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Economic Prediction of Medal Wins at the 2014 Winter Olympics

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Abstract

This paper uses forecasting techniques to predict outcomes at the 2014 Winter Olympics using economic variables.

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ECONOMIC PREDICTION OF MEDAL WINS AT THE 2014 WINTER OLYMPICS

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To the best of our knowledge nobody has attempted to elaborate on an economic model for predicting medal wins at Winter Olympics so far. This contrasts with Summer Olympics for which about thirty studies have estimated economic determinants of sporting performances. Namely, it has been empirically verified that the number of medals a country can make at Summer Olympics significantly depends on its population and GDP per inhabitant (Andreff, 2001). On the other hand, in the past decade, a number of papers have started to provide economic predictions of medal distribution per country at the next Olympic Games (Bernard, 2008; Bernard & Busse, 2004; Hawksworth, 2008; Johnson & Ali, 2004; Johnson & Ali, 2008; Maennig & Wellebrock, 2008; Wang & Jiang, 2008). Our own model has exactly predicted 70% of medal wins at the 2008 Beijing Olympics and correctly (with a small error margin) 88% of the sporting outcomes at these Games (Andreff *et al.*, 2008 & Andreff, 2010). Although the dependent variable is the same – the number of medals won by each participating nation -, some independent variables have to be kept for the Winter Games whereas some new variables must be introduced to capture the specificity of Winter Olympic sports disciplines. In this paper, we would take stake of the good predictions achieved with our model for Summer Olympics to adapt it in view of forecasting the distribution of medal wins per nation at the 2014 Sochi Winter Games.

We start with briefly reminding the most interesting methodologies at work in estimating Summer Olympics medal distribution (**1**). Then we show how our own model has resolved the issue (**2).** The model is used to predict how many medals each nation would obtain at the 2008 Olympics and our prediction is compared to actual outcomes of different nations in Beijing, a comparison which is absolutely rare in the literature so far (**3**). A brief discussion

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provides a justification for keeping some similar variables in a model attempting to estimate the determinants of medals distribution at Winter Olympics and to introduce some new variables that fit better with explaining winter sports performance; the discussion comes out with a somewhat different model (**4**). The latter is estimated with data about Winter Olympic Games from 1964 up to 2010 (**5**). The estimated model is then used to predict the medal distribution across participating nations at the 2014 Sochi Winter Olympics with a focus on the performance of Russia, CIS and Central and Eastern European countries – CEECs (**6**). A conclusion reminds the reader that all such predictions are to be taken with a pinch of salt (**7**).

1. Economic determinants of Olympic medals

A widespread assumption across sports economists is that a nation's Olympic performance must be determined by its endowment in economic and human resources and the development of these resources. Thus, the starting point of most studies about economic determinants of Olympic medals consists in regressing a nation's medal wins on its level of GDP per capita and population. Note that the growth in medal wins by one country logically is an equivalent decrease in medals won by all other nations participating to the Olympics. Therefore, if one wants to understand the Olympic performance of one specific nation, one has to take into account all other participating nations within the overall constraint of the allocated medals total during this year's Olympics.

In the first papers about the economic determinants of Olympic performance, such as GDP per capita and population, these variables were combined with weather, nutrition, and mortality in the athlete's home nation. Later on, in various studies up to the 1970s, other variables had been considered as possible determinants of Olympic medal wins: protein consumption, religion, colonial past, newspapers supply, urban population, life expectancy, geographical surface area, military expenditures, judicial system and those sport disciplines taught at school. However, with the cold war period, another very significant variable emerged: a nation's political regime. The first Western work attempting to explain medal wins by the political regime of nations (Ball, 1972) immediately triggered a Soviet rejoinder (Novikov & Maximenko, 1972), both differentiating capitalist and communist regimes. The first two *econometric* analyses of Olympic Games (Grimes *et al.*, 1974; Levine, 1974) exhibited that communist countries were outliers in regressing medal wins on GDP per capita and population: they were winning more medals than their level of economic development and population were likely to predict. A last variable has been introduced, namely since

Clarke (2000), which is the influence on medal wins of being the Olympics hosting country. The host gains more medals than otherwise due to big crowds of national fans, a stronger national athletes' motivation when competing on their home ground and being adapted to local weather, and not tired by a long pre-Games travel.

More sophisticated econometric methodology has been used in more recent articles that predicted Olympic medal wins, such as an ordered Logit model (Andreff, 2001), a Probit model (Nevill *et al.*, 2002) or an ordered Probit model (Johnson and Ali, 2004). The most quoted reference is Bernard and Busse (2004) whose Tobit model has been assessed as the most performing one and then used by Jiang and Xu (2005), Pfau (2006) and others. Bernard and Busse's model is now considered as the best achieved economic model for estimating and predicting Olympic performance, in which two major independent variables do explain the great bulk of medal distribution across participating countries: GDP per capita and population. Three dummy variables capture a host country effect, the influence of belonging to Soviet-type and other communist (and post-Soviet and post-communist after 1990) countries as against being a non communist market economy. Such dummies are supposed to capture the impact of political regime on medal wins.

2. Countries' sport performances at Summer Olympics: estimation of their determinants

Starting from Bernard and Busse, we have elaborated on a more specified model (Andreff *et al.*, 2008) with a few improving emendations. The dependent variable is the number of medal wins[4] by each nation: $M_{i,t}$. Our first two explanatory variables are GDP per inhabitant in purchasing power parity dollars (PPP $) and population. Both variables are four-year lagged (t-4) under the assumption that four years are required to build up, train, prepare and make an Olympic team the most competitive in due time, four years later. That is, for explaining medal wins in 2008, we take the 2004 GDP per capita and population as estimators. A *Host* dummy variable is used to capture the host country effect, *i.e.* the observed surplus of medals usually won by the national squad of the Games hosting nation.

Our first emendation to Bernard and Busse's model regards the political regime variable: Bernard and Busse rather crudely divide the world into communist regimes and capitalist market economies which obviously fits with the cold war period. Since then, this is too crude

[4] Bernard and Busse use the percentage of medal wins by each country i for $M_{i,t}$ instead. Our regressions are calculated with both the absolute number of medals (Table 1) and the percentage of medals per country, and the results are not significantly different.

when it comes to the so-called post-communist transition economies (Andreff, 2004 & 2007) in particular with regards to the sports economy sector which has differentiated a lot across former socialist countries during their institutional transformation process (Poupaux and Andreff, 2007). Such differentiation has translated into a scattered efficiency in winning Olympic medals after 1991 (Rathke & Woitek, 2008).

Our classification distinguishes first Central Eastern European countries (*CEEC*) which have left a Soviet-type centrally planned economy in 1989 or 1990, and transformed into a democratic political regime running a market economy: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia (and Czechoslovakia until the 1993 split), Slovenia, and the GDR (until German reunification in 1990). Another commonality to this group is that these countries have all joined the European Union in 2004 or 2007. A second country group (*TRANS*) gathers new independent states (former Soviet republics) and some former CMEA member states which have started up a process of transition similar to the one in CEECs but are lagging behind in terms of transformation into a democratic regime and some are stalling on the path toward a market economy: Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Mongolia, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan and Vietnam. None of them has joined the EU so far or has really an option to do so. The two next groups have not been Soviet regimes properly speaking in the past, although they have been both communist regimes and planned economies. In the first one (*NSCOM*), we sample those countries which have started up a transition process in the 1990s: Albania, Bosnia-Herzegovina, China, Croatia, Laos, Macedonia, Montenegro, and Serbia (and the former FSR Yugoslavia before the 1991 breakup). Two countries have not yet engaged into a democratic transformation and a market economy: Cuba and North Korea, and must be considered as still communist regimes (*COM*). All other countries are regarded as capitalist market economies (*CAPME*), the reference group in our estimations.

Then we have introduced a last variable that captures the influence on Olympic performance of a specific sporting culture in a region. For example, Afghan ladies are not used to have much sport participation or to attend sport shows, even less to be enrolled in the Olympic team. As a result of these cultural (sometimes institutional) disparities, some nations are more specialised in one specific sport discipline such as weight-lifting in Bulgaria, Turkey and Armenia, marathon and long distance runs in Ethiopia and Kenya, cycling in Belgium and the Netherlands, table tennis, judo and martial arts in Asia, sprint in Caribbean islands and the U.S., etc. It is not easy to design a variable that would exactly capture such regional sporting culture differences[5], but we have considered that regional dummies may reflect them. For model estimation, we divide the world into nine "sporting culture" regions: *AFS*, sub-Sahara African countries; *AFN*: North African countries; *NAM*, North American countries; *LSA*, Latin and South American countries; *EAST*, Eastern European countries; *WEU*, Western European countries (taken as the reference region in our estimation); *OCE*, Oceania countries; *MNE*, Middle East countries; and *ASI*, (other) Asian countries.

Our first model is simply a specification *à la* Bernard and Busse, but with a differently defined political regime variable. Our estimation is based on a censored Tobit model since a non negligible number of countries that participate to the Olympics do not win any medal. Therefore, a zero value of the $M_{i,t}$ dependent variable does not mean that a country has not participated and we work out a simple Tobit, not a Tobit 2 (with a two stage Heckman procedure). Contrary to Bernard and Busse, we do not assume that preparing an Olympic team is timeless and, then, independent variables are four-year lagged behind the dependent variable. Thus, GDP per inhabitant is noted $(Y/N)_{i,t-4}$, measured in 1995 PPP dollars, and $N_{i,t-4}$ stands for population. Dummies are introduced to test whether the Olympic year is significant, taking 2004 as the reference. These dummies come out to be non significant. In a second model, we adopt a data panel Tobit, in order to take into account unobserved heterogeneity, whose test is significant[6], and then we opt for estimation with random effects. Our data[7] encompass all Summer Olympics from 1976 to 2004, except 1980 and 1984 which are skipped out due to boycotts which have distorted the medal distribution per country. Our first specification (**1**) is:

$$M^*_{i,t} = c + \alpha \ln N_{i,t-4} + \beta \ln\left(\frac{Y}{N}\right)_{i,t-4} + \gamma\, Host_{i,t} + \sum_p \delta_p\; Political\, Regime_{p,i} + \sum_q \kappa_q\, Year_{q,i} + \varepsilon_{i,t}$$

where $\varepsilon_{i,t} \sim N(0,\sigma^2)$

$M_{i,t}$ observation is defined by $M_{i,t} = \begin{cases} M^*_{i,t} \; if \;\; M^*_{i,t} > 0 \\ 0 \;\; if \;\; M^*_{i,t} \leq 0 \end{cases}$

[5] Hoffmann *et al.* (2002) consider that an important determinant of Olympic successes lies in the degree to which sport and sporting activities are embedded in a nation's culture. The proxy used to capture such determinant is the total number of times a country has hosted Olympic Summer Games between 1946 and 1998. Our regional variable does not intend to capture only a nation's sporting culture but how much it is specific (different from the one of nations located in a different geographical area).

[6] A test of maximum likelihood shows that the rho coefficient is significant (*Pr = 0.00*).

[7] Our data panel is not balanced since the number of existing countries in the world has increased between 1976 and 2004, namely due to the breakup of the former Soviet Union, former Yugoslavia and former Czechoslovakia (+ 20 countries), only partly compensated by the re-unification of Germany and Yemen (- 2 countries).

Our second specification (**2**) is an emended variant of Bernard and Busse model, including our more specific political regime variable, but also the above described dummies standing for regions of sporting culture ($Region_{r,i}$):

$$M^*_{i,t} = c + \alpha \ln N_{i,t-4} + \beta \ln\left(\frac{Y}{N}\right)_{i,t-4} + \gamma\, Host_{i,t} + \sum_p \delta_p\ Political\,Regime_{p,i}$$
$$+ \sum_r \rho_r\ Regions_{r,i} + u_i + \varepsilon_{i,t}$$

where $\varepsilon_{i,t} \sim N(0,\sigma^2_\varepsilon)$ and $u_i \sim N(0,\sigma^2_u)$

$M_{i,t}$ observation is defined by $M_{i,t} = \begin{cases} M^*_{i,t} & if \quad M^*_{i,t} > 0 \\ 0 & if \quad M^*_{i,t} \le 0 \end{cases}$

In a third specification (**3**), the one used for prediction, we have introduced an additional variable $M_{i,t-4}$ on the right-hand side of model (**2**), just like Bernard and Busse who do not comment why they proceed in such a way. Our idea is that winning medals at the previous Olympics matters for an Olympic national team which usually expects and attempts to achieve at least as well as four years ago. Such inertial effect is all the more relevant for a nation eager to win as many medals as possible from one Olympiad to the other (a national 'Olympics cult'[8]) and mobilise a lot of resources to succeed in. The resulting inertia differentiates those nations pulled by Olympics cult from those nations which are used to win zero or few medals. These two groups must be distinguished with using $M_{i,t-4}$ otherwise the prediction will be distorted.

Table 1 – Tobit estimation of medals won at Summer Olympics

Independent variables	Tobit Model 1	Tobit (panel) Model 2	Tobit Model 3 with lagged *M*
Log population (t-4)	9,14***	4,15***	2,15***
Log GDP per capita (t-4)	12,42***	5,44***	2,73***
Host	24,37***	10,40***	10,04***
Political Regime (ref. CAPME)			
COM	24,34***	11,18***	5,76**
TRANS	23,24***	20,97***	8,15***
CEEC	21,43***	17,94***	6,71**
NSCOM	11,98***	8,06***	5,22*
Region (ref. WEU)			
AFN		-4,45*	-1,81

[8] Which has been fuelled in particular by the cold war, but it has not vanished yet in a number of countries.

AFS		3,67*	0,75
NAM		7,93***	0,076
LSA		0,57	-1,08
ASI		-4,34***	-2,58*
EAST		-5,53*	-3,5
MNE		-5,00***	-2,47*
OCE		6,277**	1,3
Year dummy (ref. 2004)			
1976	4,63		
1988	-0,2		
1992	3,33		
1996	3,35		
2000	0,31		
Medals (t-4)			0,95***
Constant	-138***	'-51,30***	-31,57***
Number of observations	941	941	831
Log-likelihood value	-1646,1	-1551,5	-1224,2
Pseudo R2	0,17	0,19	0,34

*** Significant at 1% threshold; ** at 5%; * at 10%.

Source: Andreff *et al.*, 2008.

All our estimations deliver significant results (Table 1). In the first estimation, all coefficients are positive and significant at a 1% threshold, except for year dummies. Thus, it is once again confirmed that medal wins are determined by GDP per capita, population and a host country effect. Political regime is also an explanatory variable, in particular in the case of communist and post-communist transition countries. Our second estimation (Tobit/panel) all in all exhibits the same results. The coefficients of regional sporting culture are significant except for Latin America, an area in which the North American sporting culture may have permeated namely through Caribbean countries and Mexico (classified in *NAM*).

Since Western Europe is the reference a significant coefficient with a positive sign means that a region performs relatively better than Western Europe in terms of Olympic medals (a negative sign means a lower relative performance than Western Europe). Sub-Sahara Africa, North America and Oceania perform better. It is a little bit surprising for Sub-Sahara African countries since they are among the least developed in the world (except South Africa), but such effect is due to a few African countries which are extremely specialised in one sport discipline where they are capable to win a non negligible number of medals, such as Ethiopia and Kenya in long distance runs. With negative coefficients, North Africa, Asia, Eastern Europe and Middle East show a lower relative performance than Western Europe. It is not surprising for North Africa and the Middle East due to some restrictions to sporting culture in various countries. In the case of Asia, only few countries are capable to win a significant number of medals (China, both Koreas, Mongolia) given their GDP per capita. A surprise is a negative coefficient of Eastern European countries which are known as outliers or over-performers (given their GDP per capita and population). In fact, the negative coefficient results from the variable *Political Regime* which already captures their over-performance.

3. Predicting medal wins at Beijing Olympics: comparison with observed outcomes

Then, our model (**3**) is used to predict medal distribution at the 2008 Beijing Olympics:

$$M^*_{i,t} = c + \alpha \ln N_{i,t-4} + \beta \ln\left(\frac{Y}{N}\right)_{i,t-4} + \gamma\, Host_{i,t} + \sum_p \delta_p\ Political\,Regime_{p,i} + \sum_r \rho_r\ Regions_{r,i} + \theta\ M_{i,t-4} + \varepsilon_{i,t}$$

where $\varepsilon_{i,t} \sim N(0,\sigma^2)$

$M_{i,t}$ observation is defined by $M_{i,t} = \begin{cases} M^*_{i,t} \ if \ \ M^*_{i,t} > 0 \\ 0 \ \ if \ \ M^*_{i,t} \leq 0 \end{cases}$

Since we use here a pooling estimation[9] of Model 3, it may suffer from an endogeneity bias and the results may be biased by a correlation between the lagged endogenous variable and the error term. We have treated this issue with a dynamic panel GMM (Arellano & Bond, 1991). This technique provides estimated coefficients and predictions that are robust and close to those estimated with a Tobit model. Our predictions are published (Andreff *et al.*, 2008) only for a sub-sample of countries[10] gathered in Table 2.

Table 2 – Prediction of medal wins at Beijing Olympics

	Medals won in 2004	Médial wins predicted in 2008	Lower bound	Upper bound
CEEC:				
Bulgaria	12	12	10	13
Hungary	17	19	17	21
Poland	10	14	12	16
Czech Republic	8	10	8	12

[9] A test of maximum likelihood shows that the rho coefficient is not significant (*Pr = 0.26*) which allows to choose a pooling estimation.
[10] Result for any other country is available on request addressed to the authors.

Romania	19	21	19	23
TRANS:				
Belarus	15	17	14	20
Kazakhstan	8	11	8	14
Russia	92	96	93	100
Ukraine	23	27	24	29
NSCOM				
China	63	80	73	86
Cuba	27	29	25	33
CAPME:				
Germany	49	52	50	54
Australia	49	51	47	54
Canada	12	15	13	18
United States	102	106	103	110
France	33	36	35	38
Great Britain	30	47	32	35
Italy	32	35	34	36
Less developed countries				
Brazil	10	12	10	14
South Korea	30	30	27	32
Kenya	7	2	1	4
Jamaica	5	11	0	4
Turkey	10	9	7	11

Source: Andreff *et al.*, 2008.

The first-ranked predicted winner is, as usual, the United States, followed by Russia and China, which benefits from a host country effect. Most developed and democratic market economies (CAPME) are predicted to be among the major medal winners together with some pot-communist transition countries. Our forecast for France was between 35 and 38 medals while the State Secretary for Sports was hoping that the national team would reach 40.

The publication of our article in French (Andreff *et al.*, 2008) one month before the opening of Beijing Olympics rapidly became a hit in different French and European media and TV channels. First interviews asked to focus on our prediction. In a second wave, after the Games end, all interviewers became eager to know for which countries the model had provided a correct or a wrong prediction and, in the latter case, why were it so. This triggered the writing of a follow up companion paper requested by the French National Institute for Sport and Physical Education (INSEP) to be included in its volume devoted to the overall outcome of Beijing Olympics for France (Andreff, 2009).

Our model provided good predictions regarding those 189 countries for which data were available and computable: 70% of the observed results are included in our predicted confidence interval. If one assesses our model prediction as acceptable when its error margin is not bigger than a two-medal difference between prevision and reality, then it correctly predicts 88% of all Beijing results. The remaining unexplained 12% (23 nations) account for sporting "surprises" – unexpected results. The model correctly predicts the first ten medal winners, except Japan (instead of Ukraine), misses only four out of the first twenty winners, although with a slightly different ranking. However, the most interesting results are witnessed when the model is clearly wrong in its prediction that is basically for 23 countries, because it means that our five variables (plus the inertial variable) have not captured some core explanation of the Olympics outcome. Fortunately, economists are not capable to predict all the detailed Olympic results, otherwise why still convene the Games?

Which are the major "surprises" delivered by actual results when compared with our predictions? The first one is the quite bigger than expected medal wins by the Chinese team – all published predictions have been wrong in this respect. Our model has clearly underestimated the host country effect in China. Possibly, Chinese performance has also been boosted by some undetected doping[11]. The second surprise is the underperformance of the Russian Olympic team, the worst since the cold war. It was regarded so much "catastrophic" that Mr. Putin convened the highest decision makers of Russian sport to command a new Olympic policy likely to avoid a repeated disaster at the 2012 London Olympics. In the same vein, some other transition countries, namely Romania, have won fewer medals than expected in Beijing. The current state of reforming institutions and restructuring the whole sports sector in these countries (Poupaux and Andreff, 2007) has not been sufficiently captured in our model, despite our more refined political regime variable.

The last three significant surprises are Great Britain, Jamaica and Kenya, the latter being the only two developing countries ranked among the first twenty medal winners. Early preparation of a super-competitive team for the 2012 London Olympics may have been the cause for higher than expected outcomes of the British team, as it is suggested by Maennig and Wellebrock (2008) who have introduced a "next Olympics host country" variable in their prediction. However, such future host country effect does not improve very much the authors' forecast: 38 predicted medals as against 47 won by Great Britain. Without such effect our own model predicted between 32 and 35 medals for Great Britain. The British medals

[11] This issue is discussed in depth in Andreff *et al.* (2008) explaining why we had not been able to integrate doping among independent variables despite the fact that we wished to do so.

concentration in cycling (12 medals) may trace back again to undetected doping and/or deep specialisation of a nation in one sport discipline. The latter is the most likely explanation for Jamaican medals[12] concentrated in sprint and Kenyan medals in long distance runs. Though we have taken into account such specialisation through our lagged $M_{i,t-4}$ variable – Kenya had won 7 medals and Jamaica 5 in the same disciplines at Athens Olympics -, the inertia captured with this variable reveals to be insufficient.

4. A model adapted to estimating the determinants of medal wins at Winter Olympics

The context of Winter Olympics is rather different from the one of Summer Olympics. In 1976, 92 countries had participated to Summer Olympics with 6,084 athletes while they were only 37 countries participating to Winter Olympics the same year, with 1,123 athletes (Table 3). In 2004, 201 countries were participating to Athens Olympics with 10,658 athletes whereas 80 countries had participated to the 2006 Winter Games in Turin with 2,651 athletes. From a global economic standpoint, Winter Olympics is a rather small sports mega-event compared to Summer Olympic Games. However, the former has grown a lot during the span of time covered in this paper. The number of participating countries has increased from 36 in 1964 up to 82 in 2010 while the number of athletes has augmented from 1,091 to 2,629. The number of medals to be won at Winter Olympics is smaller than the one observed at Summer Olympic Games (over 900 overall since 2000): it has grown from 103 in 1964 up to 258 in 2010. When it comes to the number of nations having won at least one Olympic medal, it has increased from 14 in 1964 to 26 in 2010 (as against a maximum of 80 countries at the 2000 Summer Games).

Table 3 - Winter Olympic performances, 1964-2010

City	Year	Participating countries	Countries with M > 0	Overall number of medals	Participating athletes
Innsbruck	1964	36	14	103	1091
Grenoble	1968	37	15	106	1171
Sapporo	1972	35	17	105	1008
Innsbruck	1976	37	16	111	1123
Lake Placid	1980	37	19	115	1072

[12] Some Jamaican sprint finalists have been controlled positive in doping tests during the weeks after the Beijing Games, which may be another explanatory variable.

Sarajevo	1984	48	17	117	1279
Calgary	1988	57	17	138	1424
Albertville	1992	63	20	171	1772
Lillehammer	1994	67	22	183	1747
Nagano	1998	72	24	205	2176
Salt Lake City	2002	77	24	234	2386
Turin	2006	80	26	252	2651
Vancouver	2010	82	26	258	2629

Source: IOC.

Since population, GDP per inhabitant and the host country dummy variable have emerged as basic determinants of medal wins at Summer Olympics, we keep them in the model for Winter Olympics. Keeping GDP per capita in the model is particularly sensible because it is nearly obvious from Table 4 that there is a relationship between the number of medal wins and the level of economic development. In Table 4, country groups are those defined by the World Bank. Developed market economies (DMEs) are countries with a GDP per inhabitant over 10,725$ in 2006; (newly) emerging economies (NMEs) are countries whose GDP per inhabitant is between 3,466$ and 10,725$; intermediary income (developing) countries (IICs) are those with a GDP per inhabitant between 876$ and 3,465$; least developed countries (LDCs) are those with a GDP per inhabitant below 876$. At Winter Olympic Games, one witness a concentration of medal wins on DMEs whatever the number of participating DMEs. The mean number of medal wins is always higher in the DME and NME groups than in IICs and LDCs. Even with a growing number of participating countries – from 4 in 1964 to 20 in 2010 for IICs and from 3 to 13 for LDCs – these two country groups are not able to substantially increase their share in the medals total. In most Winter Games, LDCs have not won even a medal (except in 1992 and 1994 with just one medal win).

Table 4 - Uneven medal distribution by level of economic development

Year	Country group	Number of medals	Mean: m	Coefficient of variation: σ/m	Number of countries	Countries with M > 0
1964	DME	77	3.67	1.27	21	12
	NEC	26	3.25	2.71	8	2
	IIC	0	0	0.00	4	0
	LDC	0	0	0.00	3	0
1968	DME	83	3,95	1.13	21	11
	NEC	23	2,56	1.70	9	4
	IIC	0	0	0.00	5	0

	LDC	0	0	0.00	2	0
1972	DME	71	3,38	1.12	21	13
	NEC	34	4,25	1.58	8	4
	IIC	0	0	0.00	4	0
	LDC	0	0	0.00	2	0
1976	DME	64	2,67	1.26	24	13
	NEC	47	5,22	1.97	9	3
	IIC	0	0	0.00	4	0
	LDC	0	0	0.00	0	0
1980	DME	67	2,91	1.24	23	14
	NEC	47	5,22	1.88	9	4
	IIC	1	0,25	2.00	4	1
	LDC	0	0	0.00	1	0
1984	DME	61	2,26	1.54	27	13
	NEC	55	5	1.96	11	3
	IIC	1	0,17	2.41	6	1
	LDC	0	0	0.00	4	0
1988	DME	78	2,44	1.56	32	13
	NEC	57	5,18	2.10	11	3
	IIC	3	0,3	3.17	10	1
	LDC	0	0	0.00	4	0
1992	DME	141	4,41	1.58	32	16
	NEC	26	1,86	3.30	14	2
	IIC	3	0,25	3.48	12	1
	LDC	1	0,2	2.25	5	1
1994	DME	149	4,52	1.58	33	16
	NEC	23	1,44	3.99	16	1
	IIC	10	1,67	0.76	12	4
	LDC	1	0,83	0.49	6	1
1998	DME	170	5,15	1.50	33	17
	NEC	21	1,4	3.33	15	2
	IIC	14	0,67	3.03	16	5
	LDC	0	0	0.00	8	0
2002	DME	197	5,97	1.64	33	16
	NEC	25	1,47	2.22	17	5
	IIC	12	0,67	2.94	18	3
	LDC	0	0	0.00	9	0
2006	DME	201	5,74	1.54	35	15
	NEC	36	2,4	2.33	15	7
	IIC	15	0,83	3.13	18	4
	LDC	0	0	0.00	12	0
2010	DME	207	6,09	1.60	34	16
	NEC	36	2,4	1,70	15	7
	IIC	15	0,75	3.35	20	3

LDC	0	0	0.00	13	0

σ: standard deviation; M: number of medals per country

Although, at first sight, the political regime seems to be less relevant as a variable that differentiates among the Winter Games' medal winners, we have kept it in the model with some slight emendation compared to the Summer Olympics model. The reference country group remains CAPME for capitalist market economies; CEECs are those post-communist economies which have joined the EU in either 2004 or 2007; and we have gathered all the remaining post-communist economies in an EXCOM country group even though it would be sensible to consider Cuba and North Korea as still communist regimes (but their performance at Winter Games is negligible or nil).

It seems that a political regime variable might be a significant determinant (to be tested) of medal distribution per nation at Winter Olympics as well (Table 5). Being a centrally planned economy with some sort of communist regime was an advantage to win Winter Olympics medals until 1988 (and from 1972 to 1988 for CEECs). The mean number of medal wins was higher in the EXCOM group than in the CEEC group and the latter higher than in the CAPME reference group during this span of time, even though medals were concentrated on a small number of communist countries, namely the former USSR. The collapse of the communist regime had a seemingly significant impact on the number of medal wins which dramatically dropped in CEECs after 1990; it dropped much less significantly in other former communist countries, namely in the former USSR, and recovered as soon as 1994 while the recovery in medal wins happened only in 2010 in CEECs. Such difference in momentum is probably due to a harsher shock of economic transition, a deeper and swifter transformation of the state-run sport system into a market sport economy in CEECs as compared with other post-communist countries, including Russia (Poupaux & Andreff, 2007).

Table 5 - Uneven medal distribution by political regime

Year	Country group	Number of medals	Mean: m	Coefficient of variation: σ/m	Number of countries	Countries with M > 0
1964	CAPME	77	2,85	1.53	27	12
	CEEC	1	0,2	2.25	5	1
	EXCOM	25	6,25	2.00	4	1
1968	CAPME	83	2,96	1.43	28	11
	CEEC	10	1,67	1.35	6	3
	EXCOM	13	4,33	1.73	3	1

1972	CAPME	71	2,84	1.29	25	13
	CEEC	18	3	1.84	6	3
	EXCOM	16	4	2.00	4	1
1976	CAPME	64	2,21	1.45	29	13
	CEEC	20	3,33	2.31	6	2
	EXCOM	27	13,5	1.41	2	1
1980	CAPME	67	2,48	1.41	27	14
	CEEC	26	4,33	2.12	6	4
	EXCOM	22	5,5	2.00	4	1
1984	CAPME	61	1,65	1.90	37	13
	CEEC	30	5	1.92	6	2
	EXCOM	26	5,2	2.13	5	2
1988	CAPME	78	1,7	1.98	46	13
	CEEC	28	4,67	2.15	6	2
	EXCOM	32	6,4	1.98	5	2
1992	CAPME	141	2,88	2.08	49	16
	CEEC	3	0,38	2.79	8	1
	EXCOM	27	4,5	2.03	6	3
1994	CAPME	146	3,32	1.96	44	15
	CEEC	3	0,3	3.17	10	1
	EXCOM	34	2,62	2.38	13	6
1998	CAPME	170	3,78	1.84	45	17
	CEEC	4	0,4	2.43	10	2
	EXCOM	31	1,82	2.53	17	5
2002	CAPME	196	3,92	2.15	50	15
	CEEC	12	1,2	1.17	10	5
	EXCOM	26	1,53	2.37	17	4
2006	CAPME	201	3,94	1.97	51	15
	CEEC	12	1,2	1.17	10	6
	EXCOM	39	2,05	2.67	19	5
2010	CAPME	204	3,92	2.14	52	15
	CEEC	21	2,1	1.13	10	6
	EXCOM	33	1,65	2.45	20	5

σ: standard deviation;   M: number of medals per country

With regards to the *Regions* dummy variable supposed to capture differences in sporting culture, we do not expect that it must be as much significant for Winter Olympics as it has been tested for Summer Olympics. The reason is very simple: all those countries which participate to Winter Games have in common a sporting culture geared towards the practice of winter sports wherever they are located and whatever their overall sporting culture. This is confirmed by the fact that, contrary to Summer Olympics, many countries in the world do not participate to Winter Olympics. Thus, we skip the regional dummy out from the Winter Olympics model.

Now if a country would like to develop a wide range of winter sports on its territory, making it able to train and select performing athletes, it could not significantly achieve it without some proper weather conditions, in particular enough snow coverage per year, and more than a minimal endowment in winter sports resorts and facilities[13]. This leads us to introduce two new variables in the model. The first one *Snow* is a dummy variable differentiating countries with regards to their average degree of annual snow coverage. Indeed, among those countries which have participated at least once to Winter Olympics, the degree of snow coverage is quite variable, but it was not easy to get a precise measure of snow coverage back to 1964. Thus we have gathered information provided by Maps of the World and the World Meteorological Organisation regarding the main climates, precipitations and temperature in order to build up the *Snow* dummy. The outcome in our sample of participating countries[14] is as follows:

POL (a so-called "polar" coverage for countries with a long duration of annual snow coverage): Belarus, Canada, Estonia, Finland, Iceland, Latvia, Lithuania, Mongolia, Nepal, Norway, Russia (by extension CIS and the former USSR), Sweden = 12 countries;

HIGH (local high winter snow coverage in otherwise temperate climate countries): Austria, Chile, Croatia, Czech Republic (by extension former Czechoslovakia), Denmark, France, Germany (by extension former GDR), Italy, Japan, Kyrgyzstan, Poland, Slovakia, Slovenia, Spain, Switzerland, Tajikistan, USA (and by extension former Yugoslavia) = 17 countries;

MIDDLE (local middle snow coverage in temperate climate countries): Albania, American Samoa, Argentina, Armenia, Australia, Azerbaijan, Belgium, Bolivia, Bosnia-Herzegovina, Bulgaria, China (including Hong Kong), Cyprus, Fiji, Georgia, Great Britain, Greece, Guam, Hungary, Ireland, Israel, Lebanon, Luxembourg, Macedonia, Moldova, Netherlands, New Zealand, North Korea, Portugal, Peru, Romania, Serbia, South Africa, South Korea, Swaziland, Taiwan, Turkey, Ukraine, Uruguay = 39 countries;

LOW (countries with no or low snow coverage): Algeria, Bermuda, Brazil, Cameroon, Colombia, Costa Rica, Ethiopia, Ghana, Guatemala, Honduras, India, Iran, Jamaica, Kazakhstan, Kenya, Madagascar, Mexico, Morocco, Netherlands Antilles, Pakistan,

[13] Thus we neglect some exceptions as Dubai with its ski resort in a country without any natural snow coverage and without even a second winter sports facility in the country.

[14] Some countries which have participated to Winter Olympics are excluded from our ample since data about population and GDP cannot be traced back to 1964. They are: Andorra, Caiman Islands, Liechtenstein, Monaco, Montenegro, Porto Rico, and San Marino. No big medal winner.

Philippines, Senegal, Thailand, Trinidad & Tobago, Uzbekistan, Venezuela, Virgin Islands = 27 countries.

Table 6 – Uneven medal distribution by level of snow coverage

Year	Country group	Number of medals	Mean: m	Coefficient of variation: s/m	Number of countries	Countries with M > 0
1964	POL	60	8.57	1.06	7	5
	HIGH	39	2.79	1,47	14	6
	MIDDLE	4	0.31	2.03	13	3
	LOW	0	0.00	0.00	2	0
1968	POL	43	6.14	0.94	7	5
	HIGH	53	3.53	1.08	15	8
	MIDDLE	10	0.83	3.12	12	2
	LOW	0	0.00	0.00	3	0
1972	POL	38	6.33	1.00	6	5
	HIGH	58	4.46	0.93	13	11
	MIDDLE	9	0.64	3.77	14	1
	LOW	0	0.00	0.00	2	0
1976	POL	46	6.57	1.44	7	5
	HIGH	58	4.14	1.35	14	9
	MIDDLE	7	0.47	3.30	15	2
	LOW	0	0.00	0.00	1	0
1980	POL	47	5.88	1.30	8	5
	HIGH	61	4.69	1.39	13	10
	MIDDLE	7	0.50	2.18	14	4
	LOW	0	0.00	0.00	2	0
1984	POL	59	7.38	1.17	8	5
	HIGH	57	4.07	1.53	14	11
	MIDDLE	1	0.05	4.60	19	1
	LOW	0	0.00	0.00	7	0
1988	POL	52	6.50	1.47	8	5
	HIGH	79	5.27	1.32	15	11
	MIDDLE	7	0.33	4.64	21	1
	LOW	0	0.00	0.00	13	0
1992	POL	61	5.55	1.51	11	5
	HIGH	95	6.33	1.32	15	9
	MIDDLE	15	0.68	1.94	22	6
	LOW	0	0.00	0.00	15	0
1994	POL	73	6.08	1.55	12	6
	HIGH	88	5.18	1.46	17	8
	MIDDLE	18	0.72	2.14	25	6
	LOW	4	0.31	2.74	13	2

1998	POL	75	6.25	1.42	12	6
	HIGH	98	5.44	1.47	18	9
	MIDDLE	30	1.03	2.56	29	8
	LOW	2	0.15	3.67	13	1
2002	POL	73	5.62	1.44	13	7
	HIGH	134	7.05	1.58	19	11
	MIDDLE	27	0.96	2.33	28	6
	LOW	0	0.00	0.00	17	0
2006	POL	93	7.15	1.30	13	8
	HIGH	122	6.78	1.43	18	11
	MIDDLE	37	1.12	2.70	33	7
	LOW	0	0.00	0.00	16	0
2010	POL	86	6.62	1.39	13	8
	HIGH	134	7.05	1.47	19	12
	MIDDLE	37	1.12	2.95	33	5
	LOW	1	0.59	0.41	17	1

σ: standard deviation; M: number of medals per country

The distribution of medal wins across these four country groups from the 1964 to 2010 Winter Olympics is shown in Table 6 and suggests that snow coverage might well be a significant determinant of medal wins in winter sports. Countries with high snow coverage followed by countries with polar-like climate and snow coverage concentrate the great bulk of medal wins at Winter Olympics. The number of countries with high snow coverage increased from 14 in 1964 up to 19 in 2010 while their number of medals won grew from 39 to 134. During the same span of time, the number of countries with polar-like snow coverage augmented from 7 in 1964 to 13 in 2010 whereas their number of medal wins increased from 60 to 86. On the other hand, 13 countries with middle snow coverage had won only 4 medals in 1964; they were 33 participating at the 2010 Games where they won 37 medals. With regards to countries with low (or no) snow coverage, the marked increase in their participation (from 2 to 17) did not translate into an impressive growth in medal wins (from 0 to 1 – with once 4 medals won in 1994 and once 2 medals in 2002). Snow coverage is seems to be a differentiating factor among countries participating to Winter Olympics.

A second new variable is introduced in the model to capture each country's endowment with winter sports resorts and facilities. Here we have relied on data available on various web sites describing ski resorts in different countries in the world, namely www.skiinfo.fr, www.sports-hiver.com, www.neigeski.com, www.levoyageur.net/stations, www.fr.snow-forecast.com, www.french-china.org. A *RESORT* dummy variable has been designed on the basis of such information, considering a country as being endowed with many ski resorts and winter sports facilities when it has over 60 of them at its disposal. A country with a number of skiing resorts between 5 and 60 is considered as having an average endowment by world standard. A country with a number of ski resorts and winter sports facilities below 5 is assessed and ranked as having few opportunities to win medals due to her short availability of resorts-facilities. The three country groups are comprised of:

MANY winter sports resorts: Austria, Canada, Czechoslovakia, France, Germany (GDR), Italy, Japan, Norway, Russia (CIS, USSR), Sweden, Switzerland, USA = 12 countries;

BETWEEN many and few winter sports resorts: Australia, Belgium, Bulgaria, Chile, China, Croatia, Czech Republic, Finland, Iran, Kyrgyzstan, Lebanon, Netherlands, New Zealand, Poland, Romania, Slovakia, Slovenia, South Korea, Spain, Turkey, Ukraine (Yugoslavia) = 21 countries;

FEW/NO winter sports resorts: Albania, Algeria, American Samoa, Argentina, Armenia, Azerbaijan, Belarus, Bermuda, Bolivia, Bosnia-Herzegovina, Brazil, Cameroon, Colombia, Costa Rica, Cyprus, Denmark, Ethiopia, Estonia, Fiji, Georgia, Great Britain, Ghana, Greece, Guam, Guatemala, Honduras, Hungary, Iceland, India, Ireland, Israel, Jamaica, Kazakhstan, Kenya, Latvia, Lithuania, Luxembourg, Macedonia, Madagascar, Mexico, Moldova, Mongolia, Morocco, Nepal, Netherlands Antilles, North Korea, Pakistan, Philippines, Portugal, Peru, Senegal, Serbia, South Africa, Swaziland, Thailand, Taiwan, Tajikistan, Trinidad & Tobago, Uruguay, Uzbekistan, Venezuela, Virgin Islands = 62 countries.

Table 7 – Medal distribution and winter sports resorts and winter sports facilities

Year	Country group	Number of medals	Mean: m	Coefficient of variation: s/m	Number of countries	Countries with M > 0
1964	MANY	89	7.42	0.97	12	10
	BETWEEN	13	0.87	2.98	15	3
	FEW / NO	1	0.11	3.00	9	1
1968	MANY	91	7.00	0.57	13	12
	BETWEEN	15	1.00	2.56	15	3
	FEW / NO	0	0.00	0.00	9	0
1972	MANY	89	6.85	0.69	13	13
	BETWEEN	16	1.14	2.31	14	4
	FEW / NO	0	0.00	0.00	8	0
1976	MANY	95	6.79	1.15	14	12
	BETWEEN	15	0.94	2.38	16	3
	FEW / NO	1	0.14	2.71	7	1
1980	MANY	95	6.79	1.11	14	13

	BETWEEN	18	1.28	2.06	14	4
	FEW / NO	2	0.22	2.00	9	2
1984	MANY	100	7.14	1.10	14	13
	BETWEEN	16	1.00	3.25	16	3
	FEW / NO	1	0.56	0.43	18	1
1988	MANY	120	8.57	1.02	14	13
	BETWEEN	18	1.13	2.14	16	4
	FEW / NO	0	0.00	0.00	27	0
1992	MANY	148	11.38	0.76	13	12
	BETWEEN	20	1.18	1.75	17	6
	FEW / NO	3	0.09	4.22	33	2
1994	MANY	150	12.5	0.71	12	11
	BETWEEN	25	1.25	1.64	20	7
	FEW / NO	8	0.23	3.00	35	4
1998	MANY	155	12.92	0.66	12	11
	BETWEEN	44	2.00	1.86	22	9
	FEW / NO	6	0.16	3.06	38	4
2002	MANY	186	15.5	0.73	12	11
	BETWEEN	42	1.83	1.47	23	10
	FEW / NO	6	0.14	4.07	42	3
2006	MANY	191	15.92	0.59	12	11
	BETWEEN	55	2.50	1.52	22	11
	FEW / NO	6	0.13	3.85	46	4
2010	MANY	188	15.67	0.72	12	11
	BETWEEN	62	2.82	1.43	22	10
	FEW / NO	8	0.17	3.29	48	5

σ: standard deviation; M: number of medals per country

It is crystal clear that countries with a good endowment in ski resorts and winter sports facilities are winning an increasing number of Olympic medals from 89 in 1964 to 188 in 2010 (even 191 in 2006) while their number has always stood between 12 and 14 (Table 7). The number of participating countries with few or no resorts-facilities has grown from 9 in 1964 to 48 in 2010 whereas their number of medal wins has increased from 1 to 8. The number of countries with an average endowment stands in between as well as their number of medal wins. It seems that a shortage of ski resorts and winter sports facilities is a hindrance to win medals at Winter Olympics whereas medal wins benefit to well-endowed countries.

Thus, the model is adapted to estimating the determinants of medal wins at Winter Olympics as follows:

$$M^*_{i,t} = c + \alpha \ln N_{i,t-4} + \beta \ln\left(\frac{Y}{N}\right)_{i,t-4} + \gamma\, Host_{i,t} + \sum_p \delta_p \; Political\,Regime_{p,i} + \sum_r \rho_r Snow_r + \sum_l \lambda_l Resort_l + \varepsilon_{i,t} \qquad \textbf{(4)}$$

where $\varepsilon_{i,t} \sim N(0,\sigma^2_\varepsilon)$.

$M_{i,t}$ observation is defined by $M_{i,t} = \begin{cases} M^*_{i,t} & si \;\; M^*_{i,t} > 0 \\ 0 & si \;\; M^*_{i,t} \le 0 \end{cases}$

and *N* is the population of a nation, *Y/N* is its GDP per inhabitant, both variables being four-year lagged for the same reason as with Summer Olympics (see above), *Host* is a dummy variable identifying the country that hosts the Games, *Political Regime* is a dummy variable which captures the impact of the political and economic system on medal wins, *Snow* is a dummy variable differentiating countries with regards to their degree of annual snow coverage, and *Resort* is a dummy capturing the significance of ski resorts and winter sports facilities located in a country.

5. Economic determinants of medal wins at Winter Olympic Games

Model (**4**) is now used for estimating whether the above-listed variables are significant determinants of medal wins at Winter Olympics. Econometric testing covers all Winter Olympics from 1964 up to 2010. Data for population and GDP per inhabitant are taken from CHELEM data base (which retrieves and proceeds to consistency checks between World Bank and OECD data). A first specification M1 resorts to a left-hand censored Tobit model since a non negligible number of countries that participate to Winter Olympics do not win any medal. Therefore, a zero value of the $M_{i,t}$ dependent variable does not mean that a country has not participated and we work out a simple Tobit, not a Tobit 2 (with a two stage Heckman procedure)[15]. Estimation with panel data has not been used since, when tested, year dummies are not significant. This first specification takes on board five explanatory variables: population, GDP per inhabitant, the three dummies *Host*, *Snow* and *Resort*. The MIDDLE country group which contains the biggest number of countries is taken as the reference for the *Snow* dummy. With the same rationale, the most numerous FEW/NO country group is taken as the reference for the *Resort* dummy. In a second specification M2, the censored Tobit

[15] Since a binomial variable is discrete - instead of a continuous in a Tobit, a binomial estimation ("negative binomial model with random effects") has been achieved. The result is meaningless seemingly because the observed distribution of non-zero medals is nearly uniform contrarily to a binomial distribution. Thus, a binomial estimation could not have been used for prediction.

model includes in addition the *Political Regime* dummy variable. A third specification M3 is the one which will be used later on for prediction and it encompasses one more explanatory variable, *i.e.* the inertial variable $M_{i,t-4}$. The results are exhibited in Table 8.

Table 8 - Tobit estimations of medals won at Winter Olympics

Independent variables	Tobit model M1	Tobit model M2	Tobit model M3
Log population (t-4)	2.006 ***	1.873 ***	0.787 ***
Log GDP per inhabitant (t-4)	3.732 ***	6.958 ***	2.813 ***
Host	2.732	3.245 *	3.874 ***
Resort (ref. FEW/NO)			
MANY	13.596 ***	15.633 ***	5.904 ***
BETWEEN	5.889 ***	6.951 ***	2.989 ***
Snow (ref. MIDDLE)			
POLAR	8.042 ***	5.390 ***	2.092 **
HIGH	0.922	-1.292	-0.286
LOW	-1.906	-0.313	-0.653
Political regime (ref. CAPME)			
CEEC		6.302 ***	3.186 ***
EXCOM		10.077 ***	3.839 ***
Medals (t-4)			0.828 ***
Constant	-24.198 ***	-34.252 ***	-15.733
Number of observations	663	663	662
Log-likelihood value	-957.881	-928.749	-811.892
Pseudo-R2	0.221	0.245	0.339

*** Significant at a 1% threshold; ** at 5%; * at 10%.

In all three specifications, GDP per inhabitant and population are very significant determinants of medal wins at Winter Olympics with a positive sign. Medal distribution is basically an affair across developed economies with a rather important population. More interesting is that the endowment in ski and winter sports resorts is also a very significant determinant of medal wins. Belonging to the BETWEEN country group significantly increases a nation's probability to win medals at Winter Olympics and it is even more so for those countries with many winter sports resorts. The very existence of winter sports resorts reflects a high capacity of having a winter sports practice in a country and, consequently, of selecting experienced athletes in the national squad.

On the other hand, snow coverage surprisingly does not appear as a significant determinant of Winter Olympics medal wins. Compared with MIDDLE coverage country group, polar-like countries have a significant probability to win more medals, but this probability is not significant for high snow coverage countries; the probability to win fewer medals is not significant for low snow coverage countries. The same result shows up with the other two specifications M2 and M3. Indeed, some countries with high snow coverage do not perform that well at Winter Olympic Games such as Tajikistan and Kyrgyzstan. It is not enough for a country to have snow, if it does not have enough ski resorts and winter sports facilities to train potential medal winners at Winter Games.

Introducing a Political regime dummy in our second specification improves the estimation overall (Pseudo-R2 increases). The host country dummy becomes significant (though at 10%). Being a Central and Eastern European post-communist nation increases its probability to win medals at Winter Olympics and it is even more so for the EXCOM country group (CIS countries and all other non Soviet former communist countries).

The third specification M3 is by far the best one with a marked improvement of the Pseudo-R2. Moreover all explanatory variables are significant except snow coverage with regards to high and low snow coverage countries. The inertial variable – medal wins at the previous Winter Olympics – is significant as well and the host country dummy becomes significant at 1%[16]. This model fits well for predicting medal wins at the Sochi Winter Games.

6. Economic prediction of medal wins at the 2014 Sochi Winter Olympics

Our prediction exercise based on model M3 takes CHELEM preliminary data for 2010 as regards to population and GDP per inhabitant and then calculates the Sochi outcome in terms of medal wins. The results are shown in Table 9. The expected winner (first ranked country) is USA with 36 medal wins, just like it has been in Vancouver 2010 with 37 medals. Germany ranks second with 28 medal wins while she has ranked first in 2006 (29 medals), 2002 (36 medals), 1998 (29 medals), 1992 (26 medals), and second in 2010 (30 medals). Canada takes over the third rank with 27 medals like in Vancouver 2010 (26 medals) and Turin 2006 (24 medals). France is expected to win 12 medals in Sochi (8th rank) as against 11 in Vancouver, 9 in Turin, 11 in Salt Lake City, 8 in Nagano, 5 in Lillehammer, 9 in Albertville 1992 and ... 9 in Grenoble 1968 (with a strong host country effect).

Table 9 - Prediction of medal wins at Sochi Winter Olympics

[16] We have also tested a fourth specification including the *Regions* dummy variable used in the Summer Olympics model. For three regions the test does not provide any result since these regions have never won a medal at Winter Games. For most other regions, the variable is not significant even at a 10% threshold.

Countries	Medals won in 2010	Medal wins predicted in 2014	Lower bound	Upper bound
USA	37	36	33	38
Germany	30	28	26	30
Canada	26	27	25	28
Russia	15	24	21	27
Norway	23	24	22	25
Austria	16	15	14	16
Sweden	11	13	12	14
France	11	12	11	13
China	11	11	9	13
South Korea	14	11	10	13
Switzerland	9	9	8	10
Japan	5	7	6	9
Italy	5	7	6	8
Netherlands	8	6	5	7
Poland	6	6	4	8
Czech Republic	6	6	4	7
Finland	5	5	3	6
Australia	3	3	1	4
Slovenia	3	2	1	4
Croatia	3	2	0	4
Slovakia	3	2	0	3
Belarus	3	1	0	3

Winning 24 medals, Russia would rank fourth at Sochi Games. It would be a quite better performance than the disastrous 15 medals won in Vancouver (6^{th} rank behind Norway and Austria) and 13 medals in Salt Lake City (6^{th} rank). Sochi Olympics might materialise the end of the deep transformation of the Russian sports system undertaken during the 1990s and 2000s. This would be a sign of Russian recovery as an Olympics sporting power but without coming back to the 1976-1988 "golden age" when the Soviet squad usually was winning between one fifth and one quarter of all distributed medals. The process of economic (and sporting system's) transformation was a shock on Russian and CIS medal wins, the share of which fell below 10% of medals total since 2002. In particular, the transformational recession (Kornaï, 1994) has seriously affected Russia's GDP per capita downwards until 1998; the same roughly applies to other CIS countries. In our model, a decreasing GDP per capita explains a lower number of medal wins. A decreasing number of medals for Russia is (only partly) compensated by the emergence of Belarus, Kazakhstan and Ukraine as more or less regular medal winners at Winter Games since 1994 (Table 10). However the confidence interval for Russian medal wins is between 21 and 27 (Table 9). So that, in the worst case, Russia may win less medals than at the 1994 and 2006 Winter Games, which would not seem to be very rewarding for the Russian sports authorities. Moreover, our model predicts no medal for Kazakhstan and Ukraine in Sochi 2014 and only one for Belarus.

Table 10 - Medal wins by (post)-communist countries, 1964-2010

Country	1964	1968	1972	1976	1980	1984	1988	1992	1994	1998	2002	2006	2010
CEECs													
Bulgaria					1					1	3	1	
Czech Republic										3	3	4	6
Estonia											3	3	1
Hungary					1								
Latvia												1	2
Poland			1								2	2	6
Romania		1											
Slovakia												1	3
Slovenia									3		1		3
former Czechoslovakia	1	4	3	1	1	6	3	3					
former GDR		5	14	19	23	24	25						
former Yugoslavia						1	3						
CEECs/medias total %	1.0	9.4	17.1	18.0	22.7	26.5	22.5	1.7	1.6	1.9	5.4	4.8	8.1
CIS countries													
Belarus									2	2	1	1	3
Kazakhstan									3	2			1
Russia									23	18	13	22	15
Ukraine									2	1		2	
Uzbekistan									1				
former USSR	25	13	16	27	22	25	29	23*					
CIS/medals total (%)	24.3	12.3	15.2	24.3	19.1	21.4	21.0	13.4	16.9	11.2	6.0	9.9	7.4
Other EXCOM													
China								3	3	8	8	11	11
Croatia											4	3	3
North Korea								1					

* CIS unified squad

With regards to CEECs, the transition economic shock was slightly milder than in CIS countries and transformational recession lasted a shorter span of time. Nevertheless, transition has triggered a dramatic drop in CEEC medal wins at Winter Games which fell down to 3 Czechoslovak medals in 1992, 3 Slovene medals in 1994, 1 Bulgarian and 3 Czech medals in 1998. The recovery in medal wins has been quite slower than economic recovery since the sports sector was not a top priority in the transition strategy backed by Washington organisations (IMF & WB). Moreover medal wins are scattered across eight CEECs since 2002, all of them but Hungary and Lithuania. The most spectacular shock on medal wins in CEECs derives from German unification in 1990. The former GDR also enjoyed a sort of "golden age" from 1972 to 1988 with between 14 and 25 medal wins at Winter Olympics[17]. At the 1992 Winter Games, the unified German squad, taking stake of Eastern German athletes, outperformed (with 26 medals) all other participating countries including the CIS unified squad (23 medals). Since then Germany has become the top performer at Winter Olympics with the biggest number of medals won from Albertville 1992 to Vancouver 2010 (except Lillehammer 1994, 2nd rank behind Norway).

In Sochi 2014, our model forecasts only 16 medal wins for CEECs taken altogether, which would be a step back compared to the 2010 recovery with 21 medals though better than 12 medal wins in 2002 and 2006. This would merely benefit to the Czech and Polish squads, 6 medals each, then to Slovenia and Slovakia (2 medals each). Estonia, Latvia and Bulgaria, which had been able to win medals in the four previous Games, are not expected to win any of them at Sochi Winter Olympics.

A final note about other post-communist countries must underline the rise of China as a new Winter Olympics winner (ranked 11th in 1998, 10th in 2002, 9th in 2006 and 8th in 2010), even though this cannot compare with this nation's outstanding performance at the Summer Games hosted in Beijing. Thus, it is not surprising that our model predicts again 11 medal wins for China in 2014 (9th rank) but note that the upper bound of the interval confidence for China is 13 medals. If the Chinese squad performs very well, it may even pretend to the 7th ranks in terms of medal wins at Sochi Games. Croatia did extremely well – given the size (population, GDP) of this country – since the 2002 Winter Games. The model forecasts 2 Croatian medals in Sochi, with an upper bound at 4 medals, like at the 2002 Winter Olympics.

7. Conclusion: Economic prediction and surprising sport outcomes

All the above predictions must be taken with a pinch of salt. This is namely due to a number of surprising sporting outcomes. Indeed, there are many unexpected sporting outcomes observed ex post – *i.e.* achieved outcomes markedly different from the forecast – even though it happens more with the FIFA World Cup than with Summer Olympics (M. & W. Andreff,

[17] We do not come back here to specific determinants of Olympics performances reached by the communist GDR, see Andreff *et al.* (2008) and Dryden (2006).

2010). Unexpected or surprising outcomes of a sport game or contest have not really been analysed so far. This happens when opponents in a game (contest) have clearly uneven sporting forces, and the underdog wins the favourite. Elaborating on a metrics to quantify surprising sporting outcomes should be a promising avenue for further research. It will be possible to check after Sochi 2014 whether Winter Olympics are characterised with many or few surprising sport outcomes.

For the time being our recommendation is: do not bet that Russia will win 24 medals at Sochi Winter Olympics! But, if Russia makes it with more than 27 medals you would be allowed to conclude that she performed very well, better than expected with an economic model, and that this must be due to exceptional efforts of Russian athletes and coaches before and during Sochi Games. If Russia would win less than 21 medals, you could join Prime Minister Putin and President Medvedev in complaining that the Russian winter sports squad should really have done better – or that it was unexpectedly bad lucky.

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