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An application of MSIASM to Chinese exosomatic energy metabolism*

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Abstract: The methodology of Multi-Scale Integrated Analysis of Societal Metabolism (MSIASM) is applied to analyze the Chinese economy. This paper presents four tasks: (i) identifying a set of benchmarks that makes it possible to compare various characteristics of the Chinese economy with those of other country groups and the world (level) average; (ii) explaining the differences over the selected set of benchmarks, by looking at the characteristics of the various sub-sectors of the Chinese economy; (iii) understanding existing trends and future feasible future development paths for China by studying the existence of reciprocal constraints between the whole economy and its sub-sectors; and (iv) examining plausible future scenarios of development.

Keywords: China, Energy, Multi-Scale Integrated Analysis, Societal Metabolism, Sustainability.

JEL Codes: O11, O13, O53, Q01, Q57, Q58

1. INTRODUCTION

This paper presents an application of a methodology for multicriteria integrated analysis of economic development across multiple scales, which is named Multi-Scale Integrated Analysis of Societal Metabolism (MSIASM). Such a methodology is described in a companion paper by the same authors, also published in this Book of Proceedings.
This paper has two goals: (1) to show that the MSIASM scheme is effective in handling in an integrated way different types of data (belonging to different categories such as variables, parameters and constraints) using extensive and intensive variables, across different hierarchical levels; and (2) to provide a Multi-Scale Integrated Analysis of the trajectory of development for China. This includes the identification of possible constraints affecting the

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* An earlier version of this paper was presented at the 5th Biennial International Workshop *Advances in Energy Studies*, "Perspectives on Energy Future", hold in Porto Venere, Italy, 12th – 16th September 2006. There is a longer version of this article dealing with this issue and adding more information (based on the PhD thesis of Jesus Ramos-Martin): Ramos-Martin J., Giampietro, M., and Mayumi, K., 2007. On China's exosomatic energy metabolism: an application of multi-scale integrated analysis of societal metabolism (MSIASM) - *Ecological Economics* Vol 63(1): 174-191.

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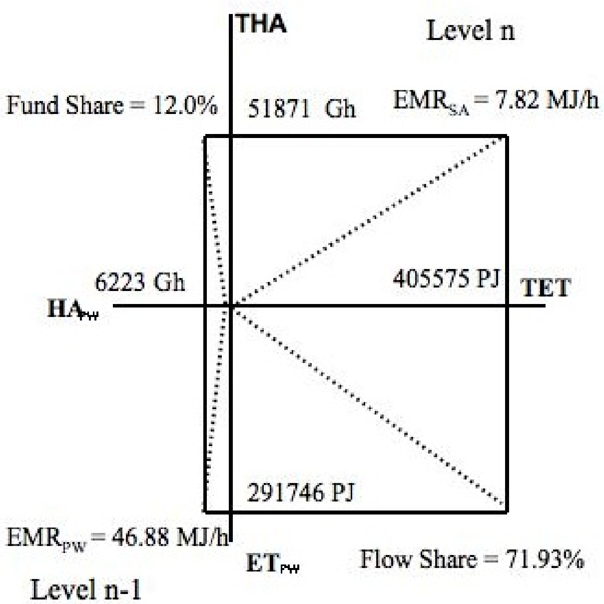
feasibility of considered scenarios and a characterization of future scenarios in relation to different dimensions and scales of analysis. The rationale and theory of MSIASM together with extensive variables and intensive variables are presented in another paper by the same authors in these proceedings (Giampietro et al. 2006).

The rest of the paper is structured as follows. Section 2 presents the results of our analysis, both on the interface world level/China level, and on the interface national level/sector level of the Chinese economy. Section 3 discusses the interface world level/national level, by considering possible future scenarios of development for China and the relative effect that the resulting characteristics of metabolism of China could have on world energy and material demand. Section 4 draws some conclusions.

2. COUNTRY GROUPS AND BENCHMARKS TO CHARACTERIZE AND CONTEXTUALIZE CHINA'S EXOSOMATIC ENERGY METABOLISM

Before getting into an analysis of China's exosomatic energy metabolism, we firstly propose a comparison of the characterization of the world economy against a set of 6 representative country groups, one of which is China.

We start with two representations of the world economy based on the MSIASM scheme in 1999. In this case, we are using a single definition of Fund (human activity) THA [Total Human Activity] and two definitions of Flows: (1) exosomatic energy – metabolized outside the human body (Georgescu-Roegen, 1975)– using as proxy variable TET [Total Exosomatic Throughput]; and (2) added value in the economy – proxy variable GDP [Gross Domestic Product]. Because of this double definition of flows, on the right of Fig. 1, there is a new category: ELP_{PW}, which is the Economic Labor Productivity (GDP divided by the amount of human labor hours in the paid work sectors). Therefore, Fig. 1 shows two representations of two kinds of dynamic budgets for the world economy: (i) THA (the total human time available for the world) is producing and consuming the flow of TET (the total exosomatic energy consumption for one year); and (ii) THA is producing and consuming GDP.



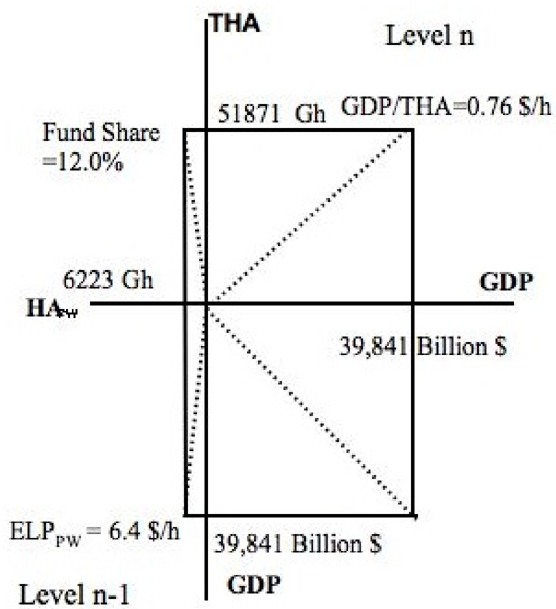


Figure 1: Flow-Fund Representation of two dynamic budgets for the world economy, 1999

We selected 6 country groups listed in Table 1: (#1) China; (#2) India; (#3) former-USSR; (#4) AUSCAN (Australia, USA and Canada); (#5) Rest of OECD countries; and (#6) Rest of the World to have a first comparison of the relative shape of the dynamic budget of these two flows against the fund.

The relative representations with the benchmarks determining the Impredicative Loop (the chicken-egg causality between demand and supply – Giampietro, 2003 – Chapter 7) for these 6 country groups together with the distribution of types of these country groups are given in Fig. 2. For the purpose of simplicity, only one flow-fund representation of each country

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Table 1 – Data set characterizing the typology of dynamic budget of the 6 country groups

	THA[a] Gh	HA_{PW}[b] Gh	TET[c] Pj	ET_{PW}[d] Pj	EMR_{PW}[e] Mj/h	EMR_{SA}[f] Mj/h	SI_{HA}[g]	SI_{ET}[h]
World	51,871	6,223	405,576	291,746	46.88	7.82	12.00%	71.93%
AUSCAN[i]	2,825	295[j]	109,503	83,005	281.25	38.77	10.45%	75.80%
Rest OECD	6,955	546[k]	109,088	82,038	150.15	15.68	7.86%	75.20%
India	8,738	945[l]	20,081	10,759	11.38	2.30	10.82%	53.58%
China	10,982	2,020[m]	45,493	31,947	15.81	4.14	18.40%	70.22%
ex-USSR	2,545	216[n]	38,272	28,093	130.00	15.04	8.49%	73.40%
RoW[o]	19,827	2,200[p]	83,139	55,903	25.41	4.19	11.10%	67.24%

Sources: OECD (2002, 2004), ILO website (www.ilo.org), Ramos-Martin (2001), Giampietro and Mayumi (2000).

[a] Total Human Activity, in Giga hours. 1 Gh = 10^9 or 1 billion hours. Population x 8760 hours. Data on population from OECD (2002).
[b] Human Activity in the Paid Work sectors in Giga hours. PW sectors are those generating economic added value. PW = PS + SG + AG, where PS stands for Industry, Mining and Energy; SG for Services and Government; and AG for agriculture, as in Giampietro and Mayumi (2000b). HA_{PW} is generated from combining employment data with working hours. Data from Laborsta data base, ILO website (www.ilo.org).
[c] Total exosomatic Energy Throughput, in Peta Joules. 1 PJ = 10^15 Joules. We use Total Primary Energy Supply (TPES) for our calculations. Data on energy from OECD (2002).
[d] exosomatic Energy Throughput in the Paid Work sectors, in Peta Joules. That is, TET minus the energy consumed at the Household Sector (HH). For HH energy we use Residential Energy plus 50% of energy use at Transportation sector (our assumption, see Chapter 7 for the rationale). Disaggregated data on energy use by sectors from OECD (2002).
[e] Exosomatic Metabolic Rate of the Paid Work sectors, in Mega Joules per hour of activity.
$EMR_{PW} = ET_{PW} / HA_{PW}$. 1 MJ = 10^6 or 1 million Joules.
[f] Exosomatic Metabolic Rate, societal average, in Mega Joules per hour. EMR_{SA} = TET / THA.
[g] This is the fund ratio between HA_{PW} at level n-1 and THA at level n. This ratio indicates how much human labor is used in the paid work sectors compared with THA.
[h] This is the flow ratio between ET_{PW} at level n-1 and TET at level n. This ratio indicates how much energy is used in the paid work sectors compared with TET.
[i] Australia, USA, and Canada.
[j] Employment data from OECD Employment Outlook 2004. working hours per year based on ILO statistics:
1,600 h for Australia, 1,930 for USA, 1,645 for Canada.
[k] Employment data from OECD Employment Outlook 2004 - 1,700 hours for Total OECD, then deduction of AUSCAN.
[l] Employment data interpolated from ILO data for 1998, and 2000 - 1,800 hours per year.
[m] Employment from ILO. 8 hours a day x 7 days x 50 weeks.
[n] 1,800 hours per year.
[o] Rest of the World.
[p] Our assumption, based on ILO statistics. 45% of Economically Active Population, and 10% unemployment.
2,400 hours per year.

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group on two levels is shown in Fig. 2 (the one dealing with energy TET). It should be noted that the definition of the eight benchmarks (four extensive and four intensive categories) – see previous paper on MSIASM theory for more explanations - associated with the flow-fund representation can be used to determine another benchmark category EMR_{HH} (ET_{HH}/HA_{HH}) referring to the compartment of consumption. EMR_{HH} indicates the level of capitalization of the Household Sector. In order to be able to produce more an economy has to be able to consume more, and this requires more exosomatic energy per hour of human activity allocated in the Household sector. By utilizing these eight categories in terms of extensive and intensive variables it is possible to: (i) characterize each one of the 6 representative country groups; and (ii) define a profile of distribution of human activity in the world over these groups. In this way, it becomes possible to establish a relation between the

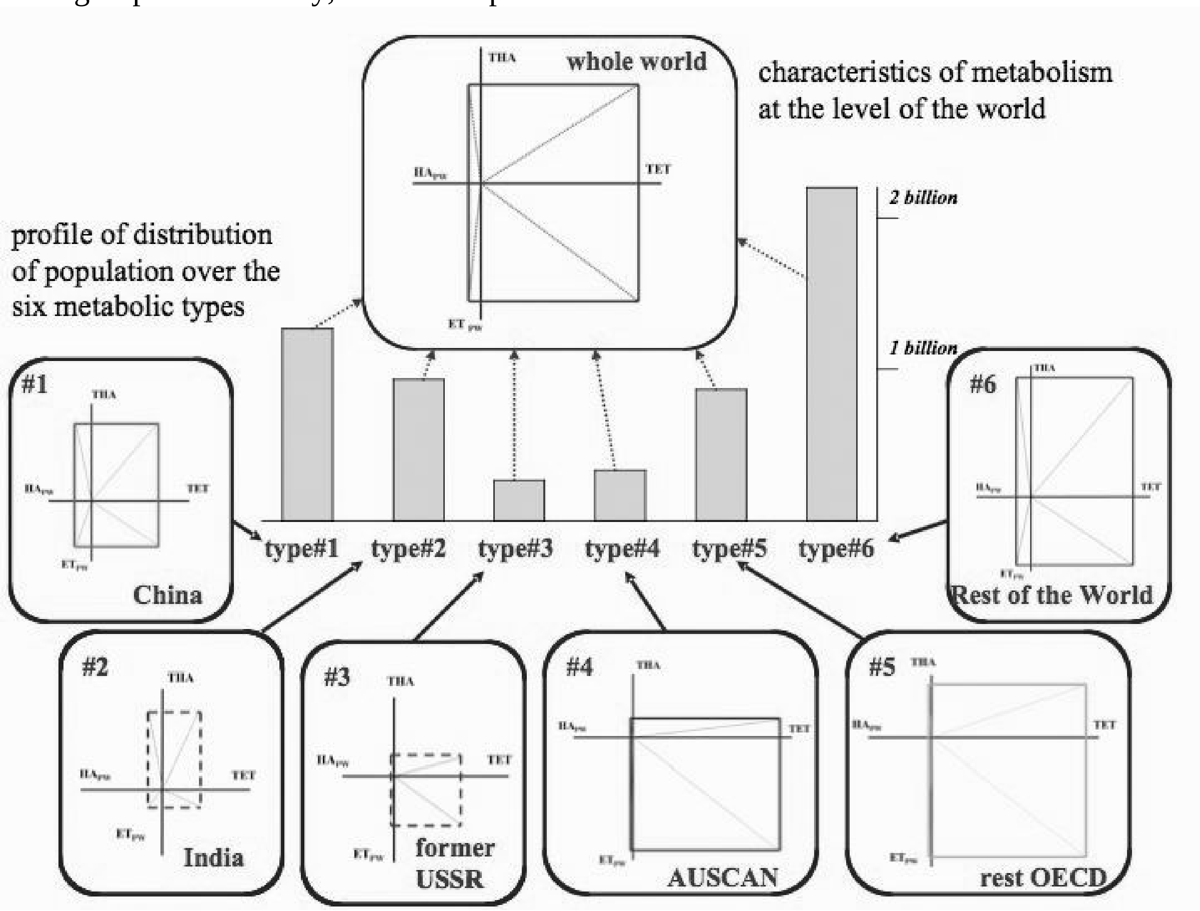

Fig. 2 World energy metabolism explained using the 6 typologies of country metabolism

overall characteristics of the world economy – e.g. total emission of GHG – and the specific characteristics of each one of the 6 groups. It is also possible to compare the exosomatic metabolic characteristics of one country group with those of other country groups. For example, useful benchmarks for studying China's exosomatic energy metabolism are compared with other country groups in Fig. 3, Fig. 4, and Fig. 5.

In Fig. 3 a new set of country groups are introduced: (i) USA, Canada, and Australia; (ii) OECD; (iii) Italy, Spain and Japan; (iv) Ecuador, Egypt and China. This new classification focuses more on population density, capital intensity and resource abundance. The biophysical energy intensity, EMR_{SA} (TET/THA), is compared among these new types of country groups in Fig. 3. Obviously, China's biophysical energy intensities are still much lower levels compared with those of USA, Canada and Australia. Fig. 4 shows EMR_{PW} and Fund Share (n-1/n) in 1999 for the same country groups. Fig. 5 shows EMR_{PW} and EMR_{HH} in 1999 for these groups. Now we can see an important characteristic of China's exosomatic energy metabolism which will be a severe constraint for China's further economic development. The value of EMR_{PW} for China is lower than the values found for Ecuador and Egypt. However, Fund Share (n-1/n) for China is 18.3%, much higher than those of Ecuador and Egypt. This Fund Share (n-1/n) is the ratio between HA_{PW} (human labor in paid work sectors) and THA (the total human time available). This anomaly can be explained by the adoption of the one-child-policy in China. The result is that now China is facing an extraordinary fraction of adults in its population. For the moment, this provides a comparative advantage in terms of cheap labor supply. However, how to secure a sufficient labor power supply to an economy specialized in labor intensive activities in the future is a critical issue, which will be touched upon later in this paper.

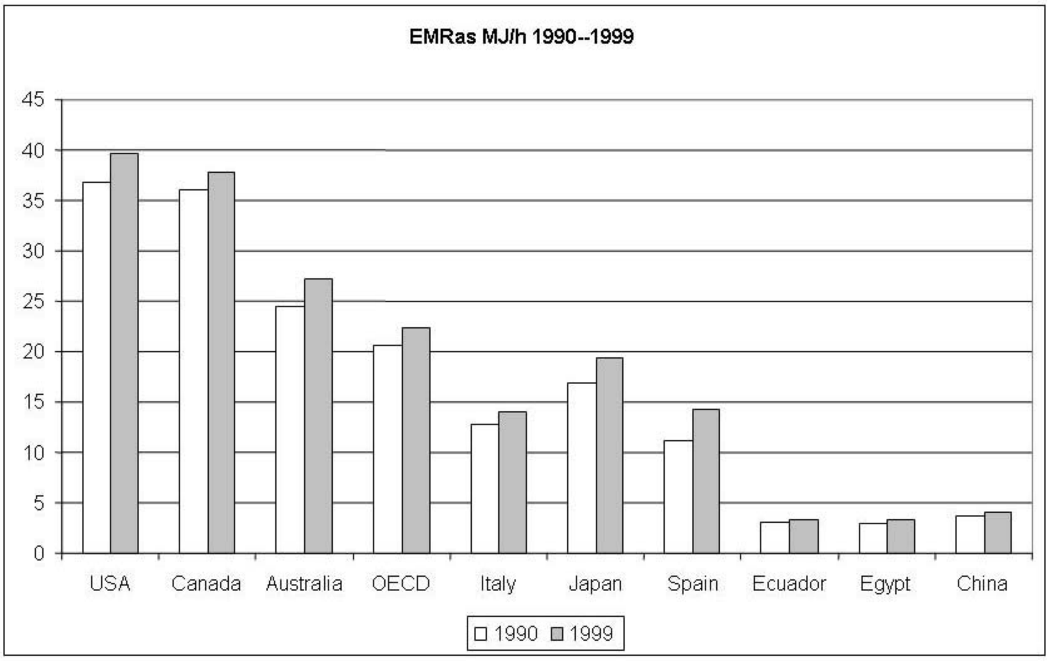

Figure 3: **EMR_{SA} for a selected group of countries, 1990 and 1999**

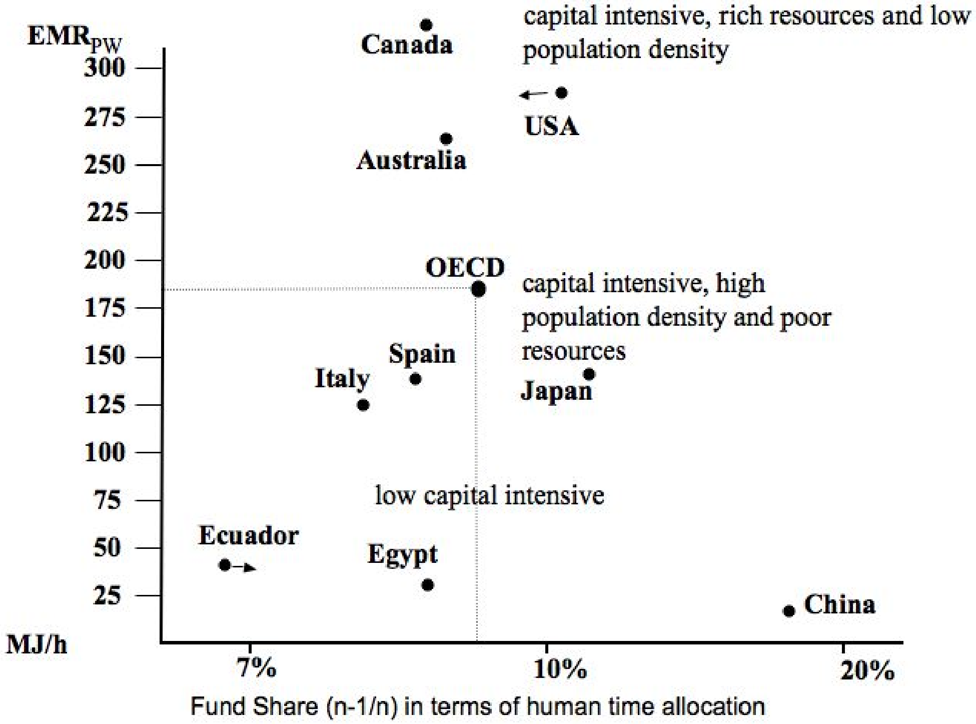

Figure 4: Fund Share (n-1/n) in terms of human time allocation 1999

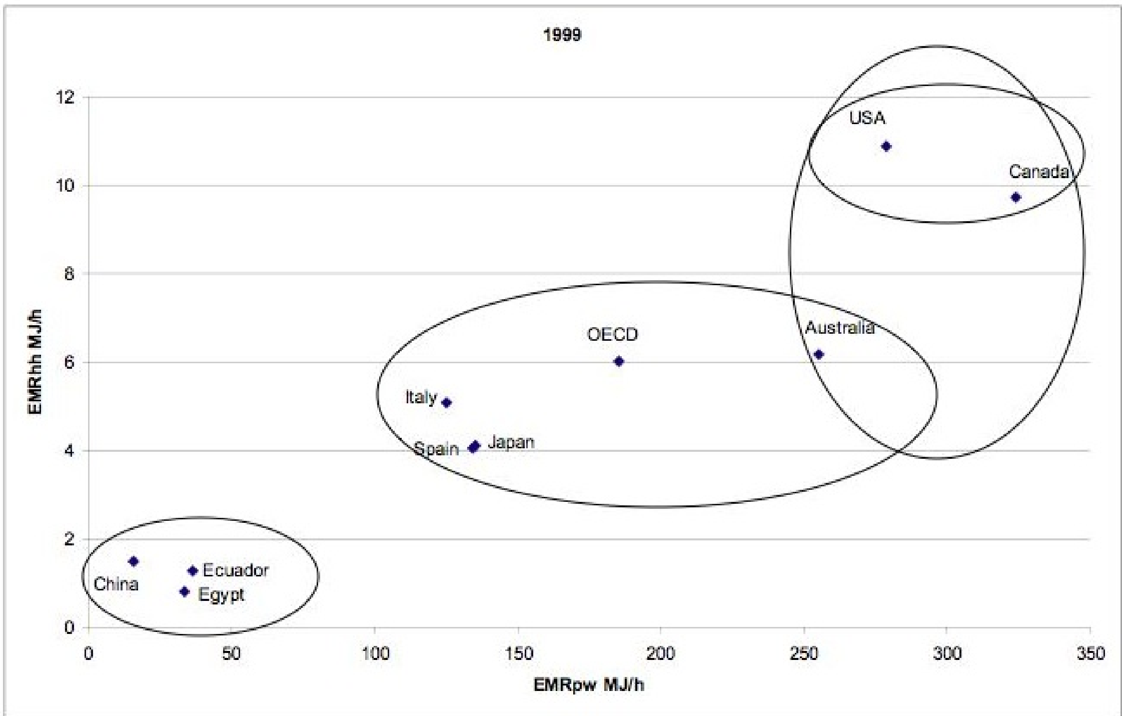

Figure 5: **EMR_{HH} and EMR_{PW} for a selected group of countries, 1999**

3. INTERFACE NATIONAL LEVEL/SECTOR LEVEL: CHARACTERIZING THE METABOLISM OF CHINA

Since the MSIASM scheme explicitly addresses the effects of demographic variables, we first check the evolution of population in the period analyzed. A flow-fund representation of the MSIASM scheme for China in 1999 is shown in Fig. 6.

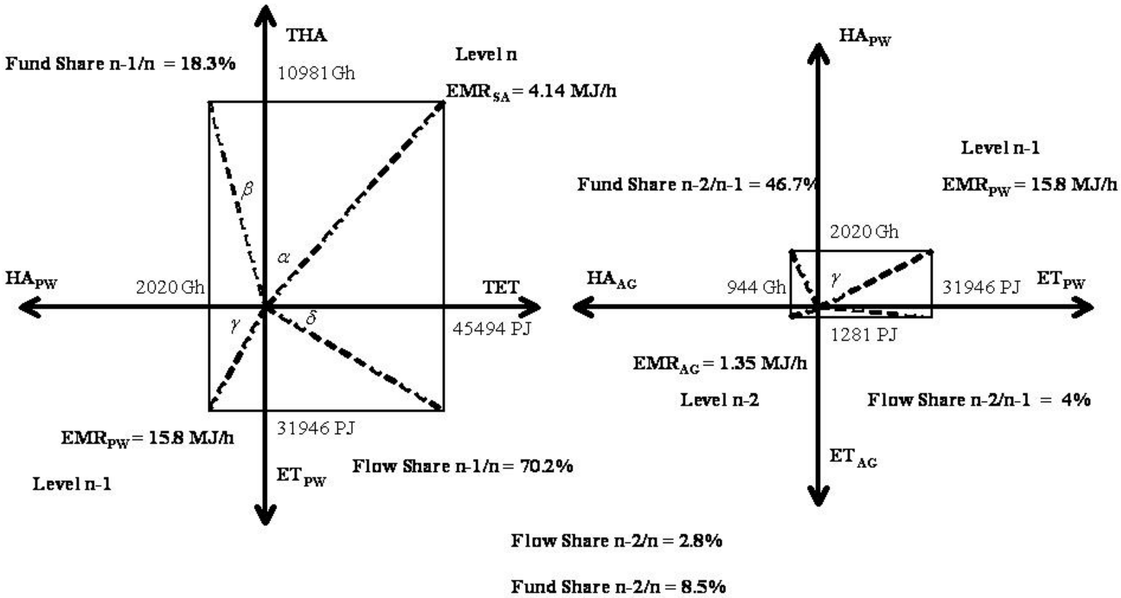

Figure 6: **A Flow-Fund Representation on Three Levels: China in 1999**

Chinese population increased from 841 million people in 1980 to 1,253 million in 1999. The population growth rate is about 2% per year on average, but due to the already very large size of the population this translated into the addition of almost 410 million people (much more than the actual population of the USA). This is a major challenge for the economy of China. During the same period, TET increased from 24,767 PJ in 1980 to 45,493 PJ in 1999 (about 3% per year on average). The combined effect of increases of both TET and population (THA) resulted in a slight increase in EMR_{SA}: from 2.8 MJ/h in 1980 to 4.1 MJ/h in 1999. Still, EMR_{SA} for China in 1999 is much lower than world average (7.8 MJ/h) and OECD levels (22.3 MJ/h), as already mentioned. As studied in the case of Ecuador (Falconi-Benitez, 2001) changes in demographic structure can entail a slow down in the level of capitalization of an economy and therefore changes in average level of energy consumption EMRSA. This can pose a real challenge to accomplish a rapid economic development. Let's start by checking the evolution in time of how total human activity was distributed between paid work activities (HA_{PW}) and non-paid work activities (HA_{HH}). HA_{PW} is used to guarantee the functioning and growth of the metabolic input (in the introduction we indicated this role as the role performed by the hypercycle part – see the theoretical paper for explanation). HA_{HH} on the contrary is related to the dissipative part to enhance the consumption activities. Fund Share (n-1/n), i.e, HA_{PW}/THA (the fraction of human activity invested in paid labor out of total amount of hours of human activity) for China increased from 14% of total available time in 1980 to 18.3% in 1999. Therefore, not only did China see a huge increase in population in absolute terms, but also a *growing fraction* of its THA which was allocated to, paid work activities [HA_{PW}]. This implied an additional challenge, in terms of the need for capital accumulation for the economy. To boost the dissipative part (final consumption) and to enjoy higher consumption in the longer time horizon, the level of capital accumulation of the Chinese economy per worker (or better per hour of work) has to keep growing. But this implies matching the pace of capital accumulation with the pace of growing of HA_{PW}. As noted earlier, the degree of increase of the extensive variable HA_{PW}

was driven by the combined effect of the increase in the extensive variable THA and by the increase in the fraction of paid working time, Fund Share (n-1/n) - Fig. 6. That is, more capital was required by China not only to deliver more goods, services and infrastructures to the growing population, but also to maintain the original level of EMR_{PW} for an increasing working population. The problem of changes in the demographic structure of China's population will remain in the future, getting worse, when this wave of adults will move to the category of retired elderly. As explained with the idea of impredicativity, the effect of changes in demographic variables that determine a change in HA_{PW} at the level (n-1) can only be studied by looking at the structural change of the economy happening at lower levels (n-2). That is the structural changes in the three sectors: AG (agricultural sector), PS (energy and mining sector together with other productive sectors) and SG (service and government sector). This implies looking at how energy is used within the PW sector to boost the productivity of workers. Two extensive and one intensive categories for level n-2 can be introduced for this task: (i) the distribution of the working time HA_{PW} over the three sub-sector sectors at level n-2 – HA_{AG}, HA_{PS} and HA_{SG}; (ii) the distribution of exsosomatic energy ET_{PW} over the three sub-sectors at level n-2 – ET_{AG}, ET_{PS} and ET_{SG}; and (iii) the resulting biophysical energy intensities for these three sub-sectors at level n-2 – EMR_{AG}, EMR_{PS} and EMR_{SG}. It is only when we look at these different types of information coming from lower levels of the metabolic system, then we can understand the overall trend of exosomatic metabolism of the Chinese economy (EMR_{PW} at level n-1 as well as EMR_{SA} at level n) over time.

For example, the trends of EMR_{PW}, EMR_{AG}, EMR_{PS} and EMR_{SG} in the period between 1980 and 1999 are shown in Fig. 7. Nine extensive and intensive variables belonging to sub-economic sectors for 1980 and 1999 together with EMR_{PW} are shown in Table 2. Fund Share (n-2/n) in agricultural sector, HA_{AG}/THA, dramatically decreased from 68% in 1980 to 47% in 1999. In spite of this negative trend, HA_{AG} itself increased from 821 Gh in 1980 to 944 Gh in 1999, an increase of 15% due to the effect of the increase in population (THA).

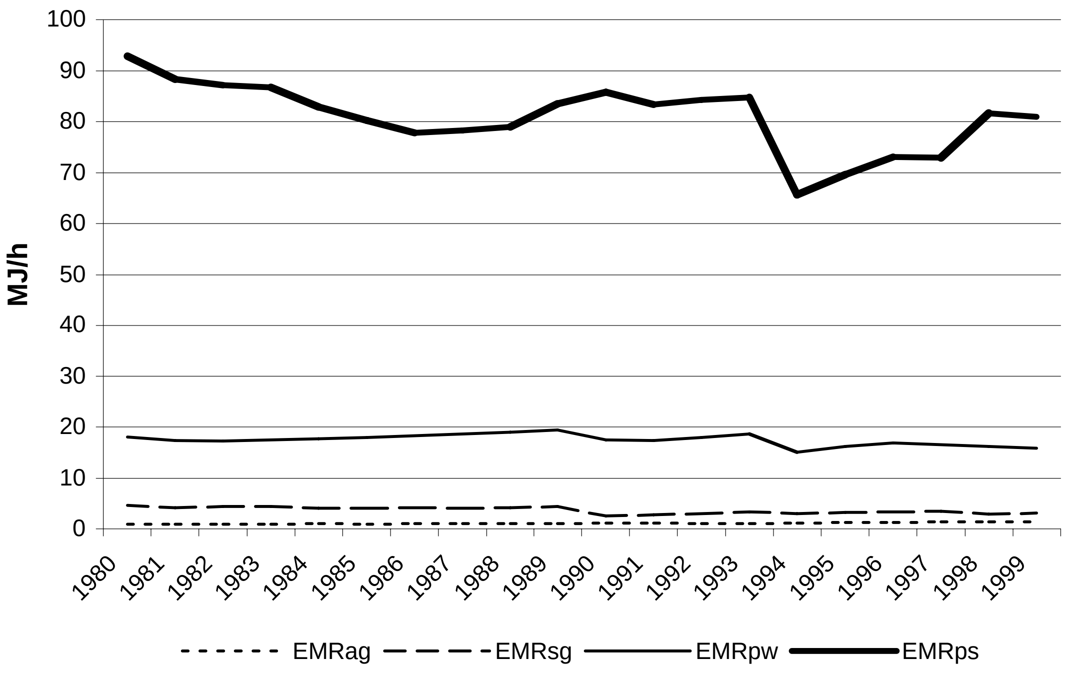

Figure 7: Evolution of EMR_i at the levels (n-1) and (n-2)

EMR_{PS} and EMR_{SG} decreased by 13% and 34%, respectively, during the same period. EMR_{AG} is the only category that increased by 41% from 0.96 MJ/h in 1980 to 1.35 MJ/h in 1999. This increase in EMR_{AG} can be easily explained by the fact that the use of agricultural inputs has increased with demographic pressure (Giampietro et al. 1999; Li, et al. 1999). For example, according to US Department Agriculture (2006) the land in agricultural production of China in 1991 and 1999 remained the same (112.3 million hectares and 113.2 million hectares). On the other hand, for example, nitrogen use increased from 12.5 million tons in 1980 to 23. 8 million tons in 1996, which is much more than the total amount of nitrogen consumed jointly by the EU and the United States (for more information on this issue, see Giampietro et.al. 1997, 1999; Paoletti et al. 1997). Between 1980 and 1999 China's GDP almost quadrupled, but it is well known that the exosomatic energy consumption, TET, increased less than twice in the same period, from 24,767 PJ in 1980 to 45,493 PJ (only 84% increase).

Four main reasons can be used to explain how China achieved the tremendous economic growth without an analogous increase in energy consumption. These reasons are also relevant for discussing the *future challenges that China would face*.

First of all, the Chinese government strongly took initiatives to promote energy efficiency policy, as reported by Sinton et al. (2005). However, the steady increase in energy consumption with rapid economic growth has rendered the Chinese government's decentralized regulatory and policy-making apparatus ineffective, as incentives for state-owned supply companies have diverged from private demand and public well-being. The relative weakness of the central government in the face of vested interests has led to energy sector inconsistencies, energy inefficiency, and policy paralysis (Sinton et al., 2005). So, it is very difficult to predict whether or not China's energy efficiency policy can be maintained, while aiming at continued economic growth. Moreover, because of the Jevons' paradox (Giampietro and Mayumi, 2006) we can expect that any improvement in efficiency will result, in the long term, in an expansion of both final consumption and in a faster rate of capitalization of the economy (leading to higher energy consumption).

Variable	1980	1999	Percent Change
EMR_{PW}	18 MJ7h	15 MJ/h	-17%
ET_{AG}	789 PJ/year	1,281 PJ/year	62%
ET_{PS}	20,186 PJ/year	28,446 PJ/year	41%
ET_{SG}	755 PJ/year	2,218 PJ/year	193%
HA_{AG}	821×10^9 hours	944×10^9 hours	15%
HA_{PS}	217×10^9 hours	351×10^9 hours	62%
HA_{SG}	163×10^9 hours	724×10^9 hours	344%
EMR_{AG}	0.96 MJ/h	1.35 MJ/h	41%
EMR_{PS}	92.87 MJ/h	80.87 MJ/h	-13%
EMR_{SG}	4.63 MJ/h	3.06 MJ/h	34%

Table 2: Values for relevant MSIASM variables for China, 1980 and 1999

Secondly, growth in the service sector has been phenomenal since 1990, as the income level in terms of per capita GDP in the service sector soared from around US$ 300 per year in 1990 to above US$ 1,200 in 2004, maintaining an average annual growth rate of 8.7% in real terms (Qin, 2006). The higher economic income in the service sector is the real reason why there is a massive labor shift from the agricultural sector to the service sector. This trend has been favored by the very low EMR_{SG} – implying a lower requirement of capital per worker - compared with the relative high EMR_{PS}. The government promotion of the service sector is mainly targeted to alleviate the acute labor supply pressure at relatively low expenses of material and capital resources. Moreover, it is felt that a growing service sector would help strengthening the non-state-owned business sector, increasing the overall economic efficiency, and accelerating trade and technological progress (Qin, 2006).

Thirdly, capital investment has been a key to rapid economic development in China. Between 1991 and 2003 its fixed investment relative to GDP was amazingly high and increased in the last years. The average value was 39.6% between 1991 and 1995; 37.6% between 1996 and 2000; and 40.5% between 2001 and 2003 (National Bureau of Statistics of China, 2004). These values can be compared with Japan's fixed investment during its most rapid economic development (between 1961 and 1970). Japan's fixed investment during that period was 32.6% (Heston, et.al. 2002). China's fixed investment in 2003 was about 2,600 billion US dollars (in terms of the year 2000). This value can be compared with Japan's fixed investment in 1970, which was about 390 billion US dollars (in terms of the year 2000). That is, in the last ten years, China's fixed investment far surpassed that of Japan in its most rapid period of economic development.

Finally, there is another key to China's rapid economic development to which our MSIASM can shed considerable light. It is related to the issue of labor supply. HA_{PW} increased from in 1,200 Gh in 1980 to 2,020 Gh in 1999 (a 68% increase). However, ET_{PW} increased only 47% from 21,730 PJ in 1980 to 31,946 PJ in 1999. This lower rate of increase of ET_{PW} compared with HA_{PW}, can be explained only partly by increases in energy efficiency. As result of these two trends the value of EMR_{PW} decreased by 17% during the same period. China's exosomatic characteristics can be seen more clearly if we make the comparison of flow-fund representation of MSIASM between 1990 and 1999 shown in Table 2. Even though EMR_{SA} increased from 3.67 MJ/h in 1990 to 4.14 MJ/h, EMR_{PW} decreased from 17.51 MJ/h in 1990 to 15.81 MJ/h in 1999. On the other hand, due to the relatively higher proportion of small children and young people at this stage of China's socioeconomic phase, EMR_{HH} increased from 0.59 MJ/h in 1990 to 1.51 MJ/h in 1999. An overview of the changes in the dynamic energy budget of China in the period 1990-1999 is given in Fig. 8.

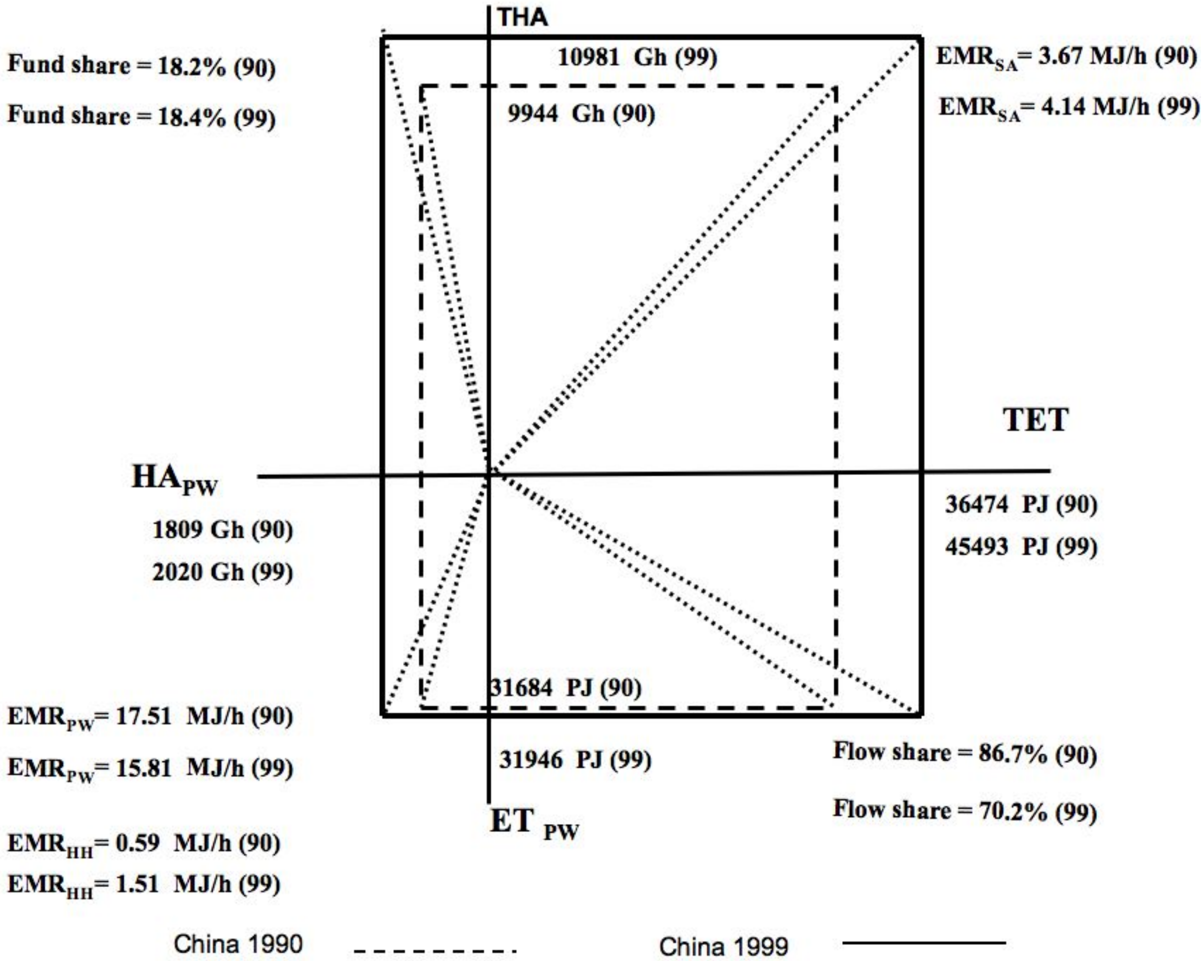

Figure 8: Flow-Fund Representation of MSIASM for China, 1990 and 1999

This illustrates that what is really happening in China is a dramatic increase in the fund share over human activity, which results in a surge in labor hours entering into the economy. During the same period (1990 and 1999), Fund Share (n-1/n) increased from 18.2% in 1990 to 18.4% in 1999, while Flow Share decreased from 86.7% in 1990 to 70.2% in 1999. Since China's effort to increase energy efficiency is stagnating and China had not had enough foreign currency to secure energy resources, in particular oil, in early 1990s, moving this huge mass of available working hours to labor intensive economic activities was an inevitable strategy for China during the phase of rapid economic development. Despite serious concern with the adoption of long working days in the Chinese economy, this strategy worked well for the economy so far. However, the solution of using comparative advantages associated with the very high fund share on human time (a very large fraction of the population in the work force) can pay only in the short/medium term. Due to China's adoption of the one-child-policy, in 20 years the country will have to face shortage of labor supply, unless it succeeds in transforming itself into a more energy intensive economy (increase dramatically the level of capitalization per worker – EMR_{PW} – of its economic sectors). Naturally, a more energy intensive economy for China will create additional problems for global energy and environmental issues.

Concerning the labor supply issue, it should be noted that the following plausible estimates based on World Population Prospects (2004) can be made. The number of elderly people (65 years or older) in China is expected to increase by 244 million between 2000 and

2050. On the other hand, the number of people whose age is between 20 and 65 is expected to remain the same (increasing only by *150 thousand!)* between 2000 and 2050.

4. BACK TO THE INTERFACE WORLD LEVEL/NATIONAL LEVEL: FUTURE SCENARIOS OF DEVELOPMENT FOR CHINA

The following quote clearly indicates the predicament associated with China's demographic trend: "During the next 50 years China will experience a dramatic population aging. According to this most recent UN population projection (the 1998 Revision) China will have about 630 million people age 50 and above in 2050 - while there will be only some 78 million children below the age of 5 and just 324 million children and teenagers below the age of 20. In other words: by 2050 China will have almost twice as many people above age 50 than below age 20" - Heilig (1999). This means that a strategy of economic development based on cheap labor with intensive work load may no longer be feasible in this time horizon. The intensive work load per year of Chinese workers (2,800 hours per year) may be totally untenable in the future of China's economy. As mentioned in the introduction the MSIASM scheme addresses the ability of a society not only to produce, but to produce and consume goods and services. As stated there, in order to be able to produce more, any economy must allocate more of the available human time and energy in consumption sectors (Zipf, 1941). A reduction in the work load for the working population, not only is an ethical imperative, but also an essential requirement for achieving this shift toward a larger level of internal consumption within China to guarantee an internal demand. When looking at both aspects (fraction of population economically active and very high work load) it looks very improbable, that China will maintain the existing peculiarity in relation to the values of these two benchmarks. Hence it should be expected that, sooner or later, China will try to move toward the benchmark values found in developed countries. When comparing the biophysical intensity (capitalization per worker) in the paid work sectors, EMR_{PW}, China (15.8 MJ/h) has a value that is almost twelve times smaller than that of the OECD (185.4 MJ/h) in 1999. Due to a low value of $EMR_{PW,}$ China's strategy was to export manufactured products with labor intensive characteristic. However, this strategy cannot achieve its aim if the import of capital intensive goods due to the increase in internal demand is not replaced by China's domestic production of capital intensive goods in the medium/long term. An expansion of the exosomatic energy consumption of ET_{PS} to be accompanied by decreased HA_{PS} will surely result in a dramatic increase in EMR_{PS} that will trigger a huge increase in energy demand. Just to have an idea of the implication of this fact, Fig. 9 provides a comparison between the exosomatic metabolism of China and the OECD in 1999, based on the MSIASM analysis (note that the two systems have a similar size in terms of population!).

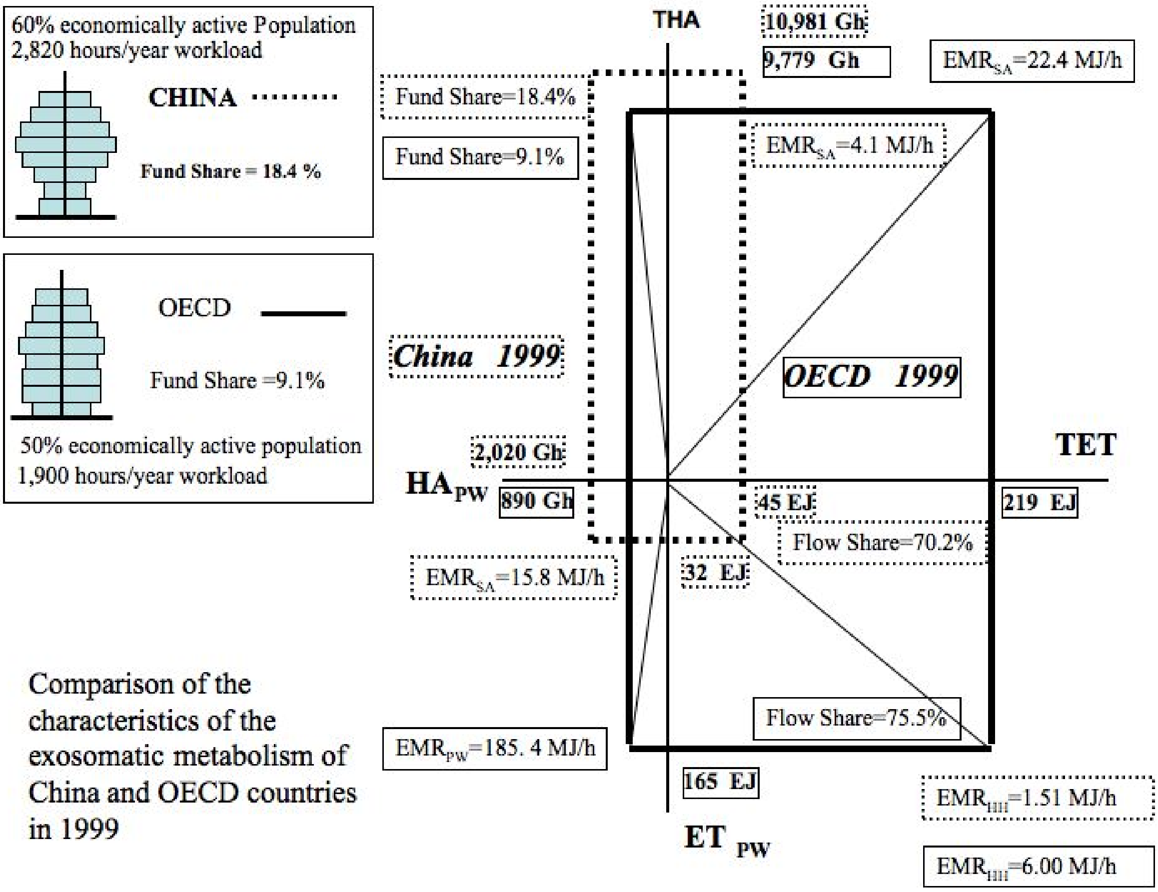

Figure 9: A comparison of China and OECD countries 1999

5. CONCLUSION

According to what has been said so far, three general points can be made about the future evolution of a Chinese exosomatic energy metabolism:

Point #1 - there is a crucial uncertainty associated with the ability to keep coherence in the process of governance of the major transition ahead. As illustrated by the study of Ramos-Martin (2001) the successful economic transition of Spain, can be explained by the combined effect of a limited population growth and a restrictive policy of the dictatorship in the previous decades (the so called ‘Franco era’). These two characteristics of Spain compressed household consumption in favor of capital investment. Can China afford to keep the extraordinary low levels of final consumption presently experienced by the majority of its households compressed in the same way?

For sure boosting of the level of capital accumulation of the PW sector as fast as possible is and must remain a key strategy for the Chinese government. In fact, keeping the level of investment in capital and infrastructures as high as possible is the only strategy for generating a virtuous circle in Chinese economy. However, the priority given to the goal of establishing as quickly as possible such a virtuous circle must be evaluated against the existing demographic trend. As already touched upon several times in this paper, when the boosted cohorts of adults will move through the age-class out of the economically active population, China may face a difficult situation, with an economic sector based only on cheap labor. Then it may be no longer able to support a larger fraction of dependent population. On the other hand, the meager material standard of living experienced now by a large fraction of the population (in rural areas, in marginal social groups in urban areas) suggests an opposite priority aimed at boosting as fast as possible the level of final consumption in the household sector. If China continues to compress final consumption we may see a further increase in the level of social unrest (with even more criminality, demonstrations, strikes, and violence), which could lead to a breakdown of the social fabric of the Chinese society, as suggested in the introduction.

Point #2 - a second crucial aspect will be the ability to prevent the possibility of a breakdown of the national unity due to the increasing tension between the rich south-eastern coastal zones, and the poor interior and former industrial area of the north east. Free market may result good at boosting the efficiency of the production and consumption of goods and services within a socioeconomic process, but it tends to preserve and amplify the existing wealth disparity. In relation to this issue the government has to face another daunting dilemma: (i) going for a maximisation of economic efficiency by letting the market forces operate freely without serious constraints; or (ii) giving priority to the unity of the country, by reducing the rate of generation of the much required economic surplus. The MSIASM approach can be used to look at different densities of added value, energy and human activity per hectare in different geographic areas, in relation to different mixes of economic activities, studying how these mixes are affected by geographic differences. However, this application has not been presented in this paper.

Point #3 – a third crucial aspect is related to what will happen in the future with demographic variables. Looking at the past changes of demographic structure of China and at future projections (from Heilig, 1999), one can notice the presence of an echo-effect. There is a possibility of another baby boom following the previous one. We can use again two quotes from Heilig (1999) to summarize the main implications of this situation:
[1] “Looking at the change of the population pyramids one can see how the "baby boom" generation from the 1960s and early 1970s "moves up" the age pyramid. The animation also visualizes the *aging* of the Chinese population, which is caused by the significant fertility decline since the mid-1970s (and the further increase in life expectancy)”.
[2] “The number of young adults of *reproductive age* (20 - 50) will reach its maximum of more than 660 million around 2010. This explains why the period between 1995 and 2025 is the most critical for the country's future population growth”.
These two quotes point at another daunting dilemma faced by the Chinese government: (i) keeping a strong control on population to prevent another rate increase of population growth. But this will imply having a large fraction of elderly in the long term; or (ii) increasing the number of young people entering into the Chinese economy to prevent a general ageing of the work force. But, this will imply getting back to an increase of population size, something that would be very dangerous.

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