate as a measure of overall country health is common in the health literature, as it is argued to reflect the

[7] The first semi-democratic elections took place in the summer of 1989 which led to the non-communist government. The Balcerowicz Plan was signed in Dec. 1989; fo details on the plan see Hunter and Ryan (2009a).

[8] See Hunter and Ryan (2009b)

[9] Today's structural break techniques do not allow for a slow transitional break, which would have been the best approach to take given the few years that it took to transition to a market economy in Poland. Note however that our results are very similar whether we consider 1990 or 1991 as the structural break.

[10] We also use a Chow Break Point test to test for instability of the real income series, as we would expect this to be effected by the switch to a market economy. We do not find a structural break in real income for 1989 or 1990; however we fail to reject no instability in 1991 at the 10% level of significance.

[11] This represents the measurement of outcomes, and is the dependent variable we refer to as Top25.

quality and access to medical care, public health practices, and socioeconomic conditions over time.[12] Rowley and Hogan (2012) argue that to lower infant mortality rates requires services that improve health status at the individual and population level.

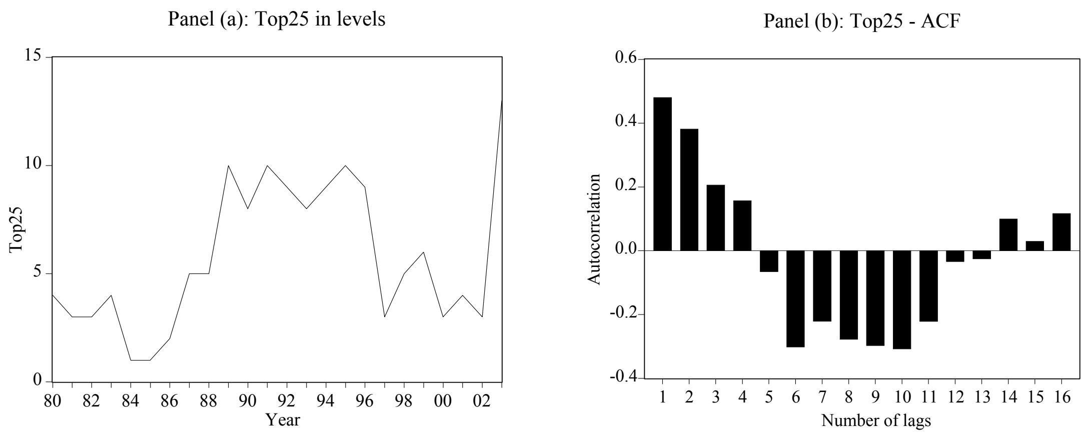
3. Descriptive Analysis

Table I contains the descriptive statistics of all variables. The Top25 time series is plotted in Figure 1. During the sample period Poland placed at maximum 13 swimmers in the Top 25 ranking and at minimum 1 swimmer. A casual inspection of the series suggests a structural break in the year 1989, the year of the intervention. We use the augmented Dickey-Fuller (ADF, 1979) test to test for stationarity of the series. We test for stationarity, under a structural break in 1989, and fail to reject stationarity at the 5% level of confidence.[13] Hence, we use the Top25 level series in estimating our model.

Table I. Descriptive Statistics

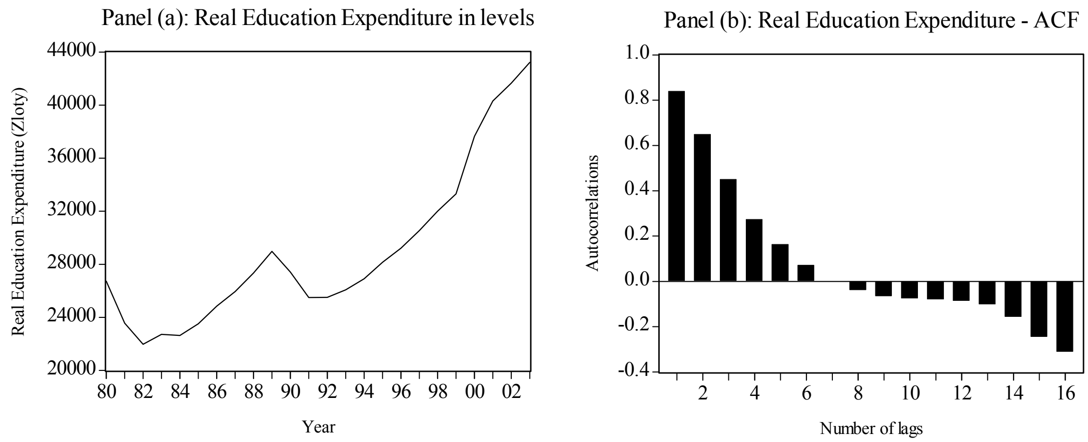
	Top25	Education	Real Income	RI - before 1991	RI - from 1991	Relative Pop	Infant Mortality
Mean	5.75	28989	541031	315	28989	0.54	16.53
Median	5	27127	15458	173	27127	0.35	17.75
Max	13	43222	2183998	1501.37	2183998	2.73	26
Min	1	21974	55	55.21	10393	-1.14	7.2
St. Dev.	3.34	6111.34	792593	422.54	842183	0.88	6.30

Figure 1. Top25 series



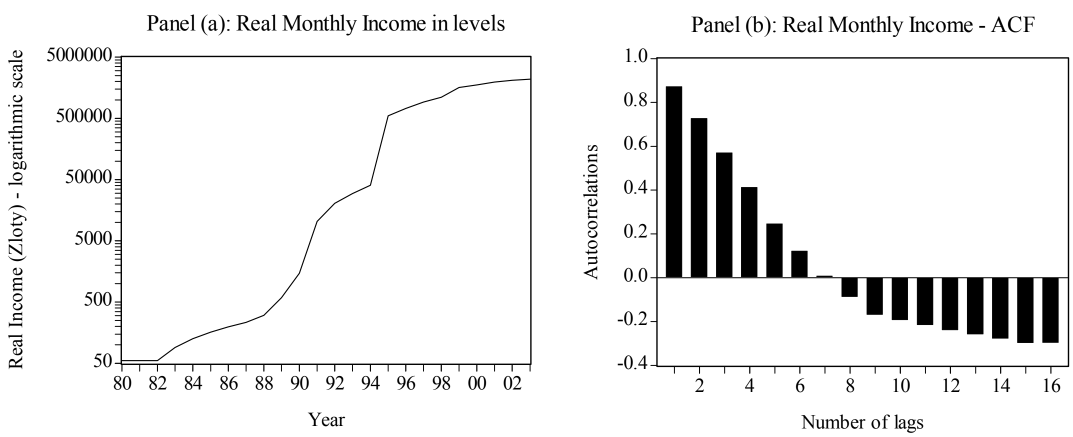
[12] See the Center for Global Development, Zakir and Wunnava (1999), etc.
[13] The ADF test statistic = -3.2189. The ACF of the series confirms this finding. Similar results obtain with a break in 1991 and 1996 (the 1996 break in subsequent sections is insignificant and hence, it is not reported).

Figure 2. Real Education Expenditure



The education expenditure series, shown in Figure 2, indicates a rising function, with a temporary decline in education expenditure between 1989 and 1992.[14] Our test for stationarity indicates that the series is first difference stationary.[15] Real average monthly income (at annual frequencies) is plotted in Figure 3. We use logarithmic scaling in the case of this variable given the large range of values that it takes over our sample. For this variable we include the descriptive statistics prior to 1991 and from 1991 onwards. There is a large increase in income starting in 1991; the increase in real income from 1990 to 1991 is approximately seven fold. Real income continues to rapidly increase over time; however it was largely stagnant from 1980 to 1990. This variable suggests that there is a structural break in 1991 due to the regime switch from communism; a chow break point test confirms this finding. A stationarity test with a break in 1991 shows that average real monthly income is first difference stationary.[16]

Figure 3. Real Average Monthly Income



The population growth rate of Poland relative to the 12 other countries is plotted in Figure 4. We test for stationarity in levels and find the test statistic to be –1.13 and –1.42 for

[14] This decline in education expenditure could be due to the transition from communism.
[15] This finding is based on the ADF test, Phillip-Perron (PP, 1988) test, as well as the ACF.
[16] The ADF and PP tests are -3.5201 and -3.2201 for the first difference test.

ADF and PP tests respectively. A unit root test in first difference yields a stationary series irrespective of the test used.[17] Lastly, infant mortality rate is plotted in Figure 5; the average level over our time period is 16.53 per 1000 with a standard deviation of 6.3. The ADF and PP test statistics for stationarity in levels are -1.7083 and -1.8748, thus the series is not stationary; additional test confirm that it is first difference stationary. Hence, when conducting our analysis we use Top25 series in levels, however all of our control variables are in first difference.

Figure 4. Relative Population Growth

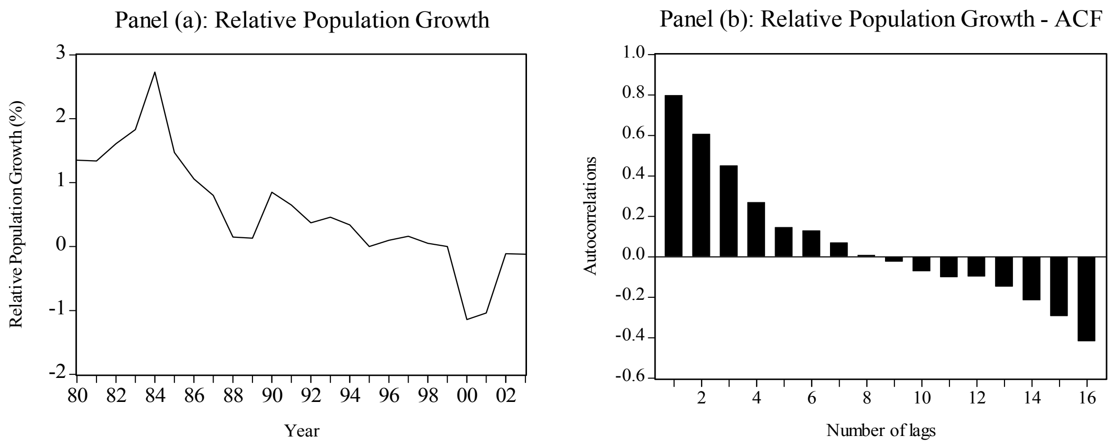
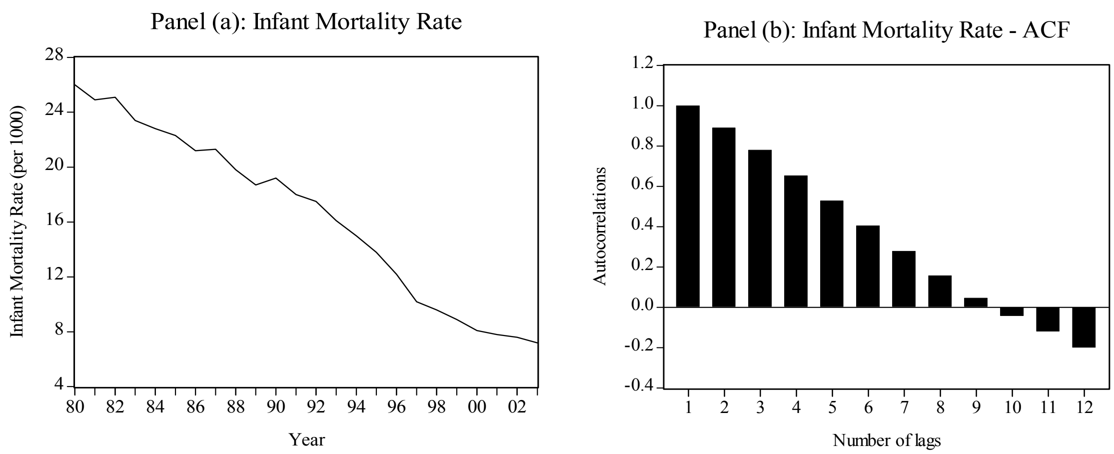


Figure 5. Infant Mortality Rate



4. Intervention Time Series Analysis

The next section presents the Autoregressive Moving Average (ARMA) time series model with a policy intervention dummy in 1989 and a dummy in 1991 to indicate the political regime switch – referred to as the Base model.[18] The impact of the policy intervention is evaluated on the basis of the pre-intervention mean, the immediate (short run) effect and the long run mean effect. All

[17] The t-stat for the ADF and PP test are –3.98 and –4.71.

[18] See Enders (1995) for a general presentation of this approach.

are a function of the estimated parameters and are common statistical tools used in this literature. Section 4.2 includes controls for education expenditure and real income, as it is possible that increases in both could have led to increases in swimming performance. Section 4.3 looks at the role of relative population, health (via the infant mortality rate), and seasonal effects.

4.1 The Base Model

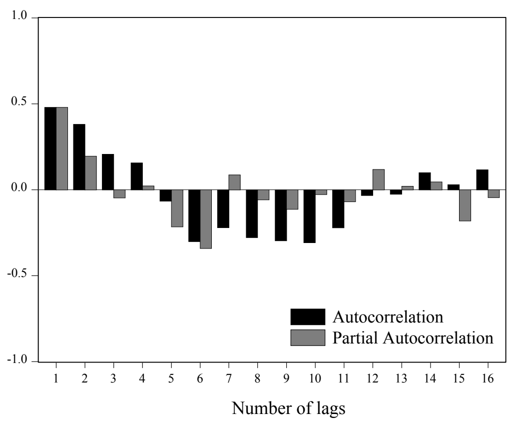
A general representation of the time series model used in this paper is an ARMA(p,q) model with a policy intervention term given by

$$\begin{aligned} \text{Top25t} \;=\; & \alpha_0 + \alpha_1 \text{Top25}_{t-1} + \alpha_2 \text{Top25}_{t-2} + \ldots + \alpha_p \text{Top25}_{t-p} \\ & + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots + \theta_q \varepsilon_{t-p} + \beta_1 \text{ID}_t + \beta_2 \text{RSD}_t + \varepsilon_t , \end{aligned} \tag{1}$$

where p and q are the order of the autoregressive and moving average processes respectively. Furthermore, Top25_t represents the number of Polish swimmers ranking in the Top 25 in any event in a given year; ID_t is the intervention variable that takes on the value of zero prior to 1989 and the value of one thereafter; RSD_t is the regime switch variable that indicates the movement from communism to a market economy – it takes on the value of 1 from 1991 on and value of zero prior to 1991; and ε_t is the error term, which is normally and independently distributed with mean zero and variance σ^2. Note that the coefficient β_1 measures the immediate impact of the intervention, while β_2 measures the immediate impact of the change in political regime.

We use the Box-Jenkins methodology to select the autoregressive and moving average components, p and q respectively.[19] Figure 4 shows the autocorrelation function (ACF) and partial autocorrelation function (PACF) of the Top25 series. A high first autocorrelation followed by a fast gradual decline and a high PAC at lag one also followed by a sharp fall suggests an AR(1) representation of the data.[20] However, the cyclical nature of the ACF and

Figure 4. Top25 - ACF and PACF



[19] The objective of the methodology proposed by Box and Jenkins (1970) is to approximate the true data generating process not to pin it down exactly. This is done in three steps: identification of p and q with the use of ACF and PACF, estimation of the ARMA model with parametric techniques, and diagnostic checking to determine the overall fit of the model. See Hamilton (1994) for details.

[20] Greene (1997) argues that a significant spike early on in the ACF indicates an AR component. Higher order seem to arise primarily in the form of non-stationary processes, which is not the case for the Top25 series.

PACF suggests a combination of AR and MA components, hence an ARMA(1,1), ARMA(1,2) and ARMA(2,1) specifications are also considered.[21] We estimate these four specifications as our starting point, although we do consider other specifications for completeness. The appropriate model specification is determined with the sum of squared residuals (SSR); the Akaike Information Criterion (AIC) and Schwarts Information Criterion (BIC) that measure the goodness of fit; and the Breusch Godrey (B-G) serial correlation LM test on the residuals.[22] Based on the aforementioned model selection criteria, we narrow down our search of the best model approximation to three possibilities. These include AR(1), ARMA(1,1) and ARMA(2,1) processes given by

$$\text{Top25t} = \alpha_0 + \alpha_1 \text{Top25}_{t-1} + \beta_1 \text{ID}_t + \beta_2 \text{RSD}_t + \varepsilon_t, \tag{2}$$

$$\text{Top25t} = \alpha_0 + \alpha_1 \text{Top25}_{t-1} + \theta_1 \varepsilon_{t-1} + \beta_1 \text{ID}_t + \beta_2 \text{RSD}_t + \varepsilon_t, \tag{3}$$

$$\text{Top25t} = \alpha_0 + \alpha_1 \text{Top25}_{t-1} + \alpha_2 \text{Top25}_{t-2} + \theta_1 \varepsilon_{t-1} + \beta_1 \text{ID}_t + \beta_2 \text{RSD}_t + \varepsilon_t, \tag{4}$$

respectively.[23]

A summary of the estimates of these three processes is shown in Table II. Clearly, the ARMA (1,1) model best fits the data due to the fact that the AIC is the lowest, as is the sum of squared residuals. The last column shows the results of the Breusch Godrey serial correlation LM test of serial correlation in the errors; the test indicates that serial correlation is rejected in all three models.[24] We find the intervention dummy variable to be significant, however the impact of the switch in regime is negative and insignificant.

Table II. Estimation Results – Base Model

Model	α_0	$Top25_{t-1}$	$Top25_{t-2}$	MA(1)	ID_t	RSD_t	SSR	AIC	B-G test
AR(1)	2.227	0.269	-	-	**4.75**	-1.706	140.23	4.99	0.066
	(1.862)	(1.085)			(1.956)	(-0.823)			(0.937)
ARMA(1,1)	3.88	-0.399	-	0.909	**7.16**	-0.657	126.08	4.95	0.048
	(1.901)	(-2.046)		(19.92)	(2.506)	(-0.236)			(0.953)
ARMA(2,1)	3.997	-0.363	0.116	0.904	**6.38**	-1.080	124.23	5.11	0.023
	(1.646)	(-1.599)	(0.335)	(16.70)	(1.946)	(-0.339)			(0.977)

Note: t-statistics are reported in parentheses, except in the case of the Breusch Godrey serial correlation LM test, where we report the p-value.

[21] Note that high order MA processes are relatively uncommon. Instead, we consider an AR and MA components, as the PACF and ACF do appear to have some AR and MA mix.
[22] SCI are not reported in the table, however they are very similar to the AIC and were used together with the AIC to narrow down the model specification. They are available upon request.
[23] The following processes were also considered: AR (2), AR (4), ARMA(1, (1,4)) and ARMA (2,(1,4)).
[24] The R^2 is also the highest at 0.5, and the Ljung-Box (1978) Q-statistics confirm that the residuals are white noise. These results are available upon request.

Table III shows the impact of the intervention under all three specifications for comparison purposes, however the best specification according to our criteria is the ARMA(1,1) model. First, we obtain the pre-intervention long-run mean of the Top25 series ($=\alpha_0/(1-\alpha_1)$). We find that prior to 1989 the mean number of Polish swimmers who ranked in the Top 25 equaled to 2.77 per year in the ARMA(1,1) model. Furthermore, the rise in HSCs in Poland had the immediate effect of increasing the number of Top 25 swimmers to 7.16.[25] This suggests that institutional specialization led to a rise in the number of Polish swimmers in the Top 25 ranking, thus increasing immediate competitiveness.

Next, we ask to what extent was the intervention permanent. The long-run effect of the intervention, given by $\beta_1/(1-\alpha_1)$ and is equal to the new long-run mean $(\alpha_0+\beta_1)/(1-\alpha_1)$ minus the pre-intervention long-run mean $\alpha_0/(1-\alpha_1)$; all are reported in Table III. With the new long-run mean equal to 7.89, the long-run impact (=5.12) of the intervention is approximately five additional swimmers in the Top 25 ranking.[26] Hence, we find that at the international level increasing the number of high-school centers specializing in swimming had a permanent positive effect on competitiveness.

Table III: Impact of Intervention - Base Model

	Pre-intervention Mean	New Long-Run Mean	Immediate Effect	Long-Run Effect
AR(1)	3.05	9.09	4.76	6.04
ARMA(1,1)	**2.77**	**7.89**	**7.16**	**5.12**
ARMA(2,1)	2.93	7.61	6.38	4.68

4.2 Controlling for Education Expenditure and Real Income

We modify the Base model by adding the change in education expenditure (EE) and the change in real income (RI) as explanatory variables. Hence, equation (1) becomes

$$\begin{aligned}\text{Top25t} \;=\; & \alpha_0 + \alpha_1\text{Top25}_{t-1} + \alpha_2\text{Top25}_{t-2} + \ldots + \alpha_p\text{Top25}_{t-p} \\ & + \theta_1\varepsilon_{t-1} + \theta_2\varepsilon_{t-2} + \ldots + \theta_q\varepsilon_{t-p} + \beta_1\text{ID}_t + \beta_2\text{RSD}_t + \gamma_2\Delta\text{EE}_t + \gamma_1\Delta\text{RI}_t + \varepsilon_t.\end{aligned} \tag{5}$$

The same method of model identification, estimation, and diagnostic checking is used as in section 4.1. The best three model specifications are reported in Table IV; in this case the ARMA(1,2) performs slightly better than the ARMA(2,1). We find the ARMA (1,1) model to best fit the data. It has low AIC and SIC, the estimates are more significant than the ARMA(1,2) model, and the B-G test indicates that the errors are white noise.[27] However, we do not find

[25] The immediate effect of the intervention is given by $\beta_1 = \Delta\text{Top25}_t / \Delta\,\text{ID}_t$.

[26] Since $\alpha_1 \in (-1,0]$, the intervention has a depressed oscillating effect on the Top25 series. Hence, after the initial increase of β_1=7.16 the successive values of the Top25 series oscillate above and below the long-run level of 5.12. See Enders (1995).

[27] The AIC for ARMA(1,1) and ARMA(1,2) are very close, however the estimates under the ARMA(1,1) specification are highly significant, thus making it a better model specification (See Enders, 1995). The Q-statistics from the Ljung-Box (1978) test (available upon request) confirm that the ARMA(1,1) residuals are white noise.

education expenditure or real income to be statistically significant in explaining the Top25 variable.

Table IV. Estimation Results - Controlling for Education Expenditure and Real Income

Model	α_0	$Top25_{t-1}$	MA(1)	MA(2)	ΔEDU	ΔRI	ID_t	RSD_t	AIC	B-G test
AR(1)	2.575	0.157	-	-	0.0003	-2.07E-06	**5.26**	-1.040	5.118	0.062
	(1.98)	(0.55)			(-0.74)	(-0.41)	(2.04)	(-0.45)		(0.81)
ARMA(1,1)	4.39	-0.473	0.909	-	0.0006	1.55E-07	**7.81**	-0.780	5.056	0.015
	(2.08)	(-2.21)	(16.27)		(-1.11)	(0.06)	(2.64)	(-0.26)		(0.90)
ARMA(1,2)	1.694	0.422	-0.587	-0.336	0.0001	-7.32E-06	**5.56**	-1.872	5.004	0.095
	(0.80)	(0.89)	(-1.07)	(-0.69)	(-0.14)	(-1.44)	(2.24)	(-0.73)		(0.76)

Note: the SSR for the three models are 133.40, 115.02 and 110.09 respectively.

The short-run and the long-run results of the intervention model with education expenditure and real income as explanatory variables are reported in Table V. We find real income to be insignificant, while education expenditure is only significant at the 15% level of confidence. Nevertheless, the results in Table V for the ARMA(1,1) model are similar to the results obtained in section 4.2. We still find the immediate impact of the policy to be high (7.31 vs. 7.16 without controls). Similarly, the long run effect remains high at 5.3 (compared to 5.12 without controls).

Table V: Impact of Intervention – Controlling for Education Expenditure and Real Income

	Pre-intervention Mean	New Long-Run Mean	Immediate Effect	Long-Run Effect
AR(1)	3.06	9.29	5.26	6.23
ARMA(1,1)	**2.98**	**8.28**	**7.81**	**5.30**
ARMA(1,2)	2.93	7.25	5.56	4.32

4.3 Role of Population Growth, Health and Seasonal Effects

First, we consider the importance of relative population growth. A simple comparison between population growth in Poland and that of 12 other countries dominating the Top 25 ranking as a whole shows that between 1980 and 1986 Poland had an average population growth rate that was higher than that of the 12 other countries, but during 1987 and 2003 the average population growth rate of Poland slowed down substantially, falling below that of the other 12 countries. Specifically, between 1980 and 1997 the Polish population grew at an annual rate of less than

1%, falling approximately to 0% for the next two years, and then turning negative during 1999-2003. In contrast, the group of 12 countries had an average population growth rate of less than 1% the entire sample period. Perhaps the more significant indicator is the fact that the average growth rates between 1990 and 2003 (after the intervention) were 0.07% in Poland and 0.57% in the group of 12 countries. Thus, it is unlikely that relative population growth was the cause of the improvement in performance.

Infant mortality rate in Poland has fallen steadily over time, thus suggesting improvements in health care services/practices and socioeconomic conditions, and a overall improvement in health status. Moreover, infant mortality rates in Poland over this time period have caught up with the mortality rates in western countries, which would indicate a general improvement in health of the population.[28] The improvement in health could contribute to the improvement in sport performance.

With additional controls our model is now modified as follows

$$\begin{aligned}\text{Top25t} \;=\; & \alpha_0 + \alpha_1 \text{Top25}_{t-1} + \alpha_2 \text{Top25}_{t-2} + \ldots + \alpha_p \text{Top25}_{t-p} \\ & + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots + \theta_q \varepsilon_{t-p} + \beta_1 \text{ID}_t + \beta_2 \text{RSD}_t + \gamma \Delta X_t + \varepsilon_t,\end{aligned} \tag{6}$$

where the X_t is a matrix containing all control variables and γ is the vector of estimators.

Several processes were considered. We found that relative population growth was insignificant in all our models, with our results being largely unchanged. For this reason we do not report the results containing relative population growth. Incorporating infant mortality rate (IMR), education expenditure and real income led to an ARMA(1,1) model using the selection criteria as above. The results are reported in Table VI, row one. We found only education expenditure to be slightly significant.[29]

Table VI. Estimation Results - Additional Analysis

Model	α_0	Top25_{t-1}	MA(1)	MA(2)	ΔEDU	ΔRI	ΔIMR	ID_t	RSD_t	AIC	B-G test
ARMA(1,1)	4.68	-0.611	1.608	-	0.0007	-3.91E-07	0.042	**8.07**	-0.488	4.35	0.007
	(2.39)	(-2.134)	(3.871)		(-1.458)	(-0.095)	(0.695)	(2.45)	(-0.16)		(0.932)
ARMA(1,2)	5.57	-0.440	1.138	0.984	-	-	0.617	**4.35**	1.488	4.77	0.005
	(2.07)	(-2.125)	(36.64)	(19.06)			(1.146)	(2.04)	(0.56)		(0.947)

Note: The SSR for the two models is 52.15 and 87.19.

The impact of the intervention given the estimates under the ARMA(1,1) specification are summaries in Table VII, row 1. We again find the long run effect of the intervention to be

[28] US infant mortality rates in 1980 and 2003 were at 13 and 7 respectively; in Germany these were 13 and 4. Source: The World Bank.

[29] Note that the adjusted R^2 in this model was 0.65; we found the adjusted R^2 in all our other model specifications to be between 0.4 and 0.55.

approximately five additional swimmers in the Top 25 ranking. The results are thus consistent with our earlier findings in section 4.1 and 4.2.

Table VII: Impact of Intervention – Additional Analysis

	Pre-intervention Mean	New Long-Run Mean	Immediate Effect	Long-Run Effect
ARMA(1,1)	**2.91**	**7.92**	**8.07**	**5.16**

Lastly, we considered infant mortality rate alone. These results are reported in row 2 of Table VI and show that health has a positive effect on performance; however this effect is not significant at conventional levels. Although the model does not perform as well as the ARMA(1,1) model (Table VI, row 1), it does suggest that a better proxy of health status of Polish swimmers could be a significant factor in determining performance. Interestingly, this is the only model out of all the specifications we considered in this paper wherein the switch from communism has a positive effect on performance (although it is still insignificant). Overall, we do not find the regime switch to be important; however it is possible that a transitional structural break would perform better if it was possible to have such a structural break dummy in the model.

Lastly, we consider the role of a seasonal effect. It is a frequent planning strategy in competitive swimming to base planning cycles on a four-year rotation. The quadrennial planning refers specifically to the time between Olympic Games. It is very common for competitive swimmers to retire en mass following the Olympic Games. If the rate of retirement from competitive swimming is approximately the same across countries, then we would expect there to be no seasonal effect. However, if competitive swimmers in Poland, on average, have fewer/more incentives to remain in competitive swimming than swimmers in other countries, then there should be a presence of seasonal effects.[30] Accounting for seasonal effect in our model implies incorporating the moving average component at lag 4, hence estimating θ_4. However, our results do not support a quadrennial effect as we do not find θ_4 to be significant in any of our models.

Overall, our analysis indicates that the establishment of high-school swim centers in Poland had a desired effect of increasing swimming performance as measured by the increase in the number of swimmers in the Top 25 ranking. Our results indicate that this had not only a short term effect but a long term effect as well, with approximately an average of five additional swimmers ranking in the Top 25 in all events annually.

5. Discussion and Conclusion

In this paper, we analyze the impact of establishing high-school swim centers on the competitiveness of Polish swimmers. We use an intervention ARMA time series model to evaluate the impact of this permanent institutional policy change on performance. Our results show that establishing four of these specialization centers across Poland had a positive and statistically significant effect on competitiveness of Polish swimmers in the international arena.

[30] Some of the incentives, for example, include scholarships, performance bonuses, or funds paid to carded athletes.

We find that while education expenditure is slightly significant in our models, real income and relative population growth remain insignificant. In the case of health, infant mortality rate is only slightly significant when used as the only control, however once we control for education expenditure and real income, it is no longer significant. We also find that the switch to communism is largely insignificant in our analysis. Lastly, it is important to note that our results are based on the Top 25 ranking; hence our findings with respect to competitiveness are dependent on this measure. Overall, we find that the intervention had a positive long term effect on swimming competitiveness.

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