4 MULTI-SCALE INTEGRATED ANALYSIS OF SOCIETAL METABOLISM AND JEVONS' PARADOX FOR ROMANIA, BULGARIA, HUNGARY AND POLAND*

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Abstract

International agencies and national governments base their energy strategies on gross domestic product (GDP) growth rates and energy intensity goals. Given the complexity of the transition process from a command economy to an open-market economy in Central and Eastern Europe, this paper argues that the use of energy intensity as an objective for the energy policy is overly simplified and suggests that a more accurate governance tool is the combined analysis of economic labor productivity and exosomatic metabolic rates as defined in the Multi-Scale Integrated Assessment of Societal Metabolism approach. The cases of structural change in Bulgaria, Poland, Hungary, and Romania are used to investigate the aforementioned claim.

Keywords: energy, Jevons' paradox, transitional economies, societal metabolism, MSIASM, Romania

JEL: O13, P28, Q4, N7

1. Introduction

The year 1989 was the beginning of the transition of Central and Eastern European (CEE) command economies towards an open-market system which necessitated many changes in the operations of the CEE countries. In particular, the energy sector, the vital link in the economic chain, experienced a large change in structure. Under the socialist/communist rule, the emphasis was on developing the energy-intensive industrial sector, causing the use of energy per unit of output to be much

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higher than in the West (Gros and Steinherr, 2004). For example, in 1989 West Germany used 8MJ per dollar produced in the industrial sector while Bulgaria, Hungary, Poland, and Romania used 47MJ, 46MJ, 79MJ, and 56MJ respectively (Manser 1993, p.128). According to Manser (1993, p.126) the inherited energy problems in the CEE countries included, among others, subsidized prices, the lack of incentives and mechanisms for energy conservation, and centralized control of electricity generation. These problems encouraged inefficient energy use. Further complicating matters was the dependence of CEE countries on imported (mainly form Russia) energy sources. To provide some perspective consider that in 2002 the dependence on energy imports was 58% for Bulgaria, 35% for Poland, 71% for Hungary, and 30% for Romania (Losoncz, 2006). As part of their ascension and membership into the European Union, all four Eastern European transitional countries were required to reduce national energy consumption and increase energy efficiency at the end-use in order to reach the energy intensity levels of the other members.

The question "will public policies promoting energy efficiency actually reduce energy consumption?" was addressed in part one of this two-part series "Energy Consumption in Transitional Economies (Part I): Jevons' Paradox for Romania, Bulgaria, Hungary, and Poland." In this paper, we will further argue that the Jevons' Paradox may exist for these four transitional countries. The rest of the paper is organized in the following way: Section 2 describes the Multi-Scale Integrated Analysis of Societal Metabolism (MSIASM) approach that is used to provide more in-depth analysis of why Jevons' Paradox may be occurring in the study countries. Section 3 provides the results and analysis of the MSIASM approach. Lastly, Section 4 discusses the implications of the findings and concludes the paper.

2. Beyond Energy Intensity: The MSIASM Model

As illustrated in Figure 1, Poland, Hungary, and Bulgaria each exhibit a small decrease in total primary energy consumption, and Romania had a rather large decrease over the period studied. Figure 2 shows the pattern of energy intensity for each of the four countries.

Figure 1

Total Primary Energy Consumption: 1990 – 2003

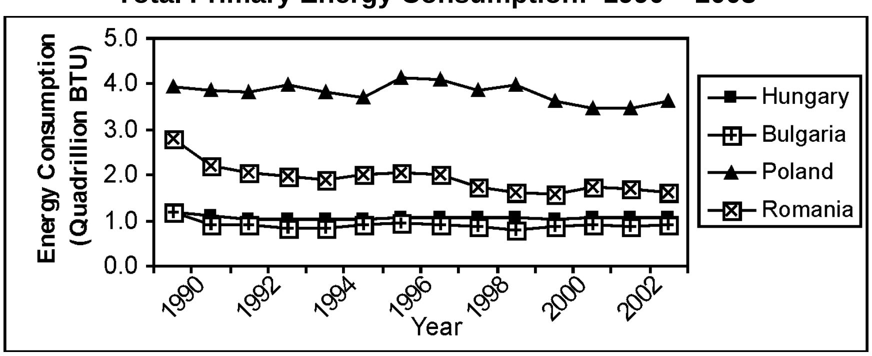
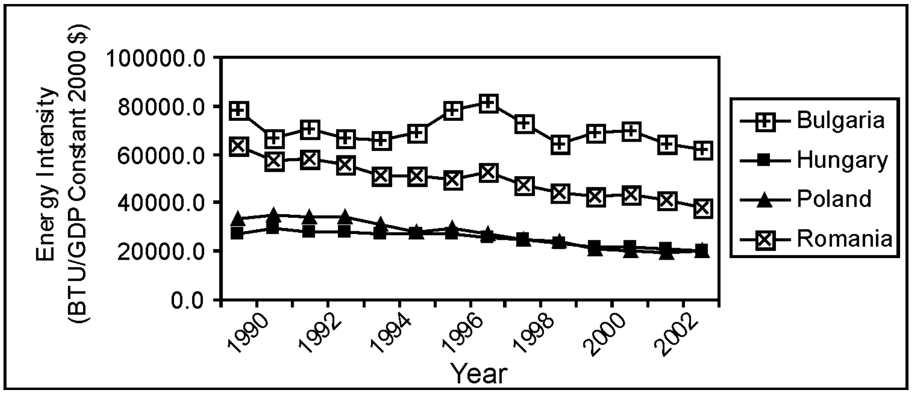


Figure 2

Energy Intensity: 1990 – 2003



As shown, each of the four countries has had a major decrease in energy intensity over the period studied, with Romania having the largest decline. A quick examination of the data would lead one to conclude that Jevons' Paradox does not exist for the four countries examined in this paper, as total primary energy consumption has decreased at the same time as energy intensity.

However, quick observational analysis can often be misleading and deeper statistical techniques are necessary. In Part I, "Energy Consumption in Transitional Economies (Part I): Jevons' Paradox for Romania, Bulgaria, Hungary, and Poland", we used generalized autoregressive conditional heteroskedasticity models (GARCH(1,1)) to analyze time-series data and we provided evidence that Jevons' Paradox may exist for the four countries studied.

However, the use of energy intensity is often questioned as an appropriate proxy for efficiency improvements. Energy intensity does not account for factors that do not reflect improvements in energy efficiency, specifically structural and behavioral effects, or perhaps even effects humans have little control over. Structural changes could potentially create a large change in energy intensity as end-user sectors alter the composition of an economy. Likewise, behavioral factors such as people using computers for personal communications rather than writing letters. Finally, changes that humans have little control over, such as the weather, can have major affects on energy intensity. Thus, energy intensity contains little information on the underlying energy consumption changes in an economy. One possible alternative to using energy intensity as a proxy for energy efficiency is to use the Multi-Scale Integrated Analysis of Societal Metabolism (MSIASM) approach. MSIASM allows for the structure of complex systems, such as an economy, to be analyzed. Therefore, different sectors of an economy can be disaggregated into various levels of economic and human activity to obtain a more comprehensive understanding of changes within an economy; in other words a hierarchical analysis. The conceptual parameters of the MSIASM approach were developed by Giampietro and Mayumi (2000a, 2000b), and we encourage the reader to refer to these papers for an in-depth explanation of MSIASM.

Socioeconomic systems can be analyzed on three hierarchical levels. (1) The national level (*level n*), is the most comprehensive. (2) The next level (*level n-1*) represents the division between the production compartment, named paid work (PW), and the consumption compartment representing households (HH). Finally, (3) the lower level (*level n-2*) is the partition of the production compartment into the four main sectors: agriculture (AG), productive sector (PS), transportation and communications (TC), and services, government and other (SG), while the consumption compartment can be seen as the sum of urban households and rural households. For the purposes of this paper, we will not discuss *level n-2* for the consumption compartment.

The hierarchical levels described above require that variables measuring the metabolism of an economy be used for analysis. We use two primary variables with all other variables centered around. The first variable is Total Human Activity (THA_i) which represents the number of hours a population spends on an activity (Giampietro et al., 2000). The theoretical underpinning of this variable is to provide a detailed examination of how people divide their time among the different sectors. Each person has 8760 hours (24 hours for 365 days) available yearly. THA corresponds to the whole population (*level n*). At the lower level (*level n-1*), total human activity is split between paid work (HA_{PW}) and household activities (HA_{HH}). Finally, at the lowest level (*level n-2*), human activity for paid work is split among the various sectors: agriculture (HA_{AG}), production (HA_{PS}), services and government (HA_{SG}), and transportation and communications (HA_{TC}). The time spent for paid work for each sector is a product of the number of workers in each sector and the number of hours worked per year. The second primary variable is Total Energy Throughput (TET) which represents the final consumption of energy (in Joules/year) and which is split between the Energy Throughput (ET_i) consumed at each of the levels *n-1* or *n-2*.

The other variables used in this paper are derived using the two primary variables described above. The Saturation Index for Human Activity ($SIHA_i$) is the percentage of total human activity (THA) that is allocated to a certain compartment or sector (HA_i). The Saturation Index of Exosomatic Energy Throughput ($SIET_i$) is the fraction of TET consumed in a certain compartment or sector (ET_i). The Exosomatic Metabolic Rate (EMR) is the rate of consumption of exosomatic energy per unit of human activity. At level *n*, the Exosomatic Metabolic Rate Societal Average (EMR_{SA}) is the ratio between TET and THA. At levels *n-1* and *n-2,* EMR_i is the ratio between the corresponding ET_i and HA_i. This intensive variable is extremely important since it allows for comparisons between different hierarchical levels or for the same hierarchical level but belonging to systems of different sizes (Giampietro 2005). Furthermore, EMR_i reveals the intensity at which a population consumes energy per hour of human activity. The last variable used in this paper for the MSIASM analysis is Economic Labor Productivity (ELP_i). ELP_i illustrates the ability of productive sectors to produce GDP and is the ratio between the value of the production in the productive sector (GDP) and the number of hours of human activity used in that sector (HA_{PW}).

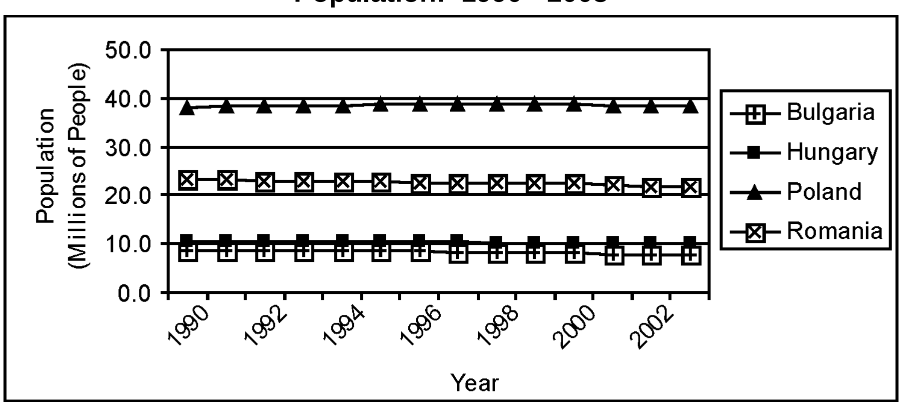
3. MSIASM Results

The variables just described allow one to gather a considerable amount of in-depth knowledge about a population. However, some historical background is always useful to put the analysis in context. Therefore, some important facts about the four study countries will be mentioned as each country has experienced a unique transition. Hungary has a different history from other three countries in this paper, as well as the other Central and Eastern European countries, because limited political liberalization and economic reforms occurred there during the 1980s, with the major reforms occurring after 1988. Due to this earlier understanding in relation to the other transitional economies in the region, it is only natural that Hungary experienced a smoother transition. In stark contrast, Bulgaria suffered through a major economic recession in 1996, only to have their currency fixed to the German Deutschmark in 1997. These two years of economic uncertainty for Bulgaria will clearly be visible in the following results and analyses. However, a micro level analysis of the changes that have occurred in the Bulgarian economy will not be discussed here, as it is not the focus of the paper. On the other hand, the Polish experience has not been nearly as turbulent. Poland was the first country in Eastern Europe to have a non-Communist government freely elected in 1989. Romania has distinguished itself as being the only Eastern European country to undergo a violent revolution ending with the summary execution of its head of state. Thus, the four study countries have had diverse histories that have deeply affected their individual transition paths.

The starting point of the MSIASM analysis will be Total Human Activity, which is directly influenced by population. Between 1990 and 2004, with the exception of Poland which had a slight population (and, accordingly, Total Human Activity THA) increase, the population of the other three countries has decreased, as shown in Figure 3. This negative population growth for Hungary, Bulgaria, and Romania has left those countries with an aging population, which can be a behavioral change to an economy (i.e. the elderly like to keep their houses warmer in the winter).

Figure 3

Population: 1990 - 2003



The next stage in the MSIASM analysis is to examine TET. As was illustrated in Figure 1, all four countries had alternating periods of increasing and decreasing TET. The oscillations were more powerful for Romania and Poland and dampened for Bulgaria and Hungary. Prior to the 1989 revolution, 45% of Romanian employment was in the productive sector that accounted for 60% of GDP. After the revolution, the restructuring of the Romanian antiquated energy and industrial sectors required the privatization or shutdown of inefficient factories and plants, a change that required time to be effective. This restructuring enabled Romania to reduce their TET by 39% from 1990 to 2000. The situation in Poland was similar with 38% of the employment in the productive sector. In Bulgaria and Hungary, productive sector employment accounted only for 33% and 30% respectively (CIA Wold Factbook 1989). Overall, from 1990 to 2000, Bulgaria managed to reduce strongly their TET by 47%. During that same period, Hungary had a 17% reduction in TET and Poland a mere 6%. In the following years, TET increased in all four countries.

Now that the two main MSIASM variables have been calculated, the hierarchical analysis can be conducted. Level *n-1* is used to provide some insight into why the four countries differ in their final energy consumption. Based upon the shape of the curves for ET_{PW} and ET_{HH}, shown in Figures 4 and 5, the restructuring of the Romanian and Polish economies impacted final energy consumption much more than in Bulgaria (mild variations) and Hungary (very smooth transition). These patterns are due in large part from the difficulties in economic transition**.** For example, the effect of the 1996-1997 shock in Bulgaria is easily visible in reduction of energy consumption for paid work. Romania and Poland experienced similar changes in the productive use of energy. However, just after the revolution, between 1990 and 1992, Romania did experience a drastic reduction in industrial energy consumption as economic reform and restructuring occurred (57% compared to only 17% for Poland). One other divergence occurred in household energy consumption after 1997 due to the liberalization of energy prices in Romania.

Figure 4

Exosomatic Throughput in the Paid Work Sector

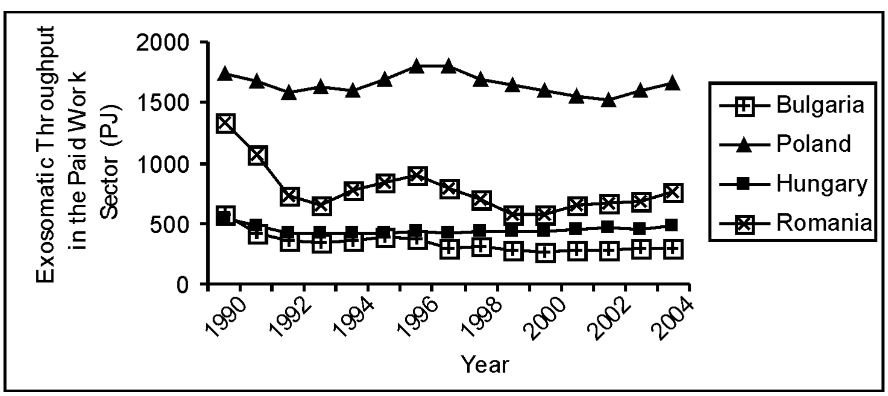
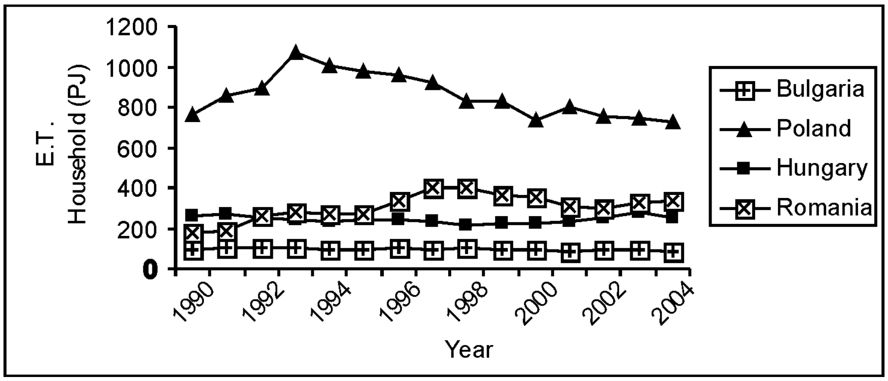


Figure 5

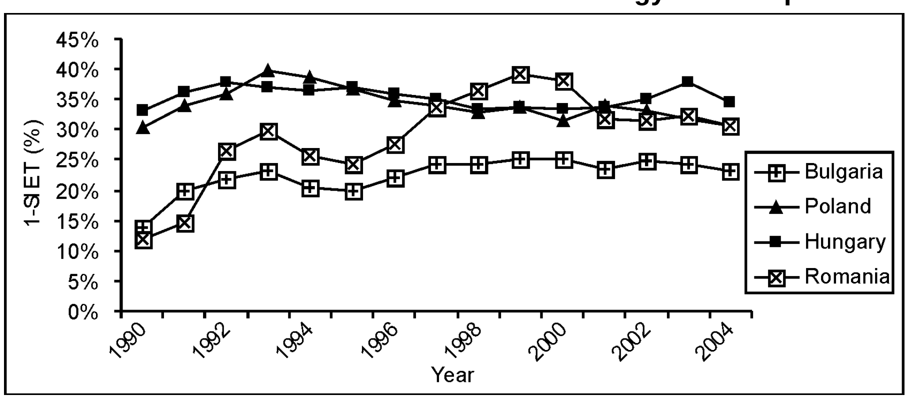
Exosomatic Throughput in Households



The share of the household sector in final energy consumption (1-SIET in Figure 6) followed a similar pattern for both Poland and Hungary, while Romania and Bulgaria exhibited different consumption paths.

Figure 6

Share of the Household Sector in Final Energy Consumption



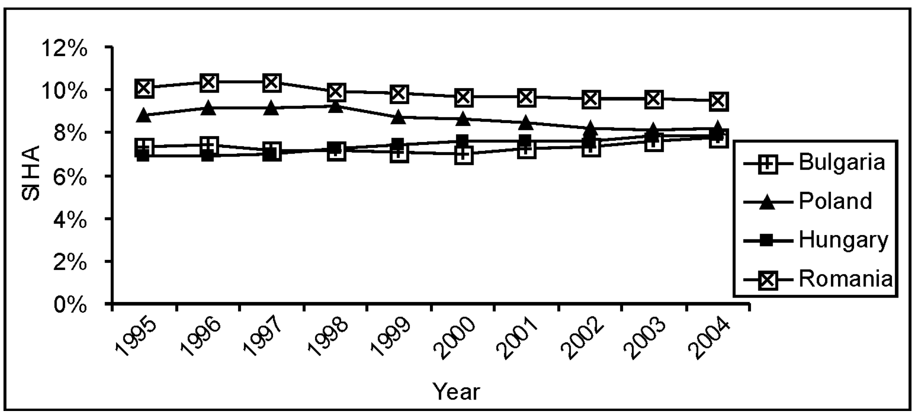
As shown in Figure 6 Romania and Bulgaria started the period of transition from similar levels (14% in Bulgaria and 12% in Romania) while Poland and Hungary started at a much higher magnitude, more than double what Bulgaria and Romania experienced (30% in Poland and 33% in Hungary). ET_{HH} provides an indication of the levels of the deprivation, by the starting point on the graph, which citizens had to endure under the different pre-revolution regimes. As shown in the graph, Bulgarians and Romanians were treated much worse by their leaders than the Polish or Hungarians. Furthermore, Figure 5 illustrates the level of improvement for Romanian and Bulgarian households after fifteen years of economic transformation, with ET_{HH} growing by 19% and 9% respectively. In comparison, ET_{HH} increased only 1% in both Poland and Hungary.

Due to a change in Hungary and Poland in 1994 of the survey methods for calculating the number of employed people by economic activity, the following intensive variables will only be examined for the 1995-2004 period. As discussed previously, the MSIASM approach will be used to go beyond energy intensity in order to obtain an understanding of the complexities associated with the interconnectedness associated with the demand for energy in each sector of an economy. From the previous country-analysis of energy intensity (Figure 2) it was shown that from 1995-2004 Bulgaria reduced its energy intensity by 11%, Poland by 30%, Hungary by 24%, and Romania by 26%. While these are impressive gains, they provide little in-depth understanding of the evolution of these economies during this period.

Therefore, to obtain the understanding of energy intensity that is necessary, $SIHA_{PW,}$ EMR_{SA}, and ELP_{PW} are used. As shown in Figure 7, from 1995 to 2004 $SIHA_{PW}$ increased by 1% for Bulgaria and Hungary; from 7% to 8%. The likely reason for this increase is that people in these countries are working more hours.

Figure 7

Saturation Index for Human Activity in Paid Work



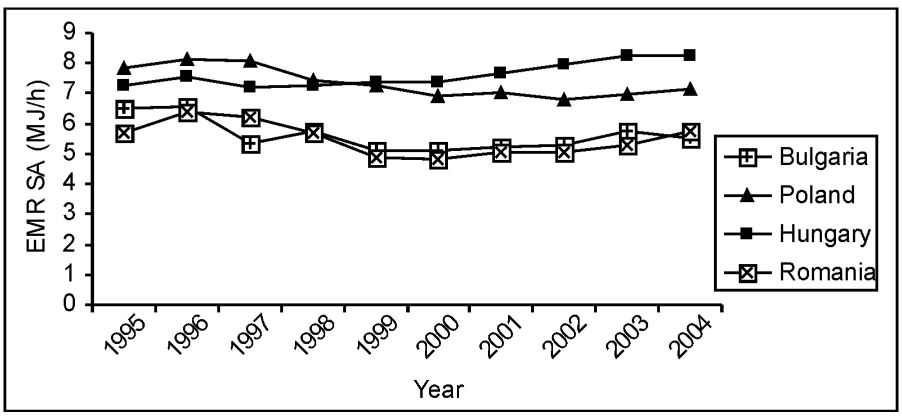
For example, the statutory maximum number of hours an employee can work per day is twelve, and the maximum number of hours an employee can work per week is forty-eight; both amongst the highest in Europe. Additionally, Hungarian law permits a close family member to be employed for up to sixty hours (Világgazdaság, 2007). There are several reasons for the average weekly working hours to be so high in Hungary and Bulgaria. First, the younger age groups in these countries work the longest. For example, 32% of Bulgarians 18-25 years of age work 45-60 hours per week and 8% work more than 60 hours per week. In comparison, 28% of Bulgarians 36-45 years of age work 45-60 hours and 6% work more than 60 hours (Eurofound, 2005). Second, people with lower education must work longer hours to obtain a sufficient income to live. Lastly, the revolutions provided for a larger percentage of people the opportunity to be self-employed, and these people typically work long hours. For example, in Bulgaria 33% of the self-employed without employees work more than 60 hours and 47% work 45-60 hours per week (Eurofound, 2005).

In Poland and Romania the opposite situation occurred, $SIHA_{PW}$ decreased by 1%, from 9% to 8% in Poland and from 10% to 9% in Romania. The likely reason for this result is a decrease of the population due to a decrease in the birth rates in these countries. In addition, both of these countries experienced a large amount of people migrating to EU countries in search of employment. Another likely reason for the $SIHA_{PW}$ decline in Romania is an increased worker participation in the informal economy. For example, the major source of household income in Romania is from the household and social economy. Even more, the cash economy (estimated to be 20% in 1998) in Romania was important in the early 1990s but has declined over time as the household economy has increased, indicating that the formal economy in that country has had the most problems since the revolution (Wallace, Haerpfer, and Latcheva, 2004). In Poland, approximately 20% of unregistered laborers are working full-time in the informal economy (Gorzynski, 2004). Additionally, Poland has experienced rising unemployment and a decrease in the number of jobs during this period contributing to the informal economy (Wallace, Haerpfer, and Latcheva, 2004).

In the MSIASM approach an alternative to energy intensity is EMR (Figure 8).

Figure 8

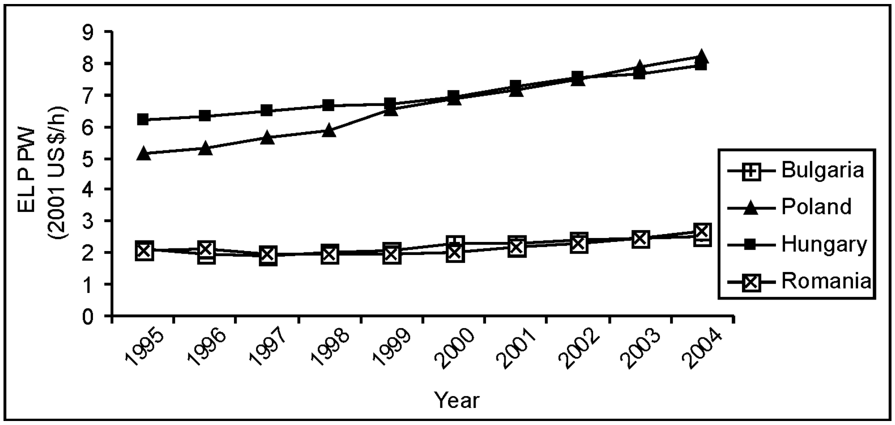
Societal Average of Exosomatic Metabolic Rate



Analysis of the four study countries finds that there are two distinct patterns. Hungary and Poland had similar energy intensities (Figure 2) between 1995 and 1997, and then diverged from one another. During this period, Poland had a higher EMR_{SA} and a lower ELP (Figure 9), which compensated for the higher $SIHA_{PW}$ in comparison to Hungary. This finding indicates that even if Poland had a higher share of HA_{PW}, the lower levels of ELP and higher final energy consumption per hour of human activity made the country have comparable levels of energy intensity with Hungary. After 1997, even though both countries achieved nearly equal levels of GDP per hour of paid work activity, Poland decreased its EMR_{SA} more than Hungary, thus reducing $SIHA_{PW}$ more as well. These results indicate that after 1997 Poland became more energy efficient than Hungary, as evidenced by EMR and ELP.

Figure 9

Economic Labor Productivity for Paid Work

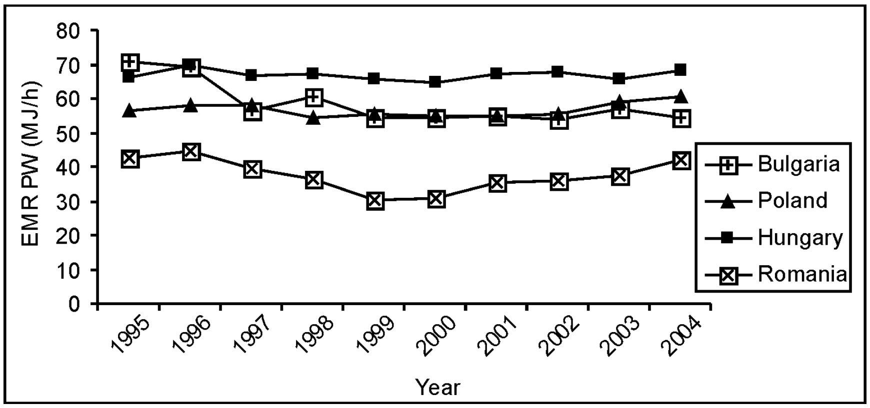


As Figures 8 and 9 illustrate, Romania and Bulgaria had nearly identical ELP levels from 1995 to 2004 and very similar EMR_{SA} between 1998 and 2002. However, as Figure 6 clearly shows, the two countries have a large deviation from one another for the percentage of energy consumption by the household. The reason for this divergence is that Romania has a higher percentage (1% to 3%) of $SIHA_{PW}$. Since the productive sector is the most energy intensive, the small difference in $SIHA_{PW}$ causes the energy intensity discrepancy between the two countries. Therefore, one can conclude that if Bulgaria is to achieve the same level of energy efficiency as Romania then that country must increase its employment ratio in total population by creating more employment opportunities. Furthermore, if EMR_{SA} and ELP follow a similar trend, a more detailed analysis can be conducted by computing $SIHA_{PW}$ for each sector (productive, transportation, services, and agriculture). Then, the sector that is most conducive for job creation can be determined; each change in the size of a sector will affect its EMR_i and GDP, which in turn will affect energy intensity. Thus, finding the appropriate public-policies will be difficult due to the complexity of the situation.

The recognition that each of the four study countries has their own transition and energy sector strategies creates an opportunity for in-depth cross-country analyses that can be conducted at the *n-1* (PW and HH) and *n-2* levels for the paid work sector. At *level n-1,* the progression of the capitalization of the four economies over a decade (Figure 10 EMR_{PW}) and of the proxy for the material standard of living (Figure 11 EMR_{HH}) is presented. As shown in Figure 10, EMR_{PW} for both Bulgaria and Poland followed a similar path, while Hungary and Romania represent the upper and lower bounds respectively. The likely reason that Romania had such a small EMR_{PW} compared to the other three countries is that Bulgaria, Poland, and Hungary had more balanced reforms of the value-added generating sectors of their economies. Romania lagged behind the other three countries because reforms, such as the liberalization of energy prices and eliminating state monopolies, were delayed until the mid 1990s.

Figure 10

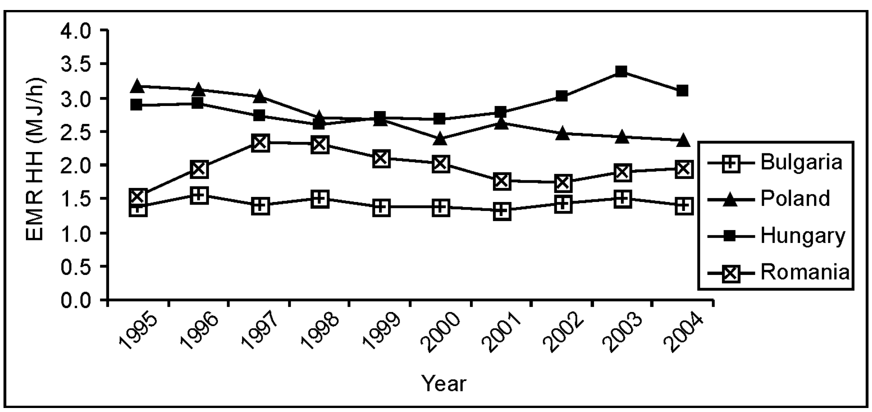
Exosomatic Metabolic Rate for Paid Work



As shown in the graphs of EMR_{HH} in Figure 11, there are substantial differences in the standard of living for the two existing member states of the EU and the two recently added members. Hungary and Poland have the best standards of living of the four study countries. Of particular interest is the apparent convergence that is occurring with Romania and Poland. As illustrated in Figure 11, Romania's standard of living has increased since 1995 while Poland's has decreased. Bulgaria has the lowest standard of living of the four countries, experiencing a stagnant standard of living since 1995.

Figure 11

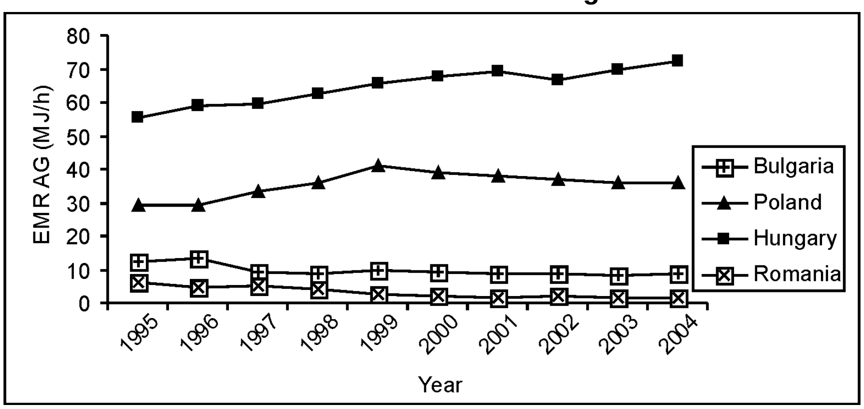
Exosomatic Metabolic Rate for Households



The analysis of *level n-1* has provided some very important information. However, to determine which sectors of the paid work compartment have been emphasized for development and which have not been stressed, analysis at *level n-2* needs to be conducted. Particular emphasis will be placed on the agricultural sector because it has undergone a major transformation during the transition and because of its importance to the four study countries. Prior to the 1989 revolutions, the agricultural sector separated the four countries into two groups; approximately 30% of the labor force in Romania and Poland was devoted to farming, while the figure was only 20% in Bulgaria and Hungary (CIA World Factbook 1989). However, in 1995, after just five years of transition, Hungary had an EMR_{AG} (Figure 12) double that of Poland, five times that of Bulgaria, and 9 times that of Romania. Of particular interest is that EMR_{AG} for Romania was the lowest of the four countries, and has been decreasing. In fact, Romania was the only country of the four to have their EMR_{AG} to fall to a level below that of the household sector. Prior to 2000, Romanian agricultural workers consumed energy per hour of work (EMR_{AG}) at a greater rate than the household level (EMR_{HH}). This trend has since reversed, with 1.54 MJ/h used in agriculture versus 1.76 MJ/h for households.

Figure 12

Exosomatic Metabolic Rate for Agriculture



However, since EMR is an intensive variable, further discussion of the extensive variables determining it is needed to obtain a more comprehensive understanding of the evolution of the sector. The energy throughput in Romania's agriculture (ET_{AG}) declined steadily since 1990. This trend is consistent with the property reform that returned agricultural land that was confiscated by the state under communist rule to the private landowners, many of whom did not have the means to maintain the energy intensive type of agriculture that was practiced; instead, only the most basic methods were used.

Thus, after the revolution, HA_{AG} increased until 2001, which is consistent with the reduction in industrial employment (Figure 13) and returning to agricultural work and services (Figure 14). In 2002, a drastic loss of 1.73Gh in EMR_{AG} started a period of reduction in the time spent on agricultural activities. The most likely reason for this change is that Romanian, and Polish, farmers migrated to Southern Europe (Italy, Portugal, Spain, and Greece) to find employment as of Romanian and Polish farmers as wage laborers in agriculture starting in 2001.

Figure 13

Exosomatic Metabolic Rate for the Productive Sector

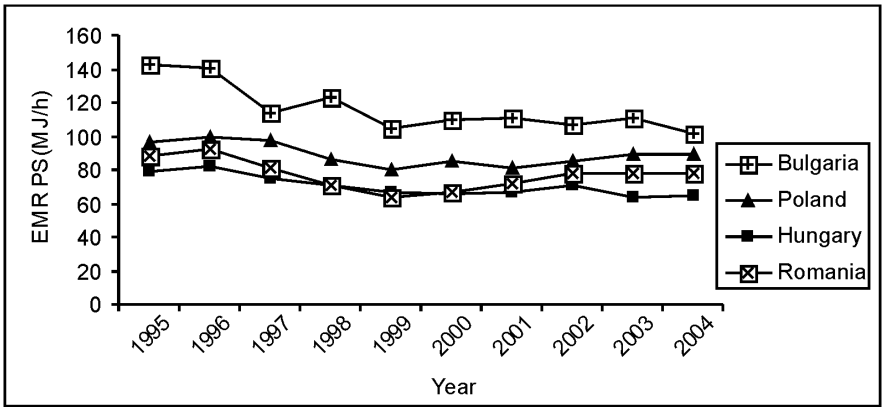
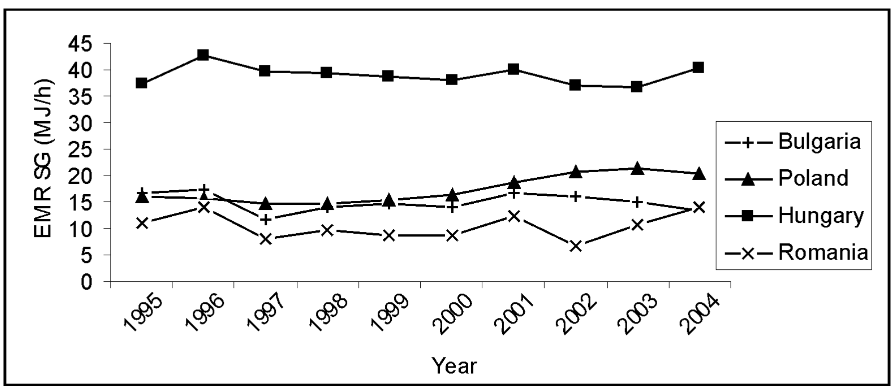


Figure 14

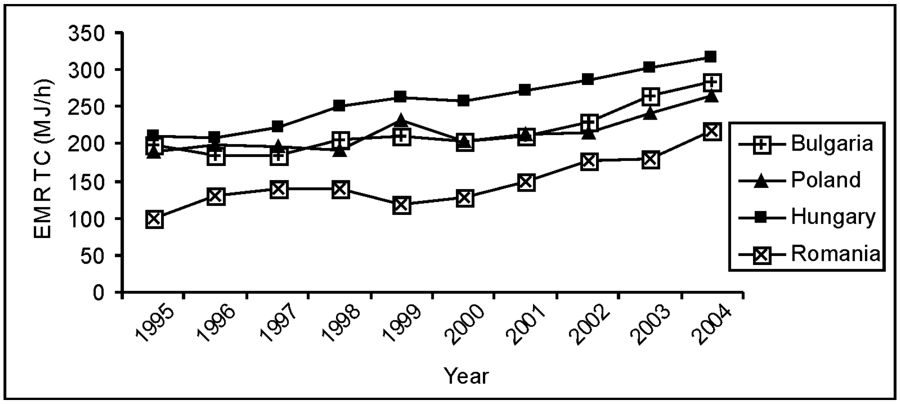
Exosomatic Metabolic Rate for the Service and Government Sectors



The last of the three sectors that is examined is the service sector. The strength of the service sector is directly associated with the degree of development of a country. As illustrated in Figure 14, after 2002 the service sector was emphasized in Hungary and Romania, although at very different levels of EMR_{SG}. This result is an indication of the maturity of these two economies, as the service sector is typically more prominent in countries with a stronger and more stabilized economy. However, Poland and Bulgaria have the opposite condition, exhibiting a service sector that has been de-emphasized. The most likely explanation for this result in those countries, and consistent with the previous analysis, is that there is a substantial amount of infrastructure development occurring in communications that is less energy intensive, as shown in Figure 15.

Figure 15

Exosomatic Metabolic Rate for the Transportation and Communication Sectors



4. Conclusions

Many policy-makers and other stakeholders believe that new technological advancements will reduce the amount of energy consumption; eliminating or strongly reducing any future energy crisis. This belief has lead to public-policies that promote these ideas. For example, the European Union has developed policy that all members must aim at achieving an energy savings of 9% by 2012 through energy efficiency measures, and have created initiatives like the ManagEnergy Initiative and the Sustainable Energy Europe Campaign 2005-2008 (European Commission, 2007). Moreover, new EU members are expected to reduce their energy intensity and energy consumption levels to those consistent with other member states. However, as Part I of this series showed Jevons' Paradox may exist for the four study countries.

This paper examined why Jevons' paradox may exist for these four CEE countries. The MSIASM analyses indicate that the urbanization of the population and the liberation of the economic markets are the reasons why Jevons' Paradox may exist. The growth rate of population for each of the countries is either negative or stagnant, suggesting that there is significant migration from the rural regions to the urban centers. This hypothesis is supported by the positive coefficients for population density in the regression results presented. The MSIASM results also provide support for this hypothesis. The share of the household sector in final energy consumption show increases for each of the study countries. Furthermore, only Hungary illustrates an increase in energy consumption in the agriculture sector, as indicated by their EMR_{AG}. Both of these measures can be viewed as a proxy for migration to the urban regions and for access to energy resources. The liberation of the markets in the countries also appears to be a factor, as indicated by the EMR in transportation and communications. This increase suggests the opening of communication markets for items such as cellular phones, the internet, and computers, all of which are energy intensive. The opening of the transportation sector allows more people to have access and the ability to purchase automotives. Both of these sectors were, in some fashion, restricted or prohibited under the previous communist rule. Therefore, these are the likely macro level reasons for the possible existence of Jevons' Paradox even if energy consumption and energy intensity has decreased over the study time period.

The micro level features as to why Jevons' paradox may exist for these countries were not discussed here because such an examination of the evolution of the structure of the regional and individual economies and societies would require a deep investigation of each of the study countries. Further research will attempt to provide this analysis. For example, the growth rates of each of the variables will be analyzed to determine if energy efficiency may be reducing energy consumption on a yearly basis. Analyses of this kind will provide additional support for the hypothesis outlined above as to the macroscopic existence of Jevons' Paradox. Energy consumption for each of the study countries will continue to change as they rapidly develop in a market economy. Thus, further analysis is necessary to fully comprehend the real causes for the potential existence of Jevons' paradox for the four CEE countries. In the two papers, Part I and Part II, a unique and important contribution to the understanding of how energy efficiency affects energy consumption was provided; analyzing both the macro and micro level concurrently.

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