The Economics of the Olympic Games: Reconsidering Former Socialist Countries' Performance

by

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This paper explores how a country can maximise its utility from the Olympic games when uncertainty exists in medal production. A theoretical model demonstrates how the value of medals, uncertainty in producing medals, a decision maker's attitudes towards risks and costs of producing medals affect the optimal number of medals and expected utility of a risk averse decision maker. An application of the model shows that, as the overall welfare level and, accordingly, investment in sports increase, the related risk premium decreases, which in turn reduces the difference between the eastern and western bloc countries' performances in the Olympic games. The difference in the performance is also supposed to decrease as the uncertainty in obtaining medals decreases and the cost of medal production increases. This phenomenon occurs even when the Eastern bloc countries attach higher values to medals than do the Western bloc countries. As a result, this study predicts that the out-performance of the former socialist countries in the Olympic games would have dissipated, even without the recent political and economic collapse of those countries, unless they had accelerated their distorted state-driven sport policies.

Key words: *the Olympic games, uncertainty, attitudes towards risks, value mark-up, cost mark-up*

JEL Classification: *D00, P52, Z00*

1. Introduction

Some aspects of the Olympic games, such as the cost-benefit analyses of hosting the Games or the straightforward statistical analyses of each country's performance, have been explored intensively. Nevertheless, it is surprising that an investment in medal collection in the Olympic games, in which many countries make substantial economic and psychological/social investments has not received wide attention from economists. The process of investing in medals and collecting them is analogous to the economic activities of producing and consuming some commodities when conditions of uncertainty exists. This paper analyzes how each country decides the optimal number of medals in a situation characterized by uncertainty. An application of the model indicates how the different performances of Eastern and Western bloc countries' might be explained, and how they should change over time as some conditions vary.

Section 2 of this paper investigates this important but under-researched topic of how a country decides the optimal number of medals under conditions of uncertainty. Considering the different values attached to medals, and the different costs required to secure them in Eastern and Western bloc countries, section 3 investigates the difference in performance between the two blocs in the Olympic games. Section 4 presents a discussion of whether, given the model developed in this paper, the two blocs' performance in the Olympic games would have converged (even if the Eastern bloc had not collapsed) due to changes in the parameters and variables that determine a country's performance in the Games.

2. A Model for Medal Production

Each country invests in the Olympic games, collects medals and basks in the glory and increased levels of national confidence that they bring. Assume that a country has a representative consumer whose utility function contains constant risk aversion γ (Arrow-Pratt measure of

absolute risk aversion). This representative consumer produces a commodity ('medal') M and has a profit (or surplus) π. Its utility function is given as

$$U(\pi) = 1 - e^{-\gamma \pi}.$$

This constant absolute risk aversion utility function helps evaluate easily the expected utility for any distribution of profit (Hey, 1981), including cost, together with uncertainty, as will be discussed below. This function is also sufficiently regular to deal with the optimal choice under uncertainty, as it is twice continuously differentiable with positive derivative (Pratt, 1964).

The cost function is assumed to be quadratic and to include a random factor δ, which is normally distributed with a mean zero and a variance of σ^2. Unlike ordinary manufacturing, it is virtually impossible to predict or establish with certainty the costs associated with producing a given number of 'medals'. The random factor δ captures this phenomenon. A quadratic cost function of medals is expressed as follows:

$$C = (1/2)\,cM^2 + \delta M$$

where c is determined by factor prices and technology and M is the number of medals, while δ represents the uncertainty, which the representative economic agent faces in medal production. The representative agent's profit or surplus gained by participating in the Olympic games (ie, paying costs and winning medals) is the difference between the total value of medals and costs. This may be expressed as follows:

$$\pi = VM - C = VM - (1/2)\,cM^2 - \delta M.$$

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The representative consumer choses M to maximize its expected utility,

$$\text{MAX} \quad EU(\pi) = E \left[1 - \exp \left[- \gamma \left\{ VM - (1/2)\, cM^2 - \delta M \right\} \right] \right]$$

where E is an expectation operator. To avoid complex calculus to maximize the afore-mentioned expected utility, Horen and Wu's (1989) lemma is applied by introducing risk premium B. Since risk premium B is defined as $EU(\pi) = U(E\pi - B)$, equation (1) follows:

$$\frac{1}{\sigma\sqrt{2\pi}} \int_{\delta} \left[\exp \left[- \gamma \left\{ VM - (1/2)\, cM^2 - \delta M \right\} - \frac{\delta^2}{2\sigma^2} \right] d\delta$$

$$= \exp \left[- \gamma \left\{ VM - (1/2)\, cM^2 - B \right\} \right] \tag{1}$$

Substitute the following equation into the left side in (1),

$$\frac{1}{\sigma\sqrt{2\pi}} \int_{\delta} \exp \left[- \frac{1}{2\sigma^2} (\delta + \sigma^2 \gamma M)^2 \right] d\delta = 1,$$

the following then can be derived.

$$\exp \left[- \gamma \left\{ VM - (1/2)\, cM^2 - (1/2)\, \sigma^2 \gamma M^2 \right\} \right] = \exp \left[- \gamma \left\{ VM - (1/2)\, cM^2 - B \right\} \right].$$

Therefore, the risk premium is

$$B = (1/2)\, \sigma^2 \gamma M^2. \tag{2}$$

The optimum value of M, that is M*, should maximize $U(E\pi - B)$, ie.,

$$\frac{dU(E\pi - B)}{dM}\bigg|_{M=M^{\cdot}} = 0 . \tag{3}$$

As $U(E\pi - B) = U [VM - (1/2)cM^2 - (1/2) \sigma^2 \gamma M^2]$, the first order condition (3) becomes

$$[\gamma V - \gamma c M - \gamma^2 \sigma^2 M] \exp [- \gamma \{VM - (1/2)cM^2 - (1/2) \sigma^2 \gamma M^2\}] = 0.$$

Therefore, M^*, which maximizes the producer's expected utility given V, γ, c and the distribution of δ, is

$$M^{\cdot} = \frac{V}{\gamma\sigma^2 + c} . \tag{4}$$

It is obvious from (4) that a country's production of medals in the Olympic games increases as it attaches a higher value to the medals, and decreases as the degree of risk aversion increases, uncertainty in medal production increases and the cost of production increases.

3. The Performance Gap between the Eastern and Western Blocs

The different performance of the Eastern and Western blocs in the Olympic games (or some other international sport competitions) has been attracting the interest of many researchers. Most of the works, however, restrict themselves to presenting statistics and identifying trends pertaining to the performance of the two blocs, without exploring the underlying explanatory factors for this performance gap, or why the gap not only persisted but widened or narrowed on some occasions. Only a few articles, attempt to investigate the sources of the different levels of performance. Even these only offer the general and non-rigorous conclusion that the performance gap was due to the tendency of socialist governments to attach great importance to

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the positive image of the country that a high medal tally would present to the world[1]. Little self-contained analysis has been carried out, which has sought to explore how, or why, the relative performance between the two blocs increases or decreases as various conditions change. This section redresses the limitations in the literature currently available, and attempts to investigate these previously ignored potential explanatory factors by introducing the socialist government as a representative consumer (and producer) in the Eastern bloc countries[2].

Consider two countries with the same size, where one is in the Eastern bloc and the other is in the Western bloc. A socialist government may confer different values on the medals than the general public of that country. Nonetheless, its decision pertaining to optimal medal production is still likely to be based on equation (4), as it is the most efficient means to maximize its expected utility. Thus, the optimal number of medals to be produced in the socialist country (E) is

$$M_E^* = \frac{V_E}{\gamma_E \sigma_E^2 + c_E} \, ,$$

where the subscript E denotes 'the Eastern bloc country', and V_E is the value of medals decided by the representative consumer (in this case, government). The optimal number of medals to be produced in the Western country is

$$M_W^* = \frac{V_W}{\gamma_W \sigma_W^2 + c_W} \, ,$$

where the subscript W denotes 'the Western bloc country', and V_W is the value of medal decided by the representative consumer (in this case, general public or the market).

Then the ratio of the medals won between the two countries (E and W) is

$$M_E^* / M_W^* = [\frac{V_E}{\gamma_E \sigma_E^2 + c_E}] \Big/ [\frac{V_W}{\gamma_W \sigma_W^2 + c_W}] . \tag{5}$$

Taking it into account that the size of the Western and Eastern countries utilized in our example are the same, it is assumed that they share the same attitude towards risk ($\gamma_E = \gamma_W$). The uncertainty involved in producing (or winning) medals is shared by all the countries participating in the games ($\sigma_E^2 = \sigma_W^2$) [3]. Moreover, it is also assumed that the Eastern bloc country attaches higher values to medals ($V_E > V_W$) and pay higher costs to produce medals ($c_E > c_W$). It has been asserted and accepted that the Eastern bloc countries, by attaching a higher value to medals, made more efforts and invested relatively more to sports. For example, Grimes et al (1984) quoted Johnson (1972) as 'the Russians spent millions to prepare for the 1952 Helsinki games while East Germany had created a "Brave New World breeding factory" environment in which athletes were trained like thoroughbred horses or racing dogs.' The assumption that the Eastern bloc pays relatively high costs reflects the inefficient allocation of resources by the centrally-planned economy [4].

Two mark-up parameters, θ_v and θ_c are introduced to denote the difference in the values and costs between the two countries, that is $V_E = (1 + \theta_v) V_W$ and $c_E = (1 + \theta_c) c_W$, where θ_v and θ_c are greater than zero.

Using these notations, equation (5) can be rewritten with $\gamma_E = \gamma_W$ and $\sigma_E^2 = \sigma_W^2$. as

$$M_E^* / M_W^* = (1 + \theta_v) [1 - \frac{\theta_c c_W}{\gamma \sigma^2 + (1 + \theta_c) c_W}] = (1 + \theta_v) [\frac{\gamma \sigma^2 + c_W}{\gamma \sigma^2 + (1 + \theta_c) c_W}] \tag{6}$$

Now the difference in performance between the two countries depends on the two mark-up parameters representing differences in values and costs (θ_V and θ_c), attitudes towards risk, γ, uncertainty, σ^2, and the Western bloc country's cost c_W. The first order differentiation of equation (6) provides the following five propositions regarding how the relative performance changes as relevant parameters or variables change.

Proposition 1: The ratio of medals collected increases (in other words, the Eastern bloc country performs relatively better), *ceteris paribus*, as the Eastern bloc country confers relatively higher value on medals, ie., $\dfrac{\partial(M_E * / M_W*)}{\partial\theta_V} > 0.$

Proposition 2: The ratio of medals collected decreases (in other words, the Eastern bloc country performs relatively worse), *ceteris paribus*, as the Eastern bloc country pays a relatively higher cost to produce medals, ie., $\dfrac{\partial(M_E * / M_W*)}{\partial\theta_c} < 0.$

Proposition 3: The ratio of medals collected increases (in other words, the Eastern bloc country performs relatively better), *ceteris paribus*, as the two countries are relatively more risk-averse, ie., $\dfrac{\partial(M_E * / M_W*)}{\partial\gamma} > 0.$

Proposition 4: The ratio of medals collected increases (in other words, the Eastern bloc country performs relatively better), *ceteris paribus*, as the two countries face more uncertainty in the Olympic games, ie., $\dfrac{\partial(M_E * / M_W*)}{\partial\sigma^2} > 0.$

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Proposition 5: The ratio of medals collected decreases (in other words, the Eastern bloc country performs relatively worse), *ceteris paribus*, as the Western bloc country's cost of production increases, ie., $\dfrac{\partial(M_E{}^*/M_W{}^*)}{\partial c_w} < 0$.

While propositions 1, and 2 are obvious and intuitively appealing, propositions 3, 4 and 5 need further discussion. In particular, propositions 4 and 5 are valid with a certain restriction on θ_C. The following section will explore these issues in detail.

4. Discussion and Evidence

Discussion

The recent Olympic games bore witness to the fact that the performance of the Eastern bloc countries or former socialist countries has declined. The collapse of the socialist system and subsequent retreat from state-driven sport policies are often cited as the reasons behind this decline. In other words, as the governments are no longer able to attach higher values to sports than the general public does, due to the market-oriented system, the equilibrium of the economy (in producing medals and non-medal commodities) moves towards that of the Western bloc economies of the same size. Increasingly more resources are allocated to non-medal commodities, in line with the representative consumer's (now the general public's) evaluation of the medals *vis a vis* non-medal commodities. If the value and cost of the medals eventually becomes the same across the two countries (ie., as θ_V and θ_C approach to zero), then the difference between the two countries will disappear. This is consistent with equation (6), where $(M_E{}^*/M_W{}^*) = 1$ as θ_V and θ_C approach to zero.

Equation (6) also allows the possibility that the Western bloc country performs better than the Eastern bloc country, ie., $(M_E{}^*/M_W{}^*) < 1$. According to the relative sizes of parameters and variables, the following three cases are possible.

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(i) $\quad (M_E^*/M_W^*) < 1 \quad$ if $\quad \theta_V < \left[\dfrac{c_W}{\gamma\,\sigma^2 + c_W} \right] \theta_C,$

(ii) $\quad (M_E^*/M_W^*) = 1 \quad$ if $\quad \theta_V = \left[\dfrac{c_W}{\gamma\,\sigma^2 + c_W} \right] \theta_C,$ and

(iii) $\quad (M_E^*/M_W^*) > 1 \quad$ if $\quad \theta_V > \left[\dfrac{c_W}{\gamma\,\sigma^2 + c_W} \right] \theta_C.$

In the world of certainty, due to σ^2 being zero, the difference in the two countries' performance depends on the only two parameters, θ_V and θ_C, as $(M_E^*/M_W^*) = (1 + \theta_V) / (1 + \theta_C)$. In the world of certainty, if the relative value of medals between the Eastern and Western bloc countries is higher than the relative costs between them (ie., if $\theta_V > \theta_C$), then the Eastern bloc country would produce more medals (ie., $M_E^*/M_W^* > 1$). In the world of uncertainty, however, the possibility that the Eastern bloc country produces relatively more medals increases. Even

when θ_V ranges $\quad \left[\dfrac{c_W}{\gamma\,\sigma^2 + c_W} \right] \theta_C < \theta_V < \theta_C$, the Eastern bloc country produces more medals

than its Western counterpart, which would not be the case in the world of certainty. As uncertainty increases, or the two countries become more risk averse, this range widens, indicating that the possibility that the Eastern bloc country produces relatively more medals would increase [5].

Variations and Evidence

Based on the movements of the relative parameters and variables such as γ, σ^2 and c_W, equation (6) predicts that the ratio of the performance between the two countries would disappear (or at

least decrease) even if the Eastern bloc country did not collapse, unless it accelerates the distortion by imposing higher values on medals.

The measure of risk aversion, γ, is assumed to be constant in the previous section for the simplicity of analysis. As Arrow (1963) pointed out, however, the willingness to engage in small bets of fixed size increases with wealth, in the sense that the odds demanded diminish. Leland (1968) confirmed Arrow, arguing that, "intuition and fact lead both Pratt and Arrow to assume that risky investment is not an inferior good -- that is $\gamma(I)$ decreases as I increases." (p.468). As total investment in sports, in particular in elite sports, has been increasing over time in both the Eastern and Western countries[6], it is understandable that each country will be less risk averse. This reduction in γ will consequently lead to the reduction of the difference in medals collection, or (M_E^* / M_W^*).

Uncertainty in the production of medals refers the possibility that a country fails to win medals in spite of investments. The probability of winning medals will depend on various variables, including some relatively trivial things such as the height and temperature of the location of the games, and the number of spectators in the stadium, as well as the physical and mental condition of the athletes. Uncertainty is considered to be very high when the decision-makers do not have sufficient information or knowledge about the game place and the strength of the competition, or when they lack of good analytical skills. Continuous studies on Olympic performance have provided valuable information and knowledge on such topics as the relationship between various physical conditions and performance (for example, Khosla, 1977, 1978), strategies and performance (Boyd and Boyd, 1995), and mental perceptions and performance (Gould, Guinan, Greenleaf, Medbery and Peterson, 1999). In association with these studies, various mathematical and functional models have been developed to predict sporting performance (for example, Edwards and Hopkins, 1979; Heazlewood and Lackey, 1998). All of

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these contributions have helped to enhance the accuracy of prediction as to the probability of winning medals and reduce uncertainty. Consequently, this reduction in uncertainty contributes to reducing the gap between the Eastern and Western bloc countries' performance, as predicted by equation (6). Appendix provides more analyses on the effect of uncertainty on the relative performance.

Proposition 5 indicates that the relative performance between the two blocs would decrease as the cost that the Western bloc country pays increases. This result is due to the assumption that the Eastern bloc pays higher cost (by θ_C c_W) compared to the Western counterpart, where θ_C does not vary as c_W changes. When θ_C is allowed to change as c_W changes (which is more realistic), equation (6) shows that, after a tedious calculus, the sufficient condition for Proposition 5 is $(\partial \theta_C / \partial c_W) > 0$. If the Western bloc country's cost to produce medals increases, it will exert pressure on the Eastern counterpart to increase its investment in medals in the Olympic games. It will in turn increase the inefficiency that the Eastern bloc country experiences in medal production, which is incurred by the attachment of distorted values (higher than the market value) to the medal by the socialist government. In consequence, it is reasonable to consider that the afore-mentioned sufficient condition, which explains that the mark-up cost coefficient (of the Eastern bloc country) θ_C increases as c_W increases, in general holds. In reality, it is difficult to find how much was invested to produce each medal in each country over time. Two prevailing problems pose obstacles when trying to measure accurate levels of investment. On the one hand, it is always difficult to know how to define investment in sport. For example, while it is straightforward to take direct investment in elite sports into consideration, it is unclear whether or not some forms of indirect investment such as infrastructure or social sports, which can be a useful base for elite sports, should be included. At the same time, some investment will be effective with time lags. Hogan and Norton (2000) investigated investment (accumulated

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every four years) in elite sports in Australia. Their findings implied that the cost per medal has increased over time. As c_W increases, equation (6) shows that the relative performance ratio between the Eastern and Western bloc countries is supposed to decrease.

The relative performance (the ratio of medals won) between the Eastern and Western bloc countries of the similar size in terms of population, at the Olympic games from 1948 to 2000, is presented in Figures 1, 2 and 3. As each bloc boycotted the 1980 and 1984 Olympic games respectively, their relative performance was interpolated for those two games using the results of the 1976 and 1988 games. Figure 3 uses the Western bloc country's performance as numerator, since both Spain and South Korea failed to collect medals in some Olympic games. The three figures indicate that:

(i)   the Eastern bloc countries outperformed their Western counterparts significantly as they accelerated investment in sports after the World War II;

(ii)   the relative performance of the Eastern bloc reached its maximum in the late 1960s or 1970s, and consequently

(iii) the overall relative performance over time has the inverted U-shaped curve (the U-shaped curves for Figure 3 when the Western countries are numerators), as discussed in this study.

It should be also pointed out that the performance ratio had started to decrease even before the collapse of the Eastern bloc took place. While the socialist governments of the four Eastern bloc countries in the figures collapsed in 1989 or 1990, the figures show that the performance ratio had started to decrease in as early as the middle 1970s or 1980s. Contrary to the general belief, the Eastern bloc countries' performance in the Olympic games was being caught up by the Western bloc countries before their dramatic transition.

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5. Conclusion

A theoretical model demonstrated the manner in which the optimal level of medal production is decided. An application of the model showed how the Eastern and Western bloc countries with the same size perform differently in the Olympic games. It was found that the Eastern bloc country's out-performance would increase as the difference in medal values between the two countries increases and the difference in medal production costs decreases. The relative performance of the Eastern bloc country is also expected to improve, as the representative consumer is more risk averse, uncertainty in medal production increases and the cost of medal production in the Western bloc country decreases. This analysis provides an interesting conclusion: even if the Eastern bloc had not collapsed, the relative superiority of those countries at the Olympic games, which was considered to be the result of an intentionally distorted sports-driven policy, would have dissipated over time. In this sense, it was sometimes argued that the performance of a country in the Olympic games has a correlation with military spending or political entities. For example, see Ball (1972) and Pooley, et al. (1975).

ENDNOTE

[1] In this sense, it was sometimes argued that the performance of a country in the Olympic games has a correlation with military spending or political entities. For example, see Ball (1972) and Pooley, et al. (1975).

[2] A few studies have analyzed the different performances between the two blocs rigorously, such as Gartner (1989) who emphasized the public-good aspect of international sporting success, while most others have just uncritically pointed to the superior performance of the Eastern bloc.

[3] Some parts of uncertainty might be country-specific, where scientific and informative advancement in a country would decrease the size of σ^2 that it faces. This assumption that each country faces the same level of uncertainty is adopted for the simplicity of analysis.

[4] This assumption about the size of θ's is adopted for simplicity, without compromising our understanding of the complexity of the real world situation. Section 4 and Appendix discuss topics related to the sizes of θ in detail.

[5] The relationship between θ_V, θ_C, σ^2 and (M_E /M_W) is more intensively discussed in Appendix.

[6] The investment in elite sports has increased due to various factors. For example, the increase in the number of sports included in the Olympic games has increased, the competition among countries over the medal tally has become more intensive as income has increased, and the increase in the size of sport market has encouraged increased levels of investment in sports.
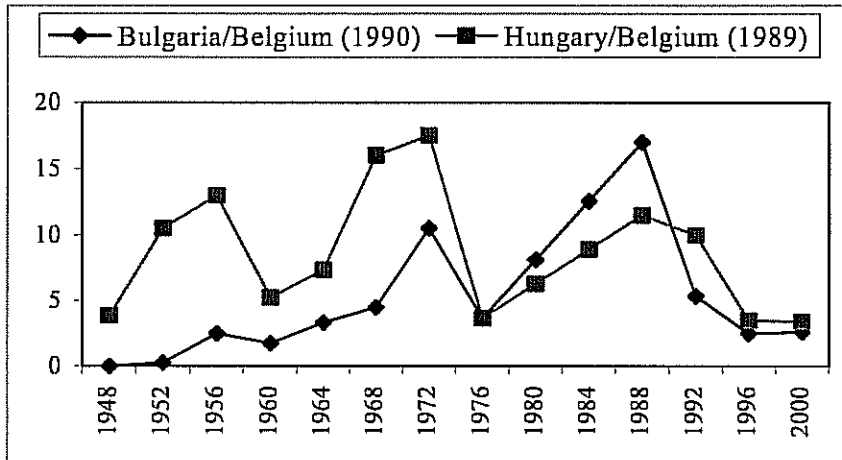
Figure 1. Relative Performance between Bulgaria and Belgium and Hungary and Belgium

NOTE: The numbers in parentheses denote the year that the relevant Eastern
bloc country's socialist government collapsed. The observations for 1980 and
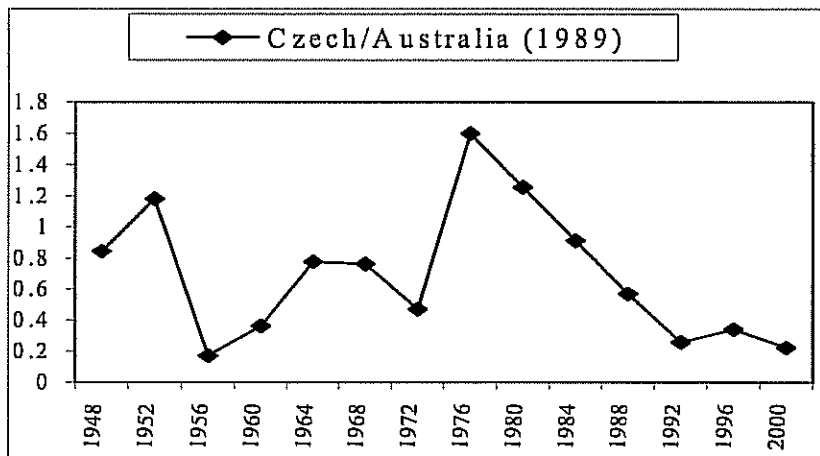1984 were obtained by interpolating.

Figure 2. Relative Performance between Czech/Slovakia and Australia

NOTE: The number in the parenthesis denotes that Czechoslovakia's socialist
government collapsed in 1989. The observations for 1980 and 1984 area were
obtained by interpolating. Since 1992, the performance of the Czech Republic
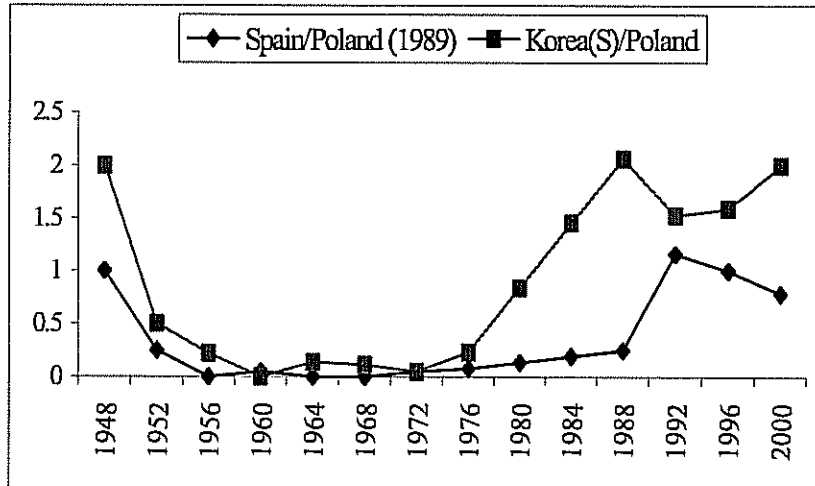and Slovakia was added.

Figure 3. Relative Performance between Spain and Poland and Korea and Poland

> NOTE: The number in the parenthesis denotes that Poland's socialist
> government collapsed in 1989. The observations for 1980 and 1984 were
> obtained by interpolating.

APPENDIX

Relative Performance, Mark-ups and Uncertainty

Equation (6) shows that, when $f = (M_E^* / M_W^*)$, the sign of $\partial f / \partial \sigma^2$ depends on the sign of θ_C, ie., if $\theta_C \leq 0$, then $\partial f / \partial \sigma^2 \leq 0$, and if $\theta_C \geq 0$, then $\partial f / \partial \sigma^2 \geq 0$. These results imply that a country which pays lower costs to produce medals is likely to increase (or decrease) the optimal number of medals to collect relatively more sensitively as uncertainty decreases (or increases). Equation (6) also shows that, regardless of the signs and relative sizes of the θ's,

$$\lim_{\sigma^2 \to \infty} [M_E / M_W] = \frac{1 + \theta_V}{1 + \theta_C}, \quad \text{and}$$

$$\lim_{\sigma^2 \to 0} [M_E / M_W] = 1 + \theta_V .$$

Considering the afore-mentioned information, the relationship between θ's, σ^2 and the relative performance in the Olympic games can be discussed as the following three cases. The case that the Western bloc country attaches higher value to medals ($\theta_V < 0$) is considered unrealistic and excluded.

(i)   When $0 < \theta_C < \theta_V$

When the Eastern bloc country's value mark-up is larger than its cost mark-up, and the former pays the higher cost than the latter, the first and second order differentiations of the relative performance (*f*) in equation (6) indicate that the relative performance is an increasing function of uncertainty with a diminishing rate. Figure A.1 delineates this function. As θ_V is larger than θ_C which is larger than zero, the lowest value of the relative performance *f* is larger than one. In this case, the Western country cannot catch up the Eastern country's performance permanently, even when uncertainty is completely removed.

(ii)   When $0 < \theta_V < \theta_C$

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This is the case that the Eastern bloc country attaches higher value to medals, however, its cost mark-up is higher than its value mark-up, representing the inefficiency in medal production. Figure A.2 indicates that the value of f can be smaller than one (meaning that the Western bloc country performs better) when uncertainty is sufficiently small (ie., $\sigma^2 < \sigma_c^2$). The critical magnitude of uncertainty, where the Western bloc country catches up the Eastern bloc country in the Olympic competition, is found to be

$$\sigma_c^2 = \frac{(\theta_C - \theta_V)c_W}{\gamma \theta_V} .$$

This equation points out that the magnitude of uncertainty that makes the two countries' performance the same will be smaller as the value that the Eastern bloc country attaches to medals is higher or the country is more risk averse.

The condition for f to be larger than one, that is $\sigma_c^2 > \frac{(\theta_C - \theta_V)c_W}{\gamma \theta_V}$, is exactly the same as the condition mentioned in the text for f to be larger than one under uncertainty, which is $\theta_V > \left[\frac{c_W}{\gamma \sigma^2 + c_W} \right] \theta_c$.

(iii)   When (-1 <) $\theta_C < 0 < \theta_V$

The Eastern bloc country may pay lower costs to produce medals, due to some reasons such as the lower labor cost. It is straightforward that the Eastern bloc country produces more medals in this case as it attaches higher values to medals and pays lower costs. Figure A.3 shows the change in the relative performance with respect to the changes in uncertainty. If the production of medals is more efficient in the Eastern bloc (ie., $\theta_C < 0$ or $c_E < c_W$), the relative performance f is a decreasing function of σ^2 (uncertainty) with an increasing rate, as shown from the first and second order differentiations of equation (6). It implies that, as uncertainty increases, the Eastern bloc country, which pays relatively less costs, reduces its medal production more rapidly than the Western counterpart does. Consequently, as uncertainty increases, the relative performance decreases and eventually converges to (1 + θ_V). The Western bloc cannot catch up the Eastern bloc as the value mark-up of the Eastern

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bloc is larger than zero (ie., $1 + \theta_V > 1$), even when uncertainty is infinitely large. This result is contrary to those discussed in the text. However, as it is not likely that the Eastern bloc country, which is centrally planned and produces more medals than the optimal number determined by the market mechanism, produces medals more efficiently, this case is excluded in the text.

Relative Performance and the Range of Value Mark-up

The range of θ_V that makes the relative performance f larger than one (ie., the Eastern bloc county performs better) is graphically presented in Figure A.4, in particular for θ_C being greater than zero. As equation (6) shows, f is a linear function of θ_V, where both the slope and the intercept are $\dfrac{\gamma \sigma^2 + c_W}{\gamma \sigma^2 + (1+\theta_C)c_W}$. As uncertainty reduces, both the slope and intercept decrease and, when there is no uncertainty (ie., $\sigma^2 = 0$), both the slope and intercept become $[1/(1+\theta_C)]$. The result indicates that under certainty the Eastern bloc country performs better if $\theta_V > \theta_C$, which is intuitively appealing. In contrast, under uncertainty ($\sigma^2 > 0$), the Eastern bloc country's performance is better than the Western counterpart (ie., $f > 1$) if $\theta_V > [\dfrac{c_W}{\gamma \sigma^2 + c_W}] \theta_C$

or $\sigma_c^2 > \dfrac{(\theta_C - \theta_V)c_W}{\gamma \theta_V}$. As expected, these conditions coincide with case (ii) mentioned above.

It is also reconfirmed that the range of θ_V that makes the ratio f greater than one, that is $[\theta_C - [\dfrac{c_W}{\gamma \sigma^2 + c_W}] \theta_C]$, increases (or decreases) as uncertainty increases (or decreases).
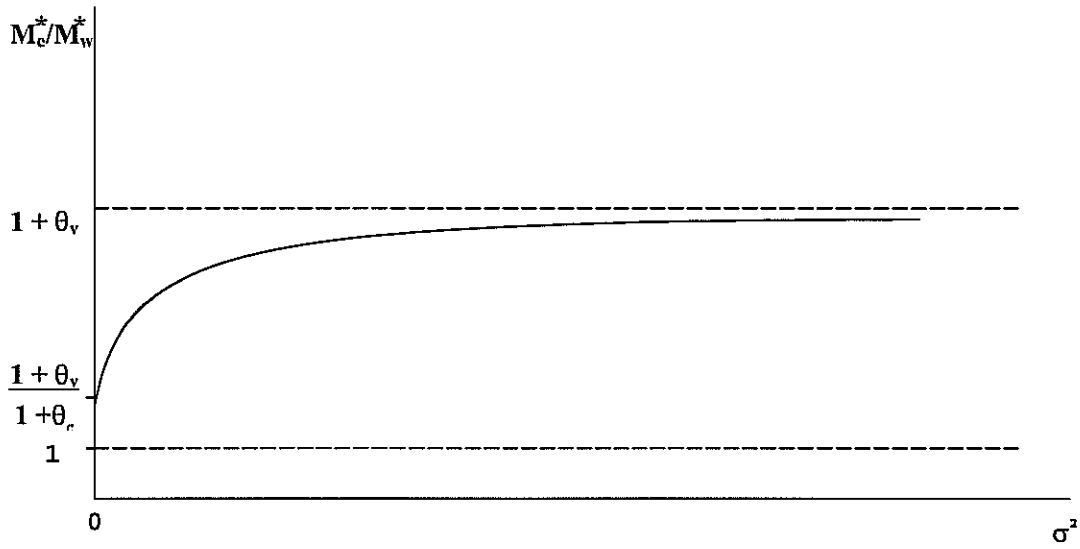
FIGURE A.1: RELATIVE PERFORMANCE, MARK-UPS AND UNCERTAINTY (WHEN $0 < \theta_c < \theta_v$)
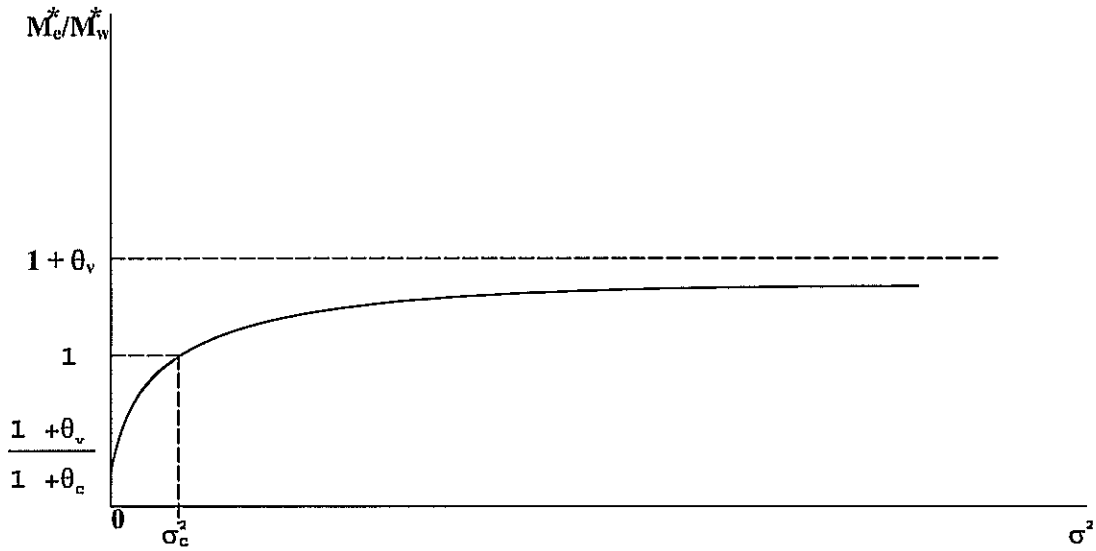

FIGURE A.2: RELATIVE PERFORMANCE, MARK-UPS AND UNCERTAINTY (WHEN $0 < \theta_v < \theta_c$)
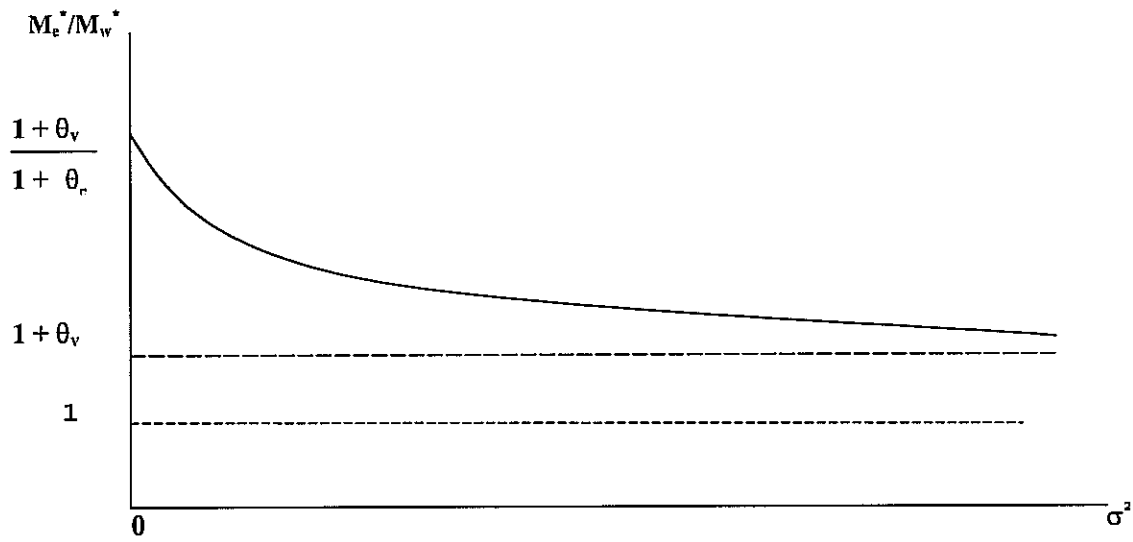
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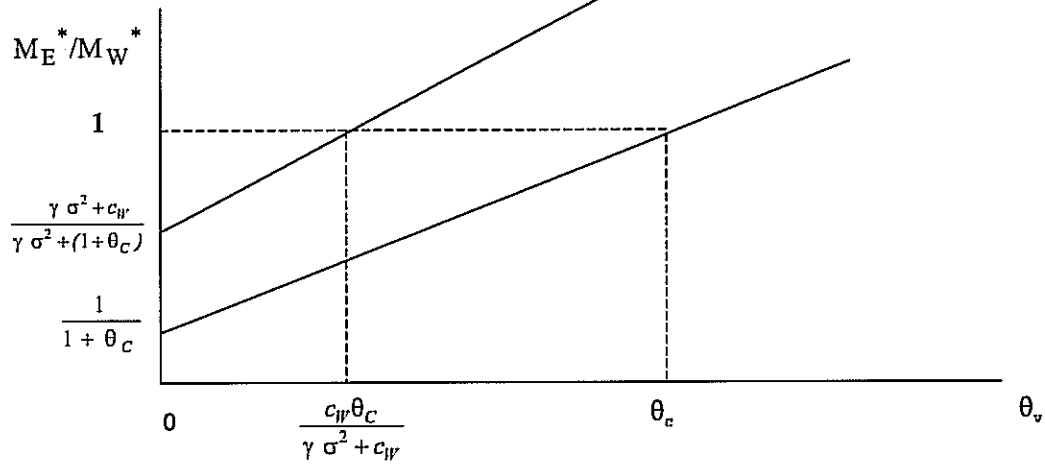FIGURE A.3: RELATIVE PERFORMANCE, MARK-UPS AND UNCERTAINTY (WHEN $\theta_C < 0 < \theta_V$)

FIGURE A.4: RELATIVE PERFORMANCE AND MARK-UP RANGE

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