DECOUPLING HOUSING-RELATED ENVIRONMENTAL IMPACTS FROM ECONOMIC GROWTH: THE HANGZHOU EXPERIENCE

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ABSTRACT
Since the national urban housing reform in the 1990s, China has been experiencing a construction boom and a high growth of the total residential building stock. On one hand, the shift in the role of the housing sector in the whole economy brings itself many opportunities to develop and to explore the potentials for pulling economic growth in diverse ways. On the other hand, the large scale and rapid pace of housing construction exert substantial pressure on natural resources and the environment. The notion of decoupling economic growth from environmental degradation has been emphasized in China’s political rhetoric and policies. By employing a case study research strategy, focused upon the Hangzhou city, the study aims to investigate the extent to which the decouplings between the economic growth, housing stock growth and housing-related environmental impacts have taken place since the 1990s. Besides the decoupling policy implications drawn from the case study evidence, the study proposes to take growth containment into China’s policies towards sustainable development with the premise of guaranteeing a decent living standard of citizens.

KEYWORDS decoupling, economic growth, housing sector, environmental sustainability, Hangzhou

1. INTRODUCTION
Since 1987 when Our Common Future was launched by the World Commission on Environment and Development, „sustainable development” has become a buzzword in the academic world and political rhetoric. Sustainable development contends that economic growth and environmental sustainability are compatible. „Reviving growth” is pointed out as a precondition for sustainable development, but the quality of growth should be changed [23]. The belief involved in the connotation of sustainable development is decoupling economic growth and environmental degradation.
“Decoupling” is defined by OECD as “breaking the link between ‘environmental bads’ and ‘economic goods’” [17]. In this sense, an economy that is able to sustain GDP growth without worsening environmental quality is said to be decoupled.

Since the national urban housing reform in the 1980s and 1990s, which constitutes one of the most important areas of China’s socialist economic reform launched in the late 1970s, the housing sector becomes an important component of China’s economic growth. As a response to the severe shortage of housing provision, urban housing reform is a process of transforming the public housing provision and allocation in a planned economy to commercialized housing in an open market economy, the whole process of which can be characterized as housing marketisation and privatization ([25, 21]. Because of the urban housing reform as well as adjunctive facilitations, e.g. the availability of mortgage loans, the strong demand for housing has been unleashed and the era of construction boom is ushered in all around the country. On one hand, the massive growth in the housing stock brings the whole economy many opportunities to develop and to explore the potentials for pulling economic growth in diverse ways. On the other hand, the magnitude of growth and rapid pace of housing construction exert tremendous pressure on the environment in terms of material and energy consumption, green house gas emission, and land loss due to urban expansion.

Ensuring a sustainable housing sector growth is therefore a big concern and challenge for the continuous economic growth and sustainable urban development. For the residential sector, decoupling implies finding ways to increase the economic growth of the residential sector but reducing the environmental impacts from the continual growth. China has since the mid 1980s been focused on sustainable buildings which is also known as ‘ecological building’, ‘green building’ and ‘energy efficient building’ [11]. What they have in common is to employ advanced technologies applied to buildings to increase the efficiency of material and energy. Design standards, regulation for valuation, measures strengthening implementation and demonstration projects were set up and developed in stages both at the national and local levels [26]. Apart from emphasizing energy issues, China also devotes a lot of attention to land conservation in relation to residential buildings by forbidding the construction of villas and spacious dwellings since 2003. This is in line with the compact city strategy in favor of concentrated types of dwellings however with the major purpose of protecting arable land from converting to urbanized areas. These decoupling policies and initiatives undertaken in China mainly concentrate on improving resource efficiency, in particular energy and land use.

Through elaborating on the meaning of decoupling with respect to the housing sector and defining the degrees of decoupling, this study first sets the stage for empirical research.
After identifying the content of empirical investigation, the study assesses the extent to which the case city - Hangzhou metropolitan area in China - has managed to decouple negative environmental impacts from housing sector growth and GDP growth. The housing market has developed much faster and been brisker in Hangzhou compared to the majority of Chinese cities, which characterizes Hangzhou as a forerunner in the pace and scale of housing construction and one of the most expensive cities to reside in. On the other hand, Hangzhou is known for its agreeable and livable environment and has received several international and national awards with respect to the environment. The study provides a close observation of Hangzhou to examine the trends of the decoupling between economic growth and environmental performances in relation to the housing sector and the effectiveness of the decoupling strategies applied in the country and locality. This observation is followed by discussions on the limitations of current decoupling strategies and policy implications to further promote sustainable housing development in China.

2. THEORETICAL FRAMEWORK FOR EMPIRICAL INVESTIGATION

Decoupling of housing-related environmental impacts from economic growth refers to two types of decoupling: (1) decoupling of housing stock growth from economic growth and (2) decoupling of housing-related negative environmental impacts (EI) from housing stock growth. The linkages of housing sector to environmental sustainability in a number of different ways have been identified by many researchers [9, 18, 22]. The major housing-related environmental impacts can be categorized into three aspects: material consumption for construction and maintenance of residential buildings and associated infrastructure, energy consumption for processing and transporting building materials, operation of buildings as well as energy-related emissions, and land-related impacts resulted from encroachments on natural areas and agricultural land by building construction and urban expansion.

Tapio [19] has proposed a theoretical framework for measuring the degrees of decoupling. On the premise of a growing GDP, logical possibilities can be strong decoupling, weak decoupling, coupling, or expansive negative decoupling. Strong decoupling occurs when GDP grows and environmental impacts keep stable or are reduced (%ΔEI/ %ΔGDP <0). In weak decoupling, GDP and environmental impacts both increase but the growth rate of environmental impacts is at least 20% lower than GDP growth rate (0< %ΔEI/ %ΔGDP <0.8). Coupling occurs when the growth in the environmental impact lies within the interval from 20% lower than the economic growth rate to 20% above this rate (0.8< %ΔEI/ %ΔGDP <1.2). Expansive negative decoupling
refers to situations where negative environmental impacts grow at a rate more than 20% above the economic growth rate (\(\Delta EI / \Delta GDP > 1.2\)).

In line with the above, the study of the decoupling trends between economic growth, housing stock, and environmental impacts should include: \(\Delta \text{Floor area} / \Delta GDP\), \(\Delta EI / \Delta \text{Floor area}\), and \(\Delta EI / \Delta GDP\). In this study, the focus is on residential energy consumption and land consumption as the major environmental influences. The research covers the period 1991-2008, divided into two equally long time horizons, i.e. 1991-1999 and 1999-2008. The main reason for this division is that policy terminating public allocation of housing in the late 1990s was a milestone in the history of China’s housing policy. Fortunately, the data available of land consumption are separated into these two periods, too.

3. HANGZHOU CITY AND HOUSING STOCK DEVELOPMENT

Hangzhou, the capital and the economic, cultural, science and education center of the Zhejiang province in China, 180 km southwest of Shanghai, is one of the central cities in the Yangtze River Delta region. With a total area of 3068 km2 [8], the urban district of the municipality consists of 8 districts, among which Shangcheng, Xiacheng, Xihu, Gongshu, Jianggan and Binjiang are the old urban district with Shangcheng and Xiacheng often referred to as the inner city (Fig.1). In 2001, in order to secure larger geographic space for urban development, Xiaoshan and Yuhang districts were merged into the administrative jurisdiction of the urban district. Since the 1990s, with the rise of Yangtze River Delta region as an emerging global city region, Hangzhou has experienced rapid globalization and growth. The economy of Hangzhou developed fast from 1978 to 2008 with an average annual GDP growth rate of more than 11%. 2008 witnessed the breakthrough in GDP per capita of 10 thousand U.S. dollars for the first time in history.

In Hangzhou, the urban housing stock increased considerably from 20.18 million m2 to 107.29 million m2 over the period 1991-2008, with an annual growth rate of 10%. The period over 1999-2008 witnessed a faster housing stock growth. The breakdown of the residential building stock by periods of construction shows that among the total residential building stock in 2008, 68% of the residential floor area was built between
The number of registered urban inhabitants was 1.11, 1.39 and 2.85 million in 1991, 1999 and 2008 respectively. Urban population increased by 25% over the period 1991-1999, while urban population in 2008 is more than doubled the population in 1999. The growth in population accompanies a decreasing average household size and thus a growing household numbers. The average household size dropped from 3.4 to 2.75 persons over the period 1991-2008 [8]. The rapid urbanization in the second period and burst of new
family formation implies a potential huge demand for dwellings to reside in and the growth in construction of new dwellings has to speed up in this period in order to accommodate the growing population in the urban area. Concurrent with an increase in population and household numbers, the considerable increase in per capita floor area took place after the nationwide urban housing reform in the late 1990s. In 1991, the average usable floor area per capita was 10.8 m². The number reached 14.6 in 1999 and 22.4 in 2008. Part of this increase is due to the fact that the number of households has increased slightly more rapidly than the general population because of a decreasing family size. What is more significant is the increase in the average size of individual dwellings.

The growth and fulfillment of the demand for dwellings are also facilitated by several other socio-economic and institutional changes. National housing policies towards increasing homeownership have tremendously triggered housing consumption. In Hangzhou, with the purpose of encouraging strangers to purchase dwellings in Hangzhou and promote the development of local real estate market, buying a dwelling at a cost of a minimum economic value means being entitled a full citizenship which gives the citizens entitlements ranging from small benefits like being able to buy free entrance to city parks and discounted bus pass to more important things like providing jobs, subsidized housing, children’s education attainment, availability of low-cost medical care and pension allowance from the cities where they work [1, 7]. This policy attracts people from less developed regions to own a dwelling in Hangzhou for the considerations of better medical care, offspring’s future education and other city facilities. Local government keeps on issuing new policies employing tax reduction, subsidy, low down pay, and easy availability of mortgage loans as incentives to encourage housing consumption for first and even second homes.

4. DECOUPLING OF HOUSING STOCK GROWTH FROM ECONOMIC GROWTH

When comparing the growth rate of housing stock and economy in two separate periods, as shown in Fig.2(a), it can be observed that in the first eight years (1991-1999), residential building stock grew at a lower rate than the economy, while during the period 1999-2008, residential building stock increased considerably with a rate almost twice the economic growth. Hangzhou has thus moved from weak decoupling between housing stock growth and economic growth between 1991 and 1999 to expansive negative decoupling between 1999 and 2008.

In Fig.2(b), an obvious increase in the share of real estate in the total GDP can be observed. The share of the real sector in GDP has been growing steadily from 2% in 1999
to 6.5% in 2008. At the same time, the GDP in constant price increased by 213%. Clearly, the combination of the increase in the scale of the economy and the share of real estate sector in GDP hardly implies reduced environmental impacts in relation to the housing sector. Residential investment plays an important role in increasing the construction of new buildings.

![Figure 2 (a) Degree of decoupling residential floor area growth from GDP growth. (b) Contribution of the real estate industry to GDP (Source: Hangzhou Statistic Yearbook, various years).](image)

The examination of the share of the residential sector in economic growth tends to indicate that the significance of the housing sector to economic growth is increasingly underpinned in Hangzhou. This is not a special case only for Hangzhou, but a widespread phenomenon for the whole country in response to the urban housing reform and an indication of the achievement of the purpose to shift the role of the housing sector from a drain to a driver of economic growth. Opposite to the idea of decoupling trying to delink economic growth and housing sector growth, the urban housing reform tries to build a positive connection between these two. Admittedly, in a city like Hangzhou, the urban housing reform is conducive to the improvement of the living conditions, which is evident from the substantial increase of the useable floor area. Solutions to the shortage of housing supply need continual growth rather than decreasing growth in the residential building stock.

5. DECOUPLING OF ENVIRONMENTAL IMPACTS FROM HOUSING SECTOR GROWTH AND ECONOMIC GROWTH

This section investigates the historic trends of decoupling of housing stock growth and economic growth from negative environmental impacts in terms of energy consumption and undeveloped land consumption. Unfortunately, the data regarding energy consumption do not allow for a quantitative investigation for the first period (1991-1999). The measure of residential energy consumption refers to electricity. Since electricity has
gradually become the major energy carrier in household energy consumption by replacing coal for space heating/cooling in recent decade, the exclusion of the first period in the investigation makes sense.

5.1 Decoupling of energy consumption from housing stock growth and economic growth

The categories of residential energy consumption influenced by the physical aspects of dwellings (size, type, spatial location) mainly include space heating/cooling, lighting, domestic appliances, and housing-related transport [9, 15, 16]. The latter one is related to the location of housing as well as urban structure, and therefore excluded from the calculation. In this study, only the energy consumption for space heating/cooling, lighting and domestic appliances is therefore taken into consideration. In Hangzhou, the major energy carrier for these items is electricity.

Hangzhou belongs to China’s „hot summer and cold winter” climate zone and therefore is located outside the heating zones where the government has obligations to provide space heating by law. However, in Hangzhou, the combination of cold and humid indoor climate in winter and hot indoor temperature in summer makes the residents subject to quite uncomfortable indoor living conditions. It is not until the recent decade that residents have been able to adjust their indoor climates, due to increasing incomes and higher living standards. For space heating and cooling, air conditioners, electric resistance heaters, electric heat radiators have emerged and boomed. In addition, peoples” standard for indoor thermal amenity has been increasing. The indoor temperature in winter increases from 12°C, 16°C to 18°C, and decreases from 32°C, 28°C to 24°C in summer [24]. However, the installation of heating and cooling equipments developed during a period without any consideration of thermal performances of residential buildings in the hot summer and cold winter zone, therefore yielding huge energy waste.

The rapid growth in the residential building stock implies a growing heating/cooling space and increased domestic appliances to fill in the floor space. Penetration of air conditioners which is the major equipment for spacing cooling/heating has grown rapidly from less than 50 units of air conditioners per hundred households to almost 200 units over the period 1995-2008. Likewise, computers and TVs also experience a similar growth rate [8].

As a result of the increasing residential floor area, the use of electronic equipments and securing more comfortable indoor environment, growing electricity consumption for residential use can be predictable. The electrical energy consumed by the residential sector increased from 900 GWh to 4115 GWh over the period 1999-2008. Compared to
the growth rate of floor area and GDP, electricity consumption is 66% and 228% higher respectively, representing expansive negative decoupling between electricity consumption and housing stock growth as well as economic growth over this period.

Even though China has begun to adopt building energy standards since the 1980s and new standards came out in stages afterwards, it was not until 2001 that design standard for energy efficiency of residential buildings in the hot summer and cold winter zone was carried out [12]. In 2002, Hangzhou promulgated detailed rules for its local residential buildings based on this national standard. The 2002 rules of Hangzhou require a reduction of 50% energy consumption compared with residential buildings without energy conservation measures [4]. To enforce the compliance with the design standards, in 2004, the Construction Committee of Hangzhou issued a regulation of strengthening the implementation of energy conservation for residential buildings [5]. The regulation covers different segments of the building development chain including design firms, construction companies, inspection institutes, and various administrative agencies. In 2006, the local law of „Management Measures of Energy Conservation for Buildings” was issued [6]. After this, the Construction Committee embarked on the development of „Plan of building energy conservation in Hangzhou (2010-2015)” which was enacted at the end of 2007. According to the plan, 25% of existing residential buildings will be renovated for energy efficiency as of 2010 and 50% as of 2015. However, likewise the incomplete compliance with the regulations at the national level [27, 26], after issuing the design standard for energy efficiency buildings in 2001, only a small percentage of newly built dwellings can reach the energy conservation target in Hangzhou.

Despite these efforts to increase energy efficiency of residential buildings nationwide and locally, as shown in Fig.3, in general, the energy intensity of residential buildings has increased. Apparently, in Hangzhou, the implementation of energy efficient buildings as the major decoupling strategy in relation to the housing sector fails to function as a counter force sufficiently offsetting the increasing energy demand due to floor area growth and increased use of electronic appliances. In China, electricity is a rather CO2 polluting type of energy source as according to IEA, in 2007, 81% of electricity generation came from coal [10]. It can be assessed that in Hangzhou CO2 emissions from the residential sector in total and per unit square meter also rose over this period as a result of the growing electricity consumption.
5.2 Decoupling of land consumption from housing stock growth and economic growth

To increase land use efficiency has for a long term been an important endeavor at different levels of planning and policies regarding land use and urban development in China. Strict policies for farmland conservation and compact city development constitute the major strategies to reach high land utilization efficiency. Since residential building is an important element of urban spatial development, it is relevant to investigate the relationship between land consumption for urban development and economic growth. This section mainly intends to show the decoupling trends between undeveloped land consumption for urban expansion and economic growth and examine land use efficiency for residential development.

5.2.1 Decoupling of land consumption for urban development from economic growth

According to Wang et al. [20], the majority of expansion from 1991 to 1999 took place within the distance belts from 10 to 20 km from the city center of Hangzhou. From 1999 to 2008, new built-up areas continued growing within these distance belts, but also in the distance belts from 20 to 30 km. The built-up areas within the whole urban districts were 326.67 km², 471.58 km² and 867.95 km² in 1991, 1999 and 2008 respectively, which means the built-up areas grew by 145.03 km² from 1991 to 1999 and 396.37 from 1999 to 2008. Urban expansion was much faster in the second period than the first one.

Seen from Fig.4, Hangzhou has obtained weak decoupling between growth in built-up areas and economic growth. Specifically, the growth rate of land consumption was 80% lower than GDP growth rate in the period 1991-1999, and it increased but still lower than...
GDP growth rate in the period 1999-2008. Although the developments in the two periods represent weak decoupling, the growth rate of land consumption was only 22% lower than GDP growth rate in the second period, which is barely within the range of weak decoupling. Arguably, the increase of the growth rate of land consumption compared to GDP growth over 1999-2008 may be a signal of coupling between land consumption and GDP growth in future.

Such changes in the degree of decoupling can be explained by the shift of spatial development pattern of Hangzhou city. In the 1990s, urban development triggered by economic growth has to a high extent taken the form of renewal of existing urban areas, typically by replacing old built-up districts with new buildings at higher densities. This is indicated by the increase in the population density in the inner city of Hangzhou over this period. Along with the densification in the inner city, outward expansion also took place and gradually took the major role in urban development in the 2000s characterised as a faster decline in population density of Hangzhou. Such an urban development pattern is more land consuming than the previous pattern of land use.

\[\text{Figure 4} \text{ Degree of decoupling between land consumption for urban development and GDP growth.}\]
5.2.2 Efficiency of land use for residential development.

In terms of land use efficiency for residential development, it can be expressed in the form of undeveloped land consumption for residential development per unit growth in floor area. Table 1 summarizes how housing stock, undeveloped land consumption for residential development, GDP and land utilization efficiency has developed over the periods 1991-1999 and 1999-2008. The share of residential area in the total area of urban expansion is larger in the second period than the first one. In absolute terms, for Hangzhou as a whole, compared to the period 1991-1999, the consumption of undeveloped land for residential development over the period 1999-2008 has increased by a factor of 3.37 (increased from 43.51 million m$^2$ to 146.66 million m$^2$), while the total floor area increased by a factor of 5.21 (increased from 14.03 million m$^2$ to 73.13 million m$^2$). This has led to a decline of around 35% in the consumption of undeveloped land per square meter growth in residential floor area. In the old urban district, the land use efficiency has been improved more considerably than in the outer part of the city - Yuhang and Xiaoshan. This is attributable to the fact that more residential floor were built in the old urban district during the period 1999-2008 than the Yuhang and Xiaoshan (49.71 million m$^2$, compared to 25.49 million m$^2$ in Yuhang and Xiaoshan), but less consumption of undeveloped land for residential development (45.44 million m$^2$, compared to 84.83 million m$^2$ in Yuhang and Xiaoshan), which implies the higher plot ratio in the old urban district.

<table>
<thead>
<tr>
<th>Measurement of land use efficiency</th>
<th>Old urban district</th>
<th>Yuhang &amp; Xiaoshan</th>
<th>Hangzhou</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of land consumption for residential development</td>
<td>35%</td>
<td>40%</td>
<td>23%</td>
</tr>
<tr>
<td>Δ Residential floor area (index '1991-1999' =1)</td>
<td>1</td>
<td>4.92</td>
<td>1</td>
</tr>
<tr>
<td>Δ Undeveloped land consumption for residential development (index '1991-1999' =1)</td>
<td>1</td>
<td>2.00</td>
<td>1</td>
</tr>
<tr>
<td>Land use efficiency for residential development (Δ Undeveloped land consumption for residential development / Δ floor area) (index '1991-1999' =1)</td>
<td>1</td>
<td>0.40</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1 Trends of land use efficiency for residential development in old urban district, Yuhang & Xiaoshan, and Hangzhou Metropolitan Area

Measurement of land use efficiency cannot present whether or not decoupling between, on the one hand, land consumption for residential development and, on the other hand, housing stock growth as well as economic growth has occurred. But assuming there is partial decoupling between land consumption for residential development and GDP
growth in the first period, the indicator at least shows that the degree of such decoupling has been undermined in the second period and a continuation of this trend may probably offset any previous decoupling if present at all as results.

6. DISCUSSIONS AND CONCLUSIONS
This paper investigated the degrees of decoupling of economic growth from negative environmental impacts in relation to the housing development in Hangzhou. The examination of the decoupling trends in Hangzhou shows that the relationship between economic growth and housing stock growth has been shifted from weak decoupling to expansive negative decoupling. As one of the spearhead Chinese cities in housing development, the trajectory of housing stock growth in Hangzhou illustrates that it has been very fruitful from the perspective of the urban housing reform. Economic growth and housing stock growth have not been decoupled from residential energy consumption and even worse, the building energy efficiency has declined. In terms of land consumption, economic growth has been weakly decoupled from land consumption for urban development. However, in spite of the increased land use efficiency, the economic growth per unit growth of land consumption for residential development has been decreased. The continuation of the current trend in the housing sector growth does not point towards environmental sustainability in Hangzhou and instead shows a tendency toward coupling in the future. The case of Hangzhou also illustrates the constraints of current decoupling policies and initiatives and therefore the need for broadening and strengthening political and socio-economic measures to deal with housing-related environmental problems.

Current decoupling strategies in China have a very constrained view of sustainable housing development in terms of emphasizing efficiency. Advanced technologies are often referred to as a way of improving eco-efficiency to achieve decoupling between economic growth and environmental impacts. However, the role of eco-efficiency in reducing land-related impacts from housing sector growth is quite limited. Even though increasing plot ratio through constructing extremely tall buildings and exploring underground space can be put into practice by future technologies, there are still social and other limitations for such a development pattern. Even worse is that in recent years, as observed in Hangzhou, urban growth has taken a way of relatively low density sprawl compared to the previous years, which is an indication of overall decrease in land use efficiency.
Confronting the big challenge that realizing non-environmentally-harmful economic growth and housing sector growth which seems impossible to realize by decoupling strategies, it is necessary to consider slowing down the growth rate. In Hangzhou, many new constructed dwellings are purchased for speculation and therefore are non-occupied. This probably shows that the current high growth rate in floor area may exceed the de facto need for dwellings to live in. In addition, given the current environmental deterioration and the condition of the whole country (e.g. large population, land scarcity, etc.), the widely held goal of „reaching the western living standard” needs to be reflected on. A living standard in terms of floor area per capita based on the balance of economic, social and environmental sustainability is likely to facilitate controlling growth within the ecological capacity and meanwhile guarantee a decent living standard for citizens, the latter of which is the premise of growth containment on housing. This could be realized gradually by, for instance, changing people”s mind in owning spacious and luxury dwellings, slowing down population growth rate and reducing household numbers.

Of course, in developing countries where continual growth is still essential to improve the inhabitants” well-being, the most urgent task to confront the challenge is to strengthen the establishment of decoupling policies and management at this moment. For China in a transitional era, the on-going social, economic and political reforms provide a chance to reshape the institutional organizations to put the ecological rationality on a parallel position with economic rationality. China has since the open door policy in the late 1970s pursued modernization and this modernization should be pulled to the direction of ecological modernization as a decoupling paradigm, which is relevant for the situation of China on the way of development when environmental problems become a big concern [2, 13]. However, in a long run, since it is hard to reach 100% decoupling between economic growth and environmental impacts [14], growth may have to halt at a certain point in order not to exceed the ecological capacity and then attention should be devoted to theories on social development after growth.

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