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Mechanical Refrigeration and the Integration of Perishable Commodity Markets[1]

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In this paper, we provide a history of the economic impact of mechanical refrigeration in the United States. We also examine spatial and temporal aspects of market integration. Specifically, we examine seasonal fluctuations in prices and analyze regional integration of markets for butter. We test the null hypothesis of no integration before and after the advent and adoption of refrigerated shipping and warehousing using 31 years of monthly data. We find strong evidence of spatially integrated markets after adoption. Our results indicate that the adoption of mechanical refrigeration brought about a significant dampening of seasonal fluctuations of butter prices and a tightening of spatial price linkages. We conclude that the adoption of mechanical refrigeration had a significant impact on both temporal and spatial butter price relationships. © 2002 Elsevier Science (USA)

1. INTRODUCTION

The last decades of the long nineteenth century have been labeled an era of "Great Inventions," which contributed to the subsequent golden years of productivity growth (Gordon, 2000, pp. 5, 11–12). Similarly, the era has been identified as one of increasing economic integration in several important markets, including capital markets (Davis, 1965; Sylla, 1969), labor markets (Rosen-

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bloom, 1996; Williamson, 1995), and grain markets (O'Rourke, 1997). This integration, which is typically associated with improvements in transportation and communication, was marked by an increase in the access of buyers and sellers to one another, usually through a reduction of the costs of obtaining that access. As such, integration brought about an increase in trade, a more efficient allocation of resources, and thus an expansion of productivity and overall output. These advances were also manifested in biological measures of the standard of living, such as increases in human stature (Costa and Steckel, 1997) and reductions in mortality (Haines *et al.*, 2000).

One of the great inventions, mechanical refrigeration, contributed directly to the spatial and temporal integration of perishable commodity markets, which in turn contributed to improved living standards. Gordon (2000, p. 21) explicitly notes the important role of refrigeration in reducing food spoilage, and Holmes (1913) observed this shortly after mechanical refrigeration was adopted in cold storage. Baten and Murray highlight the importance of dairy products as a source of protein in explaining nineteenth-century living standards, and refrigeration contributed to the wider distribution of dairy products. Explaining the absence of market integration of perishables before the great inventions, O'Rourke and Williamson (1999, p. 47) note that ". . . the delay in price convergence for meat, butter, and cheese has an easy explanation: it requires advances in refrigeration made towards the end of the [19th] century." Thus the study of refrigeration's economic impact offers an important link between the literatures on invention, integration, and growth.

Despite the importance of refrigeration suggested or implied by the growth and integration literature, which dates from Holmes (1913) and Zapoleon (1931), there are no direct econometric estimates of the initial impact of mechanical refrigeration. Hence, in this paper, we analyze the effects of refrigeration on the temporal and spatial integration of the market for butter—one of the most important of the perishable commodities. Our task is to quantify changes in the degree of integration before and after the adoption of refrigeration. We do so by employing a set of astructural econometric tests to evaluate the null hypothesis of no integration before and after refrigeration. In addition, we estimate changes in the returns to storage and the seasonality of butter prices as a result of the adoption of refrigeration. Each of these estimates serves as an indicator of the impact of refrigeration.

2. THE ADOPTION OF MECHANICAL REFRIGERATION

Although the physics of refrigeration were understood by the ancient Egyptians, at least in an empirical sense, "natural" ice, as it was called, provided refrigeration until the late nineteenth century.[2] Prior to the 1820s, the technology

[2] The Egyptians observed that the vaporization of a liquid cooled the surrounding environment (i.e., it is an endothermic process); so they chilled drinks by placing them in vessels which were then

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