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# Chapter 1

# Secular Cycles

We believe that one of the most important recent findings in the study of the long-term dynamic social processes was the discovery of the political-demographic cycles as a basic feature of complex agrarian systems' dynamics.[1]

The presence of political-demographic cycles in the pre-modern history of Europe and China has been known for quite a long time (*e.g.*, Postan 1950, 1973; Abel 1974, 1980; Le Roy Ladurie 1974; Hodder 1978; Braudel 1973; Chao 1986; Cameron 1989; Goldstone 1991; Kul'pin 1990; Mugruzin 1986, 1994 *etc.*), and already in the 1980s more or less developed mathematical models of demographic cycles started to be produced (first of all for Chinese "dynastic cycles") (Usher 1989). At the moment we have a very considerable number of such models (Chu and Lee 1994; Nefedov 1999e, 2002a; 2004; S. Malkov, Kovalev, and A. Malkov 2000; S. Malkov and A. Malkov 2000; Malkov and Sergeev 2002, 2004a, 2004b; Malkov *et al.* 2002; Malkov 2002, 2003, 2004; Turchin 2003, 2005a).[2]

Recently the most important contributions to the development of the mathematical models of demographic cycles have been made by Sergey Nefedov, Peter Turchin and Sergey Malkov. What is important is that on the basis of their models Nefedov, Turchin and Malkov have managed to demonstrate that demographic cycles were a basic feature of complex agrarian systems (and not a specifically Chinese, or European phenomenon).

Nefedov (2004) starts with the population model developed by Raymond Pearl (1926) and described by the logistic equation suggested by Verhulst (Verhulst 1838; see also, *e.g.*, Riznichenko 2002; Korotayev, Malkov, and Khaltourina 2006):

[1] As these cycles are of an order of 1–2 centuries, it was suggested by Turchin (2003, 2005b) to denote them as "secular cycles". We would also like to acknowledge that it also was Peter Turchin who in October 2002 suggested to us to denote the macrotrends we are dealing with in this *Introduction to Social Macrodynamics* as "millennial trends".

[2] There are also a rather large number of pre-industrial population-economy dynamic models designed to account for "the escape from Malthusian Trap", rather than for the structure of pre-industrial population cycles (Artzrouni and Komlos 1985; Steinmann and Komlos 1988; Komlos and Artzrouni 1990; Steinmann, Prskawetz, and Feichtinger 1998; Wood 1998; Kögel and Prskawetz 2001).

$$\frac{dN}{dt} = r(1 - \frac{N}{C})N \quad ,$$

where $N$ is population, $r$ is rate of natural growth, and $C$ is maximum carrying capacity.

This results in dynamics demonstrated in Diagram 1.1[3]:

**Diagram 1.1.** Dynamics Generated by Raymond Pearl's Model

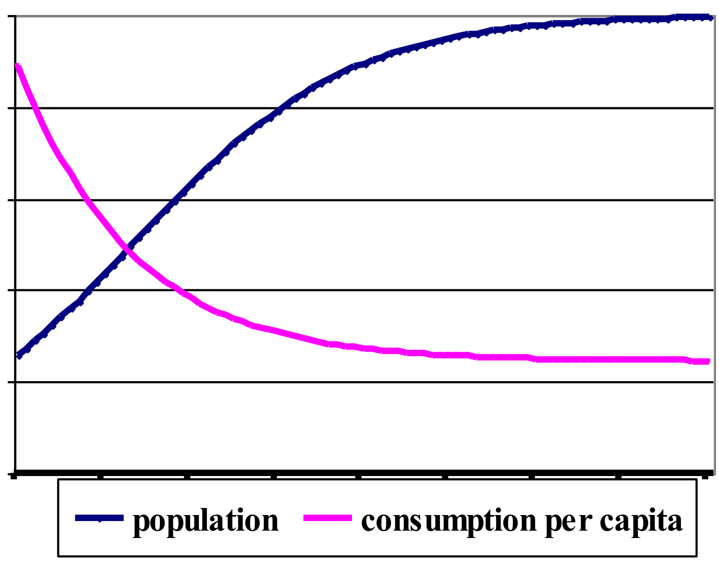



**Fig. 1. The logistics curve and the curve of consumption per capita**

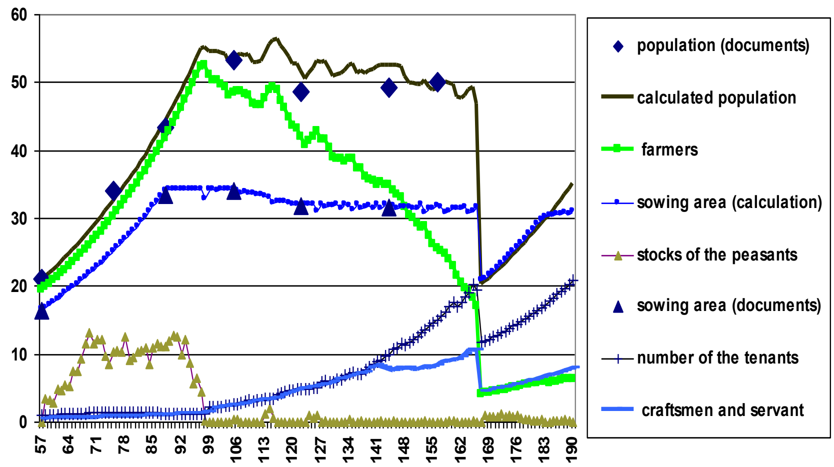
Starting from this basis Nefedov developed his mathematical model of pre-industrial sociodemographic cycles. The basic logic of these models looks as follows: after the population reaches the ceiling of the carrying capacity of land its growth rate declines toward zero values and the system experiences significant stress with decline of the living standards of common population, increasing severity of famines, growing rebellions *etc.* As has been shown by Nefedov,

[3] From Nefedov 2004.

most complex agrarian systems had considerable reserves for stability, however, within 50–150 years these reserves usually got exhausted and the system experienced a demographic collapse, when increasingly severe famines, epidemics, increasing internal warfare and other disasters led to a considerable decline of population. As a result of this collapse, free resources became available, per capita production and consumption considerably increased, the population growth resumed and a new demographic cycle started. It has turned out to be possible to model these dynamics mathematically in a rather effective way.

It seems necessary to stress that a new generation of models has moved far beyond this basic logic. For example, models now describe effects of class structure and elite overproduction; the new models predict dynamics of a great number of variables like food prices, urbanization levels, growth of wealth differentiation and so on. These models have achieved a rather close fit with observed data. As an example, we present a diagram from a recent article by Nefedov (2004) displaying the social and economic dynamics for the East Han cycle predicted by Nefedov's model and the ones actually observed in historical sources (see Diagram 1.2):

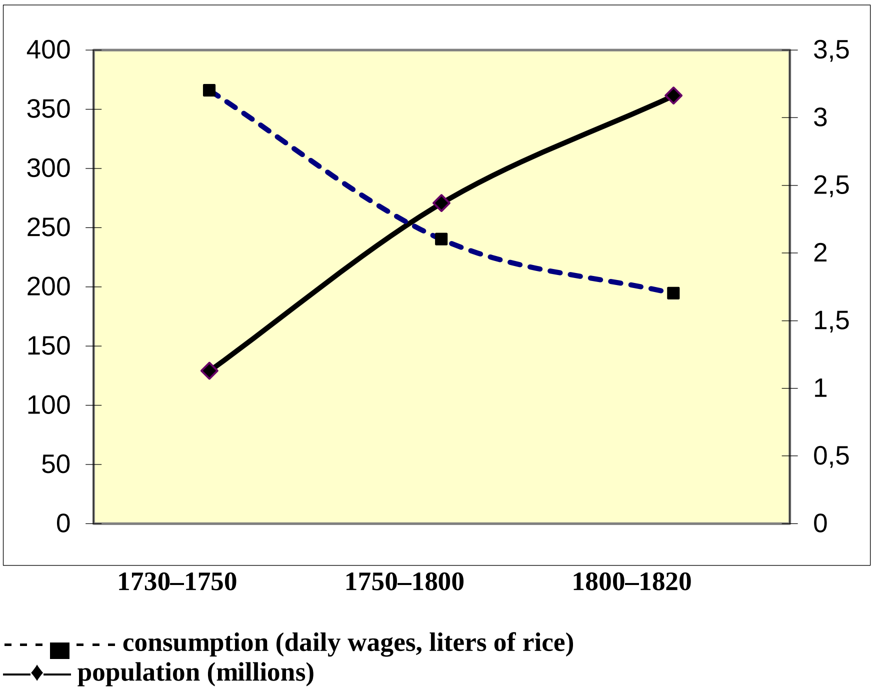
**Diagram 1.2.** Social and Economic Dynamics of China in the Later Han Period (Nefedov 2004: 77)




As we have already mentioned, a new generation of demographic cycle models has made it possible to show that demographic cycles were a basic feature of complex agrarian systems (and not a specifically Chinese, or European phenomenon).

It is not very often that we have direct evidence for long-term trends for both population numbers and consumption rates. It is very rare that we have long-term data on both variable dynamics within a cycle (as for Qing China, see Diagram 1.3):

**Diagram 1.3.** Population and Consumption in China in the Qing Epoch




NOTE: Adopted from Nefedov 2003: 5. The data on daily wages are from Chao 1986: 218–9. The data on population are from Zhao and Xie 1988: 541–2.

Much more frequently we have data just for one of such variables. Thus, for most Chinese dynastic cycles we have data on population dynamics (see, *e.g.*, Diagrams 1.4 and 1.5), and usually they display dynamics quite close to the those predicted by demographic cycle models:

**Diagram 1.4.** Population in Early Tang China (number of households in millions) (Nefedov 1999c. Fig. 2).

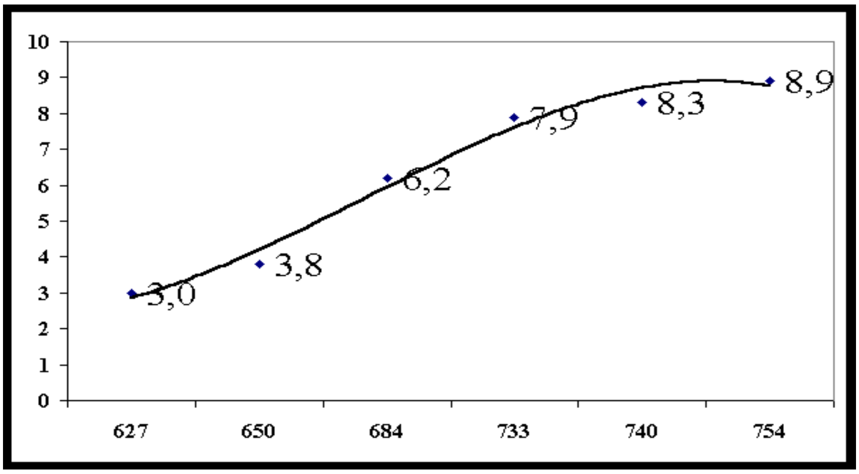
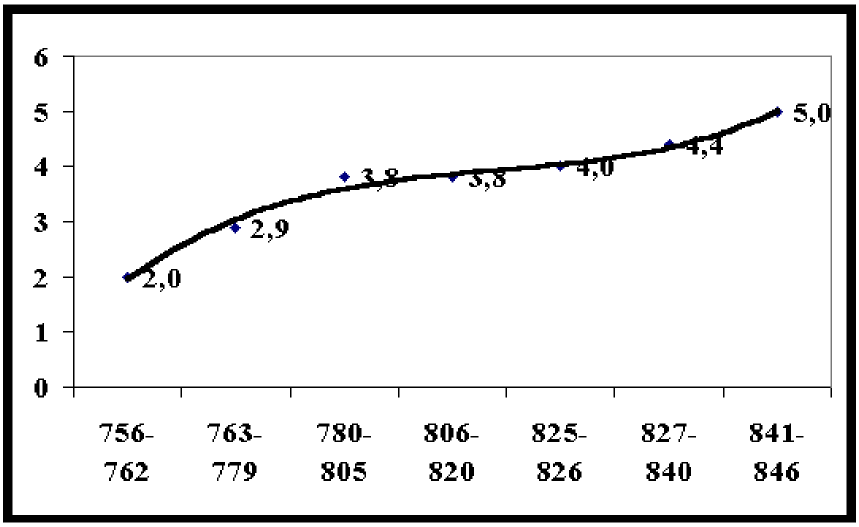


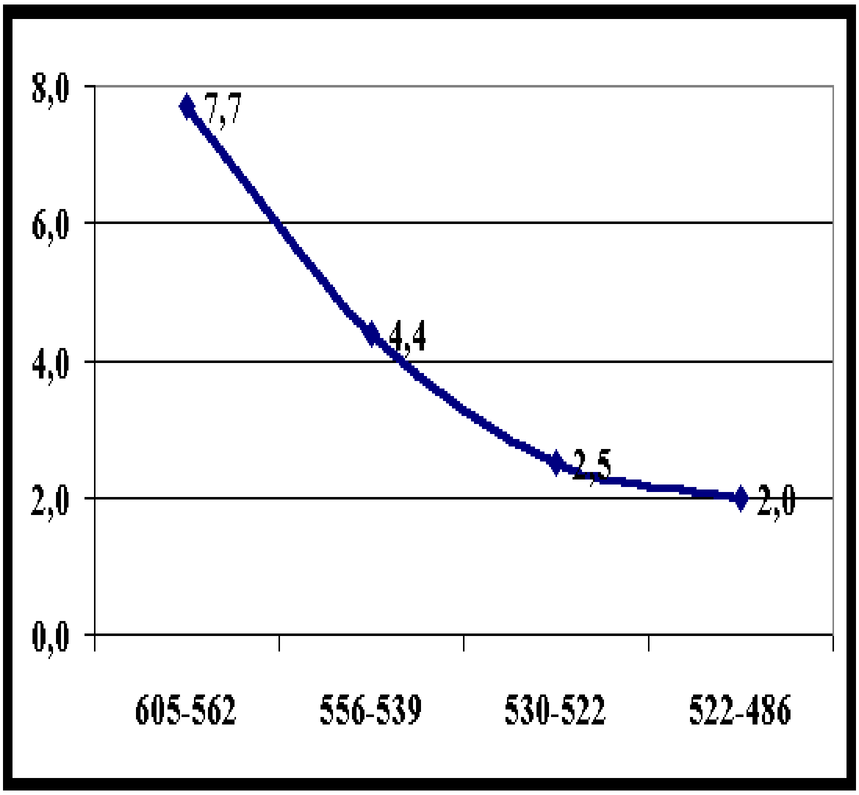

**Diagram 1.5.** Population in Late Tang China (the number of households in millions) (Nefedov 1999c. Fig. 3).



Note that the form of the population curves is quite close to the one predicted by Nefedov's model.

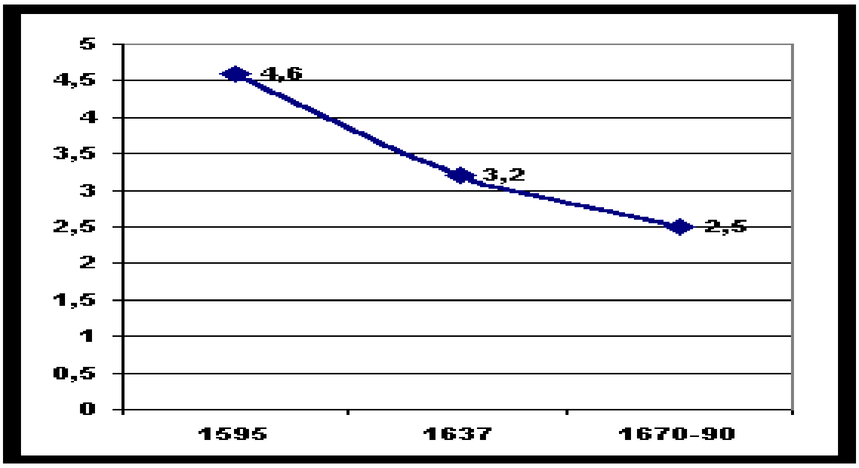
We have practically no long-term population data outside China (and, to some extent, Europe), and this made it difficult to detect demographic cycles outside Europe and China. However, not so infrequently we can find long-term data on some other variables predicted by Nefedov's model (first of all per capita consumption rates), and quite regularly they have just the form predicted by Nefedov's model (see, *e.g.*, Diagrams 1.6–8):

**Diagram 1.6.** Consumption Dynamics in Babylonia in the 6th – early 5th centuries BC (Nefedov 2003: Fig. 4)



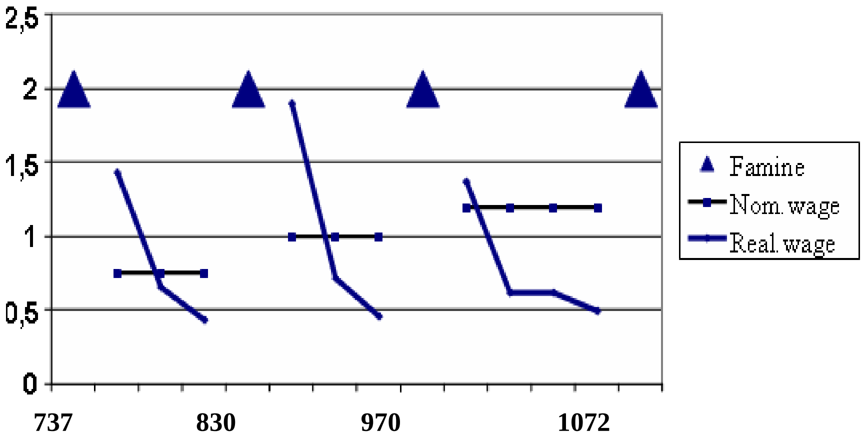

NOTE: The numbers indicate the amount of barley in liters that an unskilled worker could buy on his daily wage.

**Diagram 1.7.** Consumption Dynamics in Northern India in the late 16th – 17th centuries (Nefedov 2003: Fig. 12).




NOTE: The numbers indicate the amount of wheat in liters that an unskilled worker could buy for his daily wage.

**Diagram 1.8.** Consumption Dynamics in Egypt in the early 8th – 11th centuries (Nefedov 2003: Fig. 8)




NOTE: Daily wages of unskilled workers. The data on nominal wages are from Ashtor 1976: 201. The real wages were calculated by Nefedov as amount of wheat (in decaliters), which an unskilled worker could buy for his daily wage.

Using such indirect data, as well as his system of qualitative indicators of various phases of demographic cycles Nefedov (1999a, 1999b, 1999c, 1999d, 1999e, 2000, 2001a, 2001b, 2002a, 2002b, 2003, 2004, 2005 *etc.*) has managed to detect more than 40 demographic cycles in the history of various ancient and medieval societies of Eurasia and North Africa, thus demonstrating that the demographic cycles are not specific for Chinese and European history only, but should be regarded as a general feature of complex agrarian system dynamics.

We would like to discuss in some detail three approaches to modeling of demographic cycles: Turchin's (2003) models, another by Chu and Lee (1994), and finally, the model of Nefedov (1999e, 2002a; 2004).

The "demographic-fiscal" model developed by Turchin (2003: 118–27, 208–13) connects population dynamics, state resources and internal warfare. In this model the elites controlling the state are not assumed to be selfish. It is rather assumed "that the state has a positive effect on population dynamics; specifically, it increases *k* [the carrying capacity]" (Turchin 2003: 122). "There are many mechanisms by which the state can increase the carrying capacity… The strong state protects the productive population from external and internal (banditry, civil war) threats, and thus allows the whole cultivable area to be put into production… The second general mechanism is that states often invest in increasing agricultural productivity by constructing irrigation canals and roads, by implementing flood control measures, by clearing land from forests, *etc.* Again, the end result of these measures is an increase in the number of people that can be gainfully employed growing food, *i.e.*, the carrying capacity" (Turchin 2003: 120–1). Thus the depletion of state resources and state breakdown are assumed to be leading to the decline of the carrying capacity and, thus, demographic collapse. As in all the other demographic cycle models the per capita rate of surplus production is assumed to be a declining function of population numbers, whereas the state expenditures are assumed to be proportional to population size. Within this model "the rate of change of *S* [state resources] is determined by the balance of two opposing forces: revenues and expenditures. When *N* [population] is low, increasing it results in greater revenues (more workers means more taxes). The growth in state expenditures lags behind the revenues, and the state's surplus accumulates. As *N* increases, however, the growth in revenues ceases, and actually begins to decline. This is a result of diminishing returns on agricultural labor. However, the expenditures continue to mount. At population density $N = N_{crit}$, the revenues and expenditures become (briefly) balanced. Unfortunately, population growth continues toward the carrying capacity, *k*, and the gap between the state's expenditures and revenues rapidly becomes catastrophic. As a result, the state quickly spends any resources that have been accumulated during better times. When *S* becomes zero, the state is unable to pay the army, the bureaucrats, and maintain infrastructure:

the state collapses", which leads to a radical decline of the carrying capacity of land and demographic collapse (Turchin 2003: 123).

Turchin has also developed a number of elegant models of population dynamics, where the peasant-elite interaction plays the role of the main mechanism of state breakdown. When the population size becomes large, food supplies are exhausted and the elite multiplies out of control – then state collapse is observed, followed by a significant decrease in the number of peasants. A large number of elite cannot be supported by a shrunken population, so eventually the elite decreases, and the cycle of growth starts over. A resulting feature is that we do not observe the population to climb up to its carrying capacity and saturate at a certain level before a collapse (for a more detailed analysis of these models see the next issue of our *Introduction to Social Macrodynamics* [Korotayev and Khaltourina 2006]). Also, the elite behaves in a strictly selfish manner; it does not play a role in food redistribution (*e.g.*, to provide food for starving people during time of famine); this mechanism, however, is important when modeling Chinese demographic cycles.

The interesting model of Chu and Lee combines elements of mathematical modeling and statistical analysis/best fit approach. The main idea is very attractive. The population consists of rulers, peasants and bandits (rulers being equated with soldiers, drafted every year at a constant rate). The population has some intrinsic growth rate, that is, the rate at which it increases given unlimited resources. As the density increases, the resources get scarce, and the growth rate decreases (this is an effect of overpopulation). At the same time, there is a flux of people from peasants to bandits and *vice versa*. Each person faces a choice of either working in the field or "defecting" and getting his food by means of force. The soldiers are supported by taxation and they fight the bandits. The rational choice is based on evaluating the "utility function" of peasants and bandits and it depends on external circumstances such as the degree to which agricultural resources are damaged by warfare. The utility function is a combination of the food share received and the probability of survival.

As the density of the population grows, it becomes more and more likely that people choose to become bandits and fight for their food instead of growing it. This leads to the reduction in population numbers and the cycle starts over.

Chu and Lee did not specify their model to the extent where it can be implemented directly. Instead, they used it as a tool to improve the fitting of real historical data. Information on warfare and winter temperatures was included in the form of exogenous variables, and the frequency of peasant rebellions was modeled based on the expected fraction of the rebels, calculated by the model. This gave an excellent fit to the existing data.

Another interesting idea presented by Chu and Li are the two possible explanations of the irregularity of the historical political-demographic cycles. One explanation is simply the ("external") stochasticity of the climatic conditions. The other one is the intrinsic chaotic behavior of the dynamics system. Depending on parameter values, the simplified system analyzed by the authors has been shown to undergo a series of period-doubling bifurcations and a transition to chaos.

What is slightly disappointing is that the authors did not include the effects of an annually changing crop yield (which is a function of climate fluctuations). Nor did they include the positive role of the ruling class in food redistribution (which is especially salient precisely in the Chinese case on which their model is based). Moreover, the historical temperature data proved to be irrelevant for the fit. These points will be addressed in more detail when we talk about our model (see Chapter 3 below).

Nefedov, who incorporated stochastic effects of year-to-year food yields on the population dynamics, has taken another approach. He noticed that as the population reaches the carrying capacity of land, and food storages become depleted, then random effects of good and bad years can play a significant role in the dynamics. As food becomes very scarce because of, say, a bad winter, people tend to sell their land and leave for cities, or join bands of rebels. In idealized conditions, that is, given a perfectly constant food yield, no cycle is expected. However, a bad harvest triggers a mechanism of collapse with a significant reduction in population number. Nefedov's models have several interesting components. For example, because of the increasing numbers of people leaving the land as population density increases, we expect to see an intense growth of cities, which is confirmed by historical observations. What seems to be missing from Nefedov's models is the direct role of rebellion and internal warfare on the cycle behavior. If only economic factors are taken into account, then there seems to be no inertia in the dynamics, and each demographic catastrophe is followed immediately by a new rise. As we shall see below, this plainly contradicts historical data where "intercycle" periods of variable (but always significant) length are observed.

In the next chapter we shall consider in more detail political-demographic cycles in China, where long-term population dynamics have been recorded more thoroughly than elsewhere.