

Geographic variation in the growth of domesticated honey bee stocks

Disease or economics?

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Declines in the stocks of domesticated honey bees in some countries have been attributed to disease, which is at odds with an increasing global trend in the total number of hives. Based on data on annual growth rates in hive numbers and honey production for 87 countries, we tested the hypothesis that geographic heterogeneity in the growth of the domesticated honey bee population can be attributed to disease. In contrast to predictions of this hypothesis, changes in honey production varied in proportion to changes in hive number. Also, growth in honey production was not more spatially heterogeneous than growth in hive numbers, as expected under a scenario of contagious pests. We argue that although disease aggravates production costs, it has less effect on changes in national hive numbers than labor costs, so that geographic variation in the growth of the global honey bee stock reflects the global division of human labor that is a hallmark of economic globalization, rather than persistent and pervasive biological causes.

In contrast to concerns about a global crisis in agricultural pollination caused by declines in both wild and managed pollinators,¹⁻³ data compiled by the Food and Agriculture Organization of the United Nations (FAO) document a 45% increase in the global stock of domesticated honey bees during the last five decades.⁴ This increase has not occurred consistently among countries, but instead reflects strong growth by countries that currently

dominate global honey production, such as China, Argentina and Turkey, which exceeded declines elsewhere, such as in the United States of America and some European countries.^{5,6} These latter declines have been blamed on biological problems affecting domesticated honey bees, including disease and pesticides. For example, in the USA the number of managed honey bee colonies decreased about 60% since the 1940s, in part owing to infestations by hemolymph-sucking mites,⁷ and more recently to the poorly understood Colony Collapse Disorder.^{8,9} Such problems undeniably reduce colony numbers and performance, but whether they have sufficient impact to explain fully the observed declines of honey-bee stocks in some countries is less certain. In particular, Aizen and Harder suggested that the economics of the global honey industry influence international dynamics of stocks of managed honey bees more strongly than biological problems.⁴

The economic and disease hypotheses lead to contrasting expectations concerning changes in stocks of honey bee hives and honey production. If the economics of the global honey industry drive the international dynamics of honey bee stocks, changes in a country's honey production should be achieved largely by proportional changes in hive numbers. In contrast, disease should modify this correspondence, because it disrupts colony life and impairs the capacity of bees to gather, process and store sugar,^{10,11} compromising honey production even if hives remain viable. Consequently, for countries with significant

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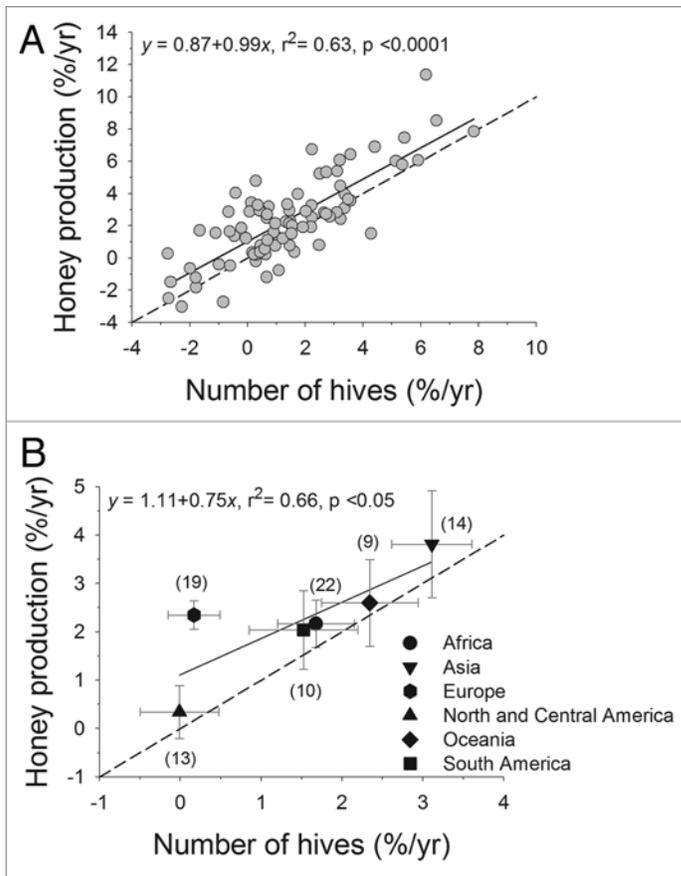


Figure 1. Relations between the annual growth rates in honey-bee stocks and honey production for (A) 87 countries and (B) six continents. Solid lines indicate the fitted linear regressions and dashed lines depict equal growth in both variables. In (B), points represent continental means \pm SE, and sample sizes (number of countries) are provided in parentheses.

disease problems poor relative growth in honey-bee stocks should be associated with even poorer growth in total honey production. Such effects should be accentuated by active management of hive numbers, such as by queen reintroduction,¹² which can mitigate effects of disease on the honey-bee stock but not on the capacity of individual bees to process nectar and produce honey. These effects lead to three predictions. First, the relative growth of honey production should vary more among countries than that of hive number. Second, a linear regression of relative change in honey production on relative change in hive number should have a slope >1 . Third, the local nature of disease transmission should create spatially-correlated variation in the impact of disease on honey production, so that differences among continents should account for a larger proportion of the total variation in growth in honey production than in hive numbers.

We assessed these predictions with annual data in the FAO database,¹³ on the number of honey-bee hives and honey production for 87 countries and territories on six continents (Table S1 in Suppl. Material). Countries were included in the analysis if they reported data for both variables without interruption from 1961 to 2006; we also included data for 2007 for the $>90\%$ of countries that had reported for that year when we accessed the database. Data treatment for countries that fragmented or fused since 1961 (e.g., USSR) follows Aizen and Harder.⁴ All statistical analyses considered the compound annual growth rate (%/yr) of hive number and honey production for each country calculated from each time series as $100(e^r - 1)$, where $r = [\ln(x_t) - \ln(x_0)]/t$, x_0 and x_t are a variable's values at the beginning (i.e., 1961) and end (2006 or 2007) of the time series,

respectively and t is the series' duration (45 or 46 years).

Statistical results based on the FAO data are largely inconsistent with the predictions of the disease hypothesis. Overall, honey production grew faster (2.23%/yr) than hive numbers (1.38%/yr), suggesting improvements, rather than disease-driven declines, in the efficiency of honey production per hive. After accounting for these mean differences by ln-transformation,¹⁴ variance among countries in growth of honey production (0.050) was just significantly greater than that of hive numbers (0.035; variance-ratio test: $F_{86,86} = 1.33$, $p = 0.049$), as predicted. However, the estimated slope of the relation of the growth of honey production to growth in hive number did not differ significantly from 1 either among countries ($t_{85} = 0.16$, $p = 0.88$; Fig. 1A), or among continents ($t_4 = 0.94$, $p = 0.40$; Fig. 1B). This pattern is particularly inconsistent with the disease hypothesis as it shows that poor growth in the number of colonies does not translate into poorer growth in honey production. Indeed, in Europe as a whole hive numbers have barely grown since 1961, but honey production grew the fastest on a per-hive basis, again indicating improvements, rather than declines, in production efficiency. Finally, in contrast to predictions, differences among continents accounted for a smaller proportion of the total variance in the growth of honey production (10.3%; $F_{5,81} = 2.56$, $p = 0.033$) than in the growth of the number of hives (25.7%; $F_{5,81} = 5.94$, $p < 0.0001$).

In our previous study,⁴ we argued that declines in the stock of domesticated honey bees in the USA and in some European countries reflected ongoing abandonment of apiculture in the face of competition from cheaper imported honey. This interpretation is reflected in our current analysis by both the increased efficiency of honey production worldwide and the faster growth in hive numbers in Asia, Africa and South America than in North America and Europe (Fig. 1B). Today, honey-bee pests are present wherever honey bees occur naturally or have been introduced.¹² In this context, disease has to be considered as an extra economic burden borne by beekeepers, which includes the costs of miticides, replacing

hives, reintroducing queens, etc. However, these costs may be relatively minor compared to the cost of human labor. For instance, Argentina probably became one of the world's major honey exporters, despite high prevalence of *Vарroa* mites throughout South America,¹² because of relatively cheap labor.¹⁵ On the other hand, the European Community recently adopted a resolution to subsidize its bee-keeping sector against external "unfair" competition.¹⁶ Thus, although our analysis of international variation finds little evidence that disease strongly affects changes in honey-bee stocks, it is consistent with the important contribution of economic globalization and protectionism to both the positive global trend and spatial variation in the growth of the global stock of domesticated honey bees.

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Note

Supplementary materials can be found at: www.landesbioscience.com/supplement/AizenCIB2-6-Sup.xls

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