The socio-economic drivers of material stock accumulation in Japan

Extended abstract

A certain level of material stock in the form of buildings and infrastructure is required to enable an economy to provide essential services to businesses and households, levels which are claimed to display economies of scale [1], hinting at a potential route for decoupling of resource use from economic growth. However, the material stocks of nations are continuously growing [2], requiring huge inflows of construction materials which dominate the material flow accounts of developed nations [3–5], rapidly developing giants such as China [6], as well as at the global scale [7]. The extraction of these materials from the environment, their transport and their disposal impose direct environmental and economic concerns [8,9]. Furthermore, the embodied energy and carbon in construction materials is high [10,11].

The Direct Material Consumption (DMC) of construction materials has been calculated for many countries as part of yearly national material flow accounts [4–6,12,13] and various analytical tools were used to explain factors that determine growth in material throughput, such as IPAT frameworks [6,12–15] and econometric analysis [16–18]. However, in order to explain the relationships between a society and the construction materials it relies on, it is essential to analyze not only the flow of the "addition to stock" in a single year but to take into account the total accumulated material stock in use by society. Demand for increases in material stock depends on the unsuitability of the existing stock – amassed for decades and longer – to effectively provide these services, whether because of limited numerical capacity, insufficient quality, improper location, or due to changing needs and tastes. It is essential to analyze not only the flow of the "addition to stock" in a single year but to take into account the total accumulated material stock in use by society.

Studies of material stock have focused on accounting for in-use stock [19,20] and the relations of flows and stocks [21–26]. Rarely have the studies gone beyond measuring the amounts of flows and stocks used in an economy to investigate the causes of stock accumulation, or, if they did, they simply compared material stock growth with population or GDP growth trends in an effort to recognize coupling and decoupling trends [2,27,28], or used information on socio-economic demand for stock to model future stocks [29–32]. The limited availability of long-term, detailed data in comparable formats has hampered more complex analysis [33]. Research on physical stocks is still in its infancy and hence little is known about what drives stock accumulation. In this research, in contrast to previous studies, we investigate relationships between stock accumulation, population and economic growth in Japan and its prefectures. The recent compilation of a highly detailed database of the material stock of Japan in the 20th and 21st centuries [20] enables the examination of Japan's stock accumulation at national and subnational level applying the analytical tools previously used exclusively in material flow research. We use this dataset to investigate to which extent trends in population and economic activity have acted as drivers of material stock accumulation in Japan,

and conduct an econometric multivariable panel analysis of the material stock of buildings and transport infrastructure in Japan's 46 prefectures (Excluding Okinawa) from 1965 to 2010, using prefectural population and GDP as the explanatory variables in order to uncover the nature of the long-term relationships of the evolution of population and economic activity with physical stocks.

The results of the panel regressions show relative decoupling of stock accumulation from economic growth with a coefficient smaller than one (0.76, *se*=0.009), while the coefficient of population is very close to zero (0.04) and its significance is weak (*se*=0.017). This doesn't necessarily mean that population has no effect on stocks, rather that any such effect is not captured, as there is fairly large variation in population trends between prefectures as well as in each prefecture over time. Thus, population was examined in greater detail by differentiating it into urban and rural populations, resulting in more significant coefficients (urban: 0.22, *se*=0.012 and rural: 0.14, *se*=0.015), finding a relative decoupling in the growth in the number of city dwellers from increases in material stocks, suggesting that as cities' population expands, less new material stock is required for each additional person. The coefficient of rural population is also positive, however rural population has been decreasing in the vast majority of prefectures and so the interpretation of this figure is that, *ceteris paribus*, material stocks slightly decrease for each decrease in rural population. In practical terms, considering the simultaneous dynamics of the other factors, this indicates that the shrinkage of rural population in Japan has a moderating and stabilizing effect on the growth of material stocks. Breaking down the components of GDP into three sectors shows that the vast majority of stock growth is caused by the development of the tertiary sector (0.67, *se*=0.009) and the coefficients of the primary and secondary sectors are close to zero (0.04 and 0.08, respectively), which could mean that demand for infrastructure and buildings from these two sectors has been mostly satisfied during, or perhaps even before, the examined time period, and thus any change in these sectors (including shrinkage of the primary sector) has little effect on material stocks.

The relationships that have been unveiled are a first step towards understanding the long-term relations of population and economic activity on the accumulation of material stocks in Japan and its constituent prefectures. In many ways Japan presents a case study for the stock implications of socio-economic development leading, after a period of fast growth, to saturation. It would be interesting to apply the learnings of this study to Korea or China to assess the dynamics and saturation points of physical stock in these economies. Material stock is a good indicator for doing that as it does not share the dependency of other material flow indicators, such as DMC, on trends found in the global economy and presented through trade of raw materials. The results of such panel analyses may facilitate scenario building for assessing the future stock requirements of the Japanese economy or other economies, providing valuable insights into the physical underpinnings of modern economies.

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